# FOREWORD

This study was initiated in September 1963 and carried out in the 6570th Aerospace Medical Research Laboratories, Behavioral Sciences Laboratory, Human Engineering Division, Performance Requirements Branch, as a part of strike-reconnaissance program 665A. The study was completed in February 1964. The support and assistance of the following persons is acknowledged: Mr. Charles Bates, Jr., Chief, Performance Requirements Branch; Mr. W.R. Borchers; Miss Barbara VanAusdall; and Professors Robert J. Wherry, James C. Naylor, and William C. Howell, The Ohio State University, Columbus, Ohio. The author wishes to express special thanks to Dr. Herschel C. Self for his numerous helpful suggestions concerning the investigative approach used in this study and his critical reading of the report draft. Finally, thanks are extended to the photointerpreters of the Foreign Technology Division, Wright-Patterson Air Force Base, and the Tactical Reconnaissance Wing, Shaw Air Force Base, whose contribution of time and effort made this study possible.

# ABSTRACT

Judgments of 12 characteristics of 200 aerial reconnaissance photographs, each containing a designated target, and physical measures of target size and location were related to (1) search time required to locate targets and (2) judged overall target difficulty. Twenty photointerpreters and 20 college students served as subjects. Photographs were divided into two equal groups to permit cross validation of results. A factor analysis of the data, including the two criterion measures, resulted in the extraction of eight orthogonal factors. These were identified as (1) target size, (2) picture sharpness and contrast, (3) picture detail, (4) logical restrictions on possible target location, (5) target shape and pattern, (6) target location, (7) target isolation, and (8) rater bias. Linear multiple-regression analysis yielded correlation coefficients ranging from .75 to .87 for predicting the logarithm of search time and .87 to .90 for predicting judged target difficulty from the 12 psychophysical judgments and the 2 physical measures. Cross validation of obtained prediction equations resulted in average correlations of .67 and .79 for search time and judged difficulty respectively. Raters were able to make highly reliable and seemingly valid judgments about complex perceptual characteristics of aerial photographs. There was no difference in reliability or validity between ratings made by photointerpreters and those made by untrained students.

PUBLICATION REVIEW

This technical documentary report is approved.

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# PREDICTING THE DIFFICULTY OF LOCATING TARGETS FROM JUDGMENTS OF IMAGE CHARACTERISTICS

Fen Rhodes

## INTRODUCTION

This report describes an investigation into the relationship between psychophysical judgments of selected characteristics of aerial reconnaissance photographs and the relative difficulty experienced by trained observers in locating particular targets. Real imagery was used and a number of overlapping variables were measured in an attempt to overcome some of the limitations of many of the existing studies that have been concerned with a functional description of the parameters influencing target detection behavior.

Previous research has been criticized by Bersh (ref 2) for its tendency to measure single variables out of context, using specially devised stimulus materials that are related in an unknown fashion to actual reconnaissance imagery. Sadacca (ref 18 ) expresses the view that "existing knowledge about the basic psychological factors operating when interpreters examine reconnaissance imagery is severely limited. Relatively little is known concerning the perceptual and cognitive processes that occur when interpreters search imagery and make critical decisions concerning the presence or absence of significant objects."

In the present study the author elected to quantify a range of psychologically meaningful image characteristics using a large number of aerial photographs containing targets of different types and difficulties. Fourteen characteristics were finally chosen, and all but two were measured with psychophysical scaling techniques. For these two variables physical measurements were taken directly from the photographs. The selected characteristics reflected not only various aspects of what may be termed image quality—such as contrast, scale, and sharpness—but also certain variables associated with image content that were believed to influence target difficulty. Examples of the latter are target density, background homogeneity, target pattern distinctiveness (relative to the particular picture in which the target appears), and distinctiveness of target shape.

Using factor analysis and linear multiple-regression analysis, the 14 measures obtained for each photograph were related to each other and to two criteria of target difficulty in an effort to (1) identify some of the basic psychological-perceptual variables underlying target detection behavior (if indeed such exist) and (2) examine their relative importance in accounting for observed differences in target difficulty.

Psychophysical judgments have been used by Saddaca and Schwartz (ref 20) in evaluating the overall quality of aerial photographs, and Kaizer (ref 17) used observer rankings of series of targets as a criterion for the development of an objective measure of image texture. There have also been multivariate studies using real imagery in which different measures of image quality or content, including so-called image complexity, have been related to time for target detection or some other criterion of target difficulty. Notable among these are two studies conducted for Aerospace Medical Research Laboratories. One is the study of Corbett, Diamantides, and Krause, "Measurement and Models for Relating the Physical Characteristics of Images to Target Detection," Goodyear Aerospace Corporation, and the other that of Nygaard, Slocum, Thomas, Skeen, and Woodhull (see footnote, page 9). Both of these related derived physical measures of image complexity using side-looking radar imagery to the performance of operators in detecting targets. An investigation using photographic imagery was carried out by Williams, Simon, Haugen, and Roscoe (ref 26), who described the effects of resolution, scale, and selected target characteristics upon observer performance in finding and identifying targets.

The present study differs from previous, similar investigations in at least three respects:

1. Psychophysical judgments have been used to quantify a number of specific image characteristics, including complex target-background relationships.

2. Factor analytic techniques are employed in an effort to get at underlying, psychologically meaningful variables.

3. Measures have been obtained across a large number of aerial photographs ($\underline{N} = 100$), and the results cross-validated on a second group of the same size.

## METHOD

### Selection and Preparation of Aerial Photographs

The selection of the aerial reconnaissance photographs that were used in this study was guided by a number of specific considerations, both theoretical and practical. The more important of these in terms of final influence upon the sample of photographs chosen were the following:

1. The desire to select photographs representing a wide range of image characteristics occurring in various combinations with one another and reflecting different levels of difficulty of target detection with relation to specific, predesignated objects chosen as targets.

2. The decision to restrict the range of certain variables, viz, contrast, scale, and target size, to what might be reasonably encountered and considered usable in the actual reconnaissance situation. In addition, an upper limit was imposed on target size by the requirement for a detection task sufficiently difficult to yield differences in performance from picture to picture.

3. The necessity for eliminating from consideration many of the available recent photographs because of their classified nature. Consequently, a large portion of photographs were several years old—some dating as far back as 1941—and therefore in in some instances contained targets not strictly comparable to present-day examples. This was especially true in the case of aircraft. Owing to the nature of the target detection task required of subjects, however, it is the author's opinion that this situation did not act to restrict the validity or generality of the results obtained.

Preliminary screening of aerial reconnaissance photographs, both vertical and oblique, available from the Aeronautical Chart and Information Center, Washington, D.C., and the files at Wright-Patterson Air Force Base resulted in the selection of approximately 400 photos for further review. This number was subsequently narrowed to 275 that were considered to meet most satisfactorily the criteria outlined above. At this point in the investigation individual variables of interest—except for a few like contrast, scale, target size, and target density—were not precisely defined and therefore did not serve systematically as bases for judging photographs. Primary emphasis was placed rather upon obtaining a range of target types, ie, storage tanks, bridges, planes, etc, and a range of target difficulties.

In each photograph the one object or group of related objects designated as the target was circled for positive identification. Pictures were then assigned a top and bottom (arbitrary in the case of vertical shots) for viewing purposes and trimmed to a standard size of 18 × 23 cm ( 7 × 9 inches).

In order to have a basis for further elimination of photographs to reduce the N below 275 and to provide some systematic verification of the presumed normal distribution of target difficulties, a psychophysical scaling procedure was undertaken using 25 students and 10 photointerpreters as judges. The 275 pictures were divided into 18 groups of 15 pictures each plus 5 photos chosen as a standard and appearing in every group. The resulting 18 groups of 20 pictures formed overlapping matrices similar to those recommended by both Guilford (ref 11) and Torgerson (ref 24) for reducing the number of judgments required in scaling by paired comparisons. In the present case the purpose for dividing stimuli into submatrices was to create groups small enough to permit reliable ranking of photographs on a continuum of target difficulty. Specifically, raters* were required to rank the 20 photos in each group according to the relative difficulty a person would experience in finding the circled target in each photograph if (1) there were no circle or other indication as to the location of the target, and (2) the individual knew exactly what he was looking for and could recognize the target when he found it. The raters were told that a circled target was always distinguishable from all other objects in the picture, even very similar objects, by at least one feature.

Scale values for each group were obtained by normalizing the average rank scores for the 20 pictures† and transforming these $\underline{z}$ values to Guilford's $\underline{C}$ scale, which has a mean of 5.0 and a standard deviation of 2.0 (ref 11). Eighteen linear regression equations were then developed to transform the scale values for the five standard photos included in every group to a common base, arbitrarily chosen as the mean of the 18 scores for each photo. These same linear transformations were applied to the remaining photographs of the various groups to achieve a single common scale measuring target difficulty for all 275 pictures.

The semi-interquartile range ($\underline{Q}$) was computed as a measure of dispersion of the 35 ratings assigned to each photograph‡ and photos having the highest Q values were discarded until the total $\underline{N}$ was reduced to a convenient 200. These photos were divided into two groups of 100 each, both having approximately equal and normal distributions of target difficulties (means of 5.5, standard deviations of 1.6). Difficulty scale values and $\underline{Q}$ for these photographs are presented in tables 19 and 20, Appendix B.

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*Ten photointerpreters from the Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, and twenty-five students from the University of Dayton, Dayton, Ohio.

†Students' ratings were combined with those of photointerpreters based on evidence that no important differences existed between the two sets of ratings for any of the 18 groups of photographs. Sign tests (ref 21) performed on medians of ranks assigned by photointerpreters and students indicated no difference in central tendency between the two samples of raters ($p > .05$ in every case), and rank-order correlations between photointerpreter and student ratings for the 18 groups of pictures yielded a median Spearman $\rho$ of .90.

‡In addition to this measure of inter-rater agreement, test-retest reliabilities were computed for 23 of the student raters by obtaining correlations between initial rankings and re-rankings of the 18 groups of pictures. These are shown in table 21, Appendix B. It will be noted that reliabilities in the .80s and .90s were not unusual.

There were 14 oblique views in photo group I and 16 in group II. A distribution of targets for the two groups according to target type is shown in table 1.

TABLE 1

DISTRIBUTION OF TARGET TYPES

| Type | No. in group I photos | No. in group II photos |
|---|---|---|
| Bridge | 13 | 11 |
| Storage tank(s) | 13 | 20 |
| Plane(s) | 25 | 28 |
| Dam | 3 | 3 |
| Roundhouse | 5 | 1 |
| Ship(s) | 6 | 3 |
| Building(s) | 25 | 22 |
| Other* | 10 | 12 |
| Total | 100 | 100 |

*Park, racetrack, pond, traffic circle, etc.

For the detection task a target card was prepared for each picture showing a 1.1 cm ($\frac{7}{16}$ in.) reproduction of the designated target. This was accomplished by projection enlargement or reduction of the negative until the target itself would just fit into a circle of 1.1 cm diameter. A print was then made approximating as closely as possible the contrast of the original picture. The target alone (as much of the background as possible was trimmed away) was glued to the center of a 7.6 × 10.2 cm (3 × 4 in.) white card in the same orientation as it appeared in the photograph.

The 1.1 cm size chosen as a standard for the 200 targets represented a compromise between having prints large enough to trim easily and keeping to a minimum the amount of enlargement required to process the smallest targets. The latter was an important consideration because the loss of apparent sharpness that accompanies photographic enlargement could if pronounced serve as a cue to the size of the target in the original photograph. It was also desirable in order to minimize size cues that the standard fall in the middle of the distribution of target sizes, size being measured in centimeters across the widest portion of the target in the original print. The 1.1 cm standard used compares with a mean target size of 0.8 cm for group I photographs and 0.8 cm for group II; the standard deviation was 0.5 cm in both cases.

**Development of Rating Scale**

Psychophysical judgments evaluating specific characteristics of the 200 aerial photographs and their targets were obtained by applying a 12-item rating scale to every picture. Judges rated on a scale ranging from one to seven (seven being highest) the extent to which the photograph being evaluated possessed each of the 12 characteristics in question. These are shown below as they appeared on the final rating form:

1. Frequency of occurrence in picture of objects that could be confused with target.
2. Distinctiveness of target shape, ie, how much target stands out because of its shape.
3. Amount and variety of picture detail.
4. Distinctiveness of target contrast, ie, how much target stands out because of its lightness or darkness.
5. Size of target relative to size of other objects in picture.
6. Freedom of target location, ie, extent to which nature of target allows it to be located anywhere in picture (eg, a building has more freedom than a bridge).
7. Homogeneity or uniformity of picture content (excluding target).
8. Overall picture contrast, ie, range of black-white gradation.
9. Isolation of target from background.
10. Distinctiveness of target pattern, ie, how much target stands out because of arrangement, detail, and texture of its elements.
11. Sharpness or clarity of picture detail.
12. Distinctiveness of target size, ie, how much target stands out because of its size.

The original version of the rating form was pretested on 10 persons, who rated five pictures selected for differences with respect to the characteristics included in the scale. Items on which there was relatively low agreement among judges were revised and retested until the author was satisfied that the differences in ratings were not due to basic misunderstandings about item meaning. The order of listing of the final items was determined by random assignment, which yielded the sequence shown above.

No special benchmarks or descriptive categories were provided for raters in the belief that any increase in reliability resulting from such procedures would not be worth the risk of a possible decrease in validity. Judges were simply informed that the assignment of ratings should be based as nearly as possible on the group of pictures being evaluated and not on their previous experience with aerial or other photographs. They were also urged to spread their ratings over the entire 7-point scale and to avoid excessive pile-up in the middle.

## Subjects

Twenty male undergraduate college students and twenty male photointerpreters* served as subjects to rate photographs and find targets. None of the students reported having had any previous experience in photointerpretation or other work dealing with aerial photographs. However, all were members of the group of 25 students who had initially scaled the original 275 photographs on overall target difficulty. This prior exposure to the photos used in the study was not considered to contaminate the final results because of (1) the large number of photographs, (2) the brief exposure involved, (3) the two months' lapse between the difficulty scaling and the main study, (4) the lack of indications by subjects of memory for specific targets, and (5) the assumption that any small carry-over effect would not confound the relationships being investigated.

The photointerpreters had all received formal training in photointerpretation and were rated by the Air Force as fully qualified. There was no overlap between this group and the group of photointerpreters who performed the difficulty scaling.

## Collection of Data

Ten photointerpreters and ten students answered the rating scale items for group I photographs and found targets for the cross-validation group. The remaining subjects found targets for group I and rated group II pictures. Between four and five hours were required for a rater to complete all 100 pictures. The target detection task took considerably less time—about one hour to one hour and a half. For both the students and the photointerpreters half served on the rating task first and the target detection task second; the reverse was true for the other half of each subject group.

In addition to counterbalancing for task order effects this arrangement allowed complete separation of rating and detection measures within each group of photographs and minimized the effect of subject carry-over between groups. Order of photograph presentation was also controlled on both tasks so as to be reversed for half of each group of subjects on each group of photographs.

In the rating task all 12 items were answered for each picture before going on to the next picture. Because of the large number of photographs being rated, it was not practical to have judges rate all pictures on one item before going to the next. Such a procedure would have been highly desirable, however, as a way of insuring minimum halo effect and maximum reliability.

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*Tactical Reconnaissance Wing, Shaw Air Force Base, South Carolina

The target detection task consisted of two parts. First, the subject was shown the target card and asked to identify the target if he could, it having been explained to him that only a gross identification by category was desired, eg, plane, tank, bridge, etc. The purpose of taking this data was to provide an index of meaningfulness for the various targets. The subject's response was recorded by the experimenter, who then placed the photograph containing the target beside the target card and started a stopwatch. (A maximum of 15 seconds was allowed for the identification portion of the task to prevent large differences in exposure time prior to finding the target in the photograph.) Subjects had been instructed to begin searching for the target immediately and to notify the experimenter to stop timing as soon as they had found it. Subjects were cautioned to be sure they had the right target before calling time, but there were a few instances in which the wrong object was located as the target. In these cases the subject was instructed to continue searching, and the additional time required to find the right target was added to the time already taken. A maximum search time of five minutes was allowed. Time was recorded to the nearest whole second.

## Data Analysis

Analysis of the relationships among the 16 variables investigated* relied almost exclusively upon multiple-regression techniques and factor analysis. There were four complete sets of data, viz, that for (1) students on photo group I, (2) students on photo group II, (3) photointerpreters on photo group I, and (4) photointerpreters on photo group II. For ease of designation these will hereafter be referred to as groups 1S, 2S, 1P, and 2P.

Two linear multiple-regression equations were developed for each group of data, each equation using the first 14 variables to predict one of the two criterion variables. A second set of equations was developed in which only the best predictors in each case were included against the criterion variables. Multiple-correlation coefficients were computed for all equations. As a cross validation to see how well the regression weights derived for one sample of photographs would hold up when applied to a second sample, the equations from 1S and 1P data were used with groups 2S and 2P, respectively. In addition 1S equations were tried with 2P data to demonstrate the combined effect of different samples of photographs and different populations of raters.

Separate factor analyses were carried out for the four groups using all 16 variables, and the sets of orthogonal loadings were rotated to reflect a common, meaningful structure. Factors were extracted by the method of principal axes, the results of

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*Variables 1-12 were the 12 items on the rating scale; variables 13 and 14 were physical measures of target size and distance from center of picture, respectively; and variables 15 and 16 were the two criterion measures, ie, judged target difficulty and target detection time.

which are entirely comparable to the more popular centroid solution. According to Harman (ref 12) the former is to be preferred, since "the centroid method of analysis is intended to approximate the results that are obtained with the principal-factor method, but with considerable savings in labor." Fruchter (ref 10) believes that "equivalent results can be obtained by the centroid method with less work if an additional factor or two is extracted so that the two solutions account for the same amount of variance." In the present study, since the analysis, including varimax rotation, was done on an IBM 7094 computer, ease of computation was not an important consideration. Following the varimax rotation of each factor matrix additional rotations were performed graphically in an attempt to satisfy what Horst (ref 15) calls "the second objective of factor analysis" (the first being reduction of the dimensionality of a set of observations), ie, finding a particular set of dimensions "which will yield relatively stable and invariant results, irrespective of the sample of entities and the sample of attributes which is used."

## RESULTS

Means and standard deviations of the 16 variables measured are shown for each experimental group in table 2. For variables 1 through 12 (the rating scale items) these are based on medians of the 10 ratings assigned to each photograph. For variable 16 the arithmetic means of the logarithms of individual detection times were used.

Detection times were transformed to log (10 × sec.) values to reduce skewness and provide a better fit for the linear regression equations used. This is in accordance with the procedure used in dealing with location-time distributions followed by Christner, Schutz, and Ray (ref 7); Eriksen (ref 9); and Nygaard et al* in a study being completed for Aerospace Medical Research Laboratories. The success of this transformation is indicated by the relative improvement in prediction that resulted from the use of log times rather than raw time scores or times for which the maximum had been reduced for computational purposes from 300 seconds to 60 or 45 seconds. For group 1S the linear multiple correlation of detection time with variables 1 through 14 was .68 using the 300-second limit, .80 for 60 seconds, .81 for 45 seconds, and .87 for log seconds.

Interjudge reliabilities for the 12 rating scale items were obtained by dividing the group of 10 judges in half and correlating for each item the sums of the five ratings in each group on the 100 photographs. These correlation coefficients, corrected for attenuation by the Spearman-Brown formula for double length, appear in table 3. As was expected, reliabilities for the photointerpreters were generally higher than those for students, although the difference between the median correlations (.83 and .90) was not significant at the .05 level.

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*Nygaard, J.E., G.K. Slocum, J.O. Thomas, J.R. Skeen, and Joan G. Woodhull, "The Measurement of Stimulus Complexity in High-Resolution Sensor Imagery," Hughes Aircraft Company.

TABLE 2

MEANS AND STANDARD DEVIATIONS OF VARIABLES

| Variable | Photo group I | | | | Photo group II | | | |
|---|---|---|---|---|---|---|---|---|
| | Students | | Photoin-terpreters | | Students | | Photoin-terpreters | |
| | M | SD | M | SD | M | SD | M | SD |
| 1. Confusing-object frequency | 3.4 | 1.5 | 3.0 | 1.5 | 3.2 | 1.7 | 3.0 | 1.3 |
| 2. Shape distinctiveness | 4.9 | 1.4 | 5.1 | 1.1 | 5.5 | 0.9 | 4.9 | 1.0 |
| 3. Picture detail | 4.2 | 1.1 | 4.4 | 1.0 | 4.6 | 1.2 | 4.7 | 0.9 |
| 4. Contrast distinctiveness | 4.1 | 1.2 | 4.0 | 1.1 | 4.0 | 1.3 | 4.0 | 1.0 |
| 5. Relative size | 4.2 | 1.1 | 3.9 | 1.1 | 3.8 | 1.2 | 3.9 | 1.0 |
| 6. Freedom of location | 4.5 | 1.3 | 4.5 | 1.2 | 4.4 | 1.4 | 4.4 | 1.4 |
| 7. Picture homogeneity | 4.4 | 0.8 | 4.4 | 0.8 | 4.6 | 0.9 | 4.4 | 0.8 |
| 8. Picture contrast | 4.7 | 0.9 | 4.3 | 0.9 | 4.0 | 0.9 | 4.2 | 0.8 |
| 9. Isolation from background | 4.1 | 1.2 | 4.2 | 1.1 | 4.1 | 1.3 | 4.2 | 1.0 |
| 10. Pattern distinctiveness | 5.0 | 1.0 | 5.0 | 0.9 | 5.1 | 1.0 | 5.2 | 0.7 |
| 11. Picture sharpness | 4.5 | 0.9 | 4.3 | 1.0 | 4.2 | 1.1 | 4.3 | 0.8 |
| 12. Size distinctiveness | 4.1 | 1.3 | 3.8 | 1.0 | 3.7 | 1.3 | 3.9 | 0.9 |
| 13. Size (cm) | 0.8 | 0.5 | 0.8 | 0.5 | 0.8 | 0.5 | 0.8 | 0.5 |
| 14. Distance from center (cm) | 6.1 | 2.6 | 6.1 | 2.6 | 6.7 | 2.6 | 6.7 | 2.6 |
| 15. Scaled difficulty | 5.5 | 1.6 | 5.5 | 1.6 | 5.5 | 1.6 | 5.5 | 1.6 |
| 16. Detection time (log sec.) | 1.7 | 0.4 | 1.8 | 0.5 | 1.8 | 0.4 | 1.7 | 0.4 |

Note: N=100 photographs

**TABLE 3**

INTERJUDGE RELIABILITIES FOR 12 RATING SCALE ITEMS*

| Item | Students | Photointerpreters |
|---|---|---|
| 1. Confusing-object frequency | .88 | .94 |
| 2. Shape distinctiveness | .82 | .86 |
| 3. Picture detail | .79 | .84 |
| 4. Contrast distinctiveness | .84 | .91 |
| 5. Relative size | .90 | .81 |
| 6. Freedom of location | .86 | .90 |
| 7. Picture homogeneity | .90 | .76 |
| 8. Picture contrast | .77 | .90 |
| 9. Isolation from background | .78 | .92 |
| 10. Pattern distinctiveness | .73 | .80 |
| 11. Picture sharpness | .78 | .94 |
| 12. Size distinctiveness | .91 | .90 |

*Based on half-scores of ratings assigned by 10 judges to group I photographs ($\underline{N}$=100). Coefficients corrected for attenuation by Spearman-Brown formula for double length.

Correlations between median ratings by students and photointerpreters were computed for both groups of photographs (table 4). In addition differences between the means of student and photointerpreter ratings for each item were tested for both photo groups, as were log detection times. In no case was there any significant group different ($p > .05$) between the students and the photointerpreters.

Most of the subjects, both students and photointerpreters, knew the names of the targets that were presented, viz, 73, 87, 86, and 80 of the 100 targets in groups 1S, 1P, 2S, and 2P were correctly identified by at least 8 of the 10 subjects performing the target detection task. It was therefore assumed that the present results were not confounded by subjects' failure to recognize specific targets.

No analysis was made of performance on oblique versus vertical photographs in view of the small proportion of oblique views represented in the sample and the results obtained by Sadacca, Ranes, and Schwartz (ref 19) indicating no substantial overall difference between the two kinds of photos insofar as target identification is concerned. There was no evidence that the oblique photos presented any problem in the rating task.

TABLE 4

CORRELATIONS BETWEEN RATINGS BY STUDENTS AND PHOTOINTERPRETERS FOR 12 ITEMS

| Item | Photo group I | Photo group II |
|---|---|---|
| 1. Confusing-object frequency | .90 | .83 |
| 2. Shape distinctiveness | .84 | .72 |
| 3. Picture detail | .66 | .79 |
| 4. Contrast distinctiveness | .79 | .84 |
| 5. Relative size | .79 | .84 |
| 6. Freedom of location | .78 | .89 |
| 7. Picture homogeneity | .57 | .73 |
| 8. Picture contrast | .81 | .74 |
| 9. Isolation from background | .85 | .80 |
| 10. Pattern distinctiveness | .73 | .56 |
| 11. Picture sharpness | .76 | .78 |
| 12. Size distinctiveness | .85 | .83 |

Note. $\underline{N}$=100 photographs

## Multiple Regression and Correlation Analysis

Multiple-correlation coefficients of the rating scale plus physical measures with detection time and judged target difficulty (variables 16 and 15 respectively) are listed in table 5. Correlations were also computed using a limited number of variables as predictors, selected by a stepwise regression procedure in order of their relative contribution to the total prediction. The criterion for inclusion of variables was significance of unique predictive variance at the 25% level or better. This was tested by comparing the increase in explained variance that resulted from the addition of a new variable to the unexplained or error variance that still remained. This comparison formed an $\underline{F}$ ratio with 1 and (99-$\underline{k}$) degrees of freedom, where $\underline{k}$ = number of current predictors, including the one just added. The 25% level of $\underline{F}$ was chosen for acceptance of a variable rather than the 5% or 1% level because it was desired to keep to a minimum the probability of a type II error, ie, failing to add a variable to the group of predictors when it should be added. It was believed that this type of error would have a more serious effect upon cross-validation results than the type I error of including as a predictor a variable that should be omitted. Using this criterion for inclusion of variables the multiple $\underline{R}$ in each case remained virtually unchanged from the coefficient reflecting all 14 predictors.

Cross validations were carried out as indicated in table 6. Regression equations that were developed for one group of data were applied to a second group to

TABLE 5

MULTIPLE CORRELATIONS FOR TWO CRITERIA

| Group* | Criterion variable† | Predictor variables†, ‡ | Number of predictors‖ | R |
|---|---|---|---|---|
| 1S | 15 | 5, 6, 2, 11, 13, 9, 8, 4, 14, 1, 7, 12, 10, 3 | 14 | .90 |
| 1S | 15 | 5, 6, 2, 11, 13, 9, 8, 4, 14, 1 | 10 | .90 |
| 1S | 16 | 10, 12, 3, 14, 6, 9, 5, 7, 8, 1, 13, 4, 11, 2 | 14 | .87 |
| 1S | 16 | 10, 12, 3, 14, 6, 9, 5 | 7 | .87 |
| 1P | 15 | 12, 9, 13, 1, 11, 3, 6, 7, 8, 10, 2, 14, 5, 4 | 14 | .90 |
| 1P | 15 | 12, 9, 13, 1, 11, 3, 6, 7, 8, 10, 2, 14 | 12 | .90 |
| 1P | 16 | 12, 9, 1, 3, 11, 8, 10, 2, 14, 6, 4, 5, 7, 13 | 14 | .75 |
| 1P | 16 | 12, 9, 1, 3, 11, 8 | 6 | .74 |
| 2S | 15 | 12, 9, 3, 11, 14, 2, 7, 8, 13, 1, 5, 6, 4, 10 | 14 | .90 |
| 2S | 15 | 12, 9, 3, 11, 14, 2, 7, 8 | 8 | .90 |
| 2S | 16 | 12, 4, 3, 6, 1, 11, 5, 14, 2, 8, 7, 10, 13, 9 | 14 | .83 |
| 2S | 16 | 12, 4, 3, 6 | 4 | .82 |
| 2P | 15 | 12, 11, 9, 13, 14, 8, 10, 5, 1, 2, 6, 4, 3, 7 | 14 | .87 |
| 2P | 15 | 12, 11, 9, 13, 14, 8, 10, 5, 1, 2 | 10 | .87 |
| 2P | 16 | 9, 1, 13, 3, 10, 4, 2, 8, 11, 7, 5, 6, 14, 12 | 14 | .75 |
| 2P | 16 | 9, 1, 13, 3, 10, 4 | 6 | .73 |

Note.--N=100 photographs. All correlations are significant at the .01 level.

*Refer to p. 8 for explanation of symbols.

†Names of variables appear on p. 10.

‡Listed in order of selection by stepwise regression procedure.

‖Criterion for stopping selection short of 14 predictors explained on p. 12.

TABLE 6

CROSS-VALIDATION RESULTS

| Original group* | Cross-validation group* | Criterion | Number of predictors | Original Multiple R | Estimated shrunken R | Actual cross-validation R |
|---|---|---|---|---|---|---|
| 1S | 2S | 15† | 14 | .90 | .88 | .84 |
| 1S | 2S | 15 | 10 | .90 | .89 | .84 |
| 1S | 2S | 16‡ | 14 | .87 | .85 | .69 |
| 1S | 2S | 16 | 7 | .87 | .86 | .69 |
| 1P | 2P | 15 | 14 | .90 | .88 | .73 |
| 1P | 2P | 15 | 12 | .90 | .89 | .73 |
| 1P | 2P | 16 | 14 | .75 | .70 | .65 |
| 1P | 2P | 16 | 6 | .74 | .73 | .67 |
| 1S | 2P | 15 | 14 | .90 | .88 | .78 |
| 1S | 2P | 15 | 10 | .90 | .89 | .80 |
| 1S | 2P | 16 | 14 | .87 | .85 | .59 |
| 1S | 2P | 16 | 7 | .87 | .86 | .56 |

Note. N=100 photographs. All correlations are significant at the .01 level.

* Refer to p. 8 for explanation of symbols.

† Scaled difficulty.

‡ Detection time (log sec.).

determine the amount of shrinkage that would occur in the multiple-correlation coefficients. This was estimated a priori from Wherry's shrunken $\underline{R}_S$, which is computed by the formula

$$\underline{R}_S^2 = 1 - (1 - \underline{R}^2)(\underline{N} - 1)/(\underline{N} - \underline{k} - 1)$$

where

$\underline{R}$ = the original correlation coefficient
$\underline{N}$ = the number of observations
$\underline{k}$ = the number of predictors

The extent of agreement of these population estimates with the actual coefficients obtained by cross validation may be seen in the table.

The eight regression equations used in the cross validation are shown below. The first four equations provide a least-squares fit to 1S data; the last four were developed for 1P data.

$$Y_{15} = .12X_1 - .15X_2 + .02X_3 - .25X_4 - .41X_5 + .23X_6 + .14X_7 + .35X_8 - .14X_9 + .09X_{10} - .29X_{11} - .11X_{12} - .14X_{13} + .05X_{14} + 7.33$$

$$Y_{15} = .11X_1 - .15X_2 - .25X_4 - .43X_5 + .25X_6 + .32X_8 - .12X_9 - .30X_{11} - .16X_{13} + .05X_{14} + 8.17$$

$$Y_{16} = .02X_1 - .00X_2 + .06X_3 + .01X_4 + .07X_5 + .02X_6 + .04X_7 + .01X_8 - .07X_9 - .15X_{10} + .01X_{11} - .16X_{12} - .01X_{13} + .03X_{14} + 2.34$$

$$Y_{16} = .06X_3 + .07X_5 + .03X_6 - .05X_9 - .16X_{10} - .17X_{12} + .03X_{14} + 2.69$$

$$Y_{15} = .14X_1 - .25X_2 + .32X_3 + .08X_4 - .09X_5 + .17X_6 + .21X_7 + .16X_8 - .44X_9 + .38X_{10} - .41X_{11} - .54X_{12} - .19X_{13} + .05X_{14} + 6.77$$

$$Y_{15} = .14X_1 - .25X_2 + .33X_3 + .18X_6 + .20X_7 + .15X_8 - .36X_9 + .38X_{10} - .39X_{11} - .60X_{12} - .20X_{13} + .05X_{14} + 6.58$$

$$Y_{16} = .05X_1 - .07X_2 + .05X_3 - .05X_4 - .02X_5 + .03X_6 - .01X_7 + .05X_8 - .10X_9 + .10X_{10} - .07X_{11} - .11X_{12} - .01X_{13} + .01X_{14} + 2.32$$

$$Y_{16} = .05X_1 + .05X_3 + .06X_8 - .11X_9 - .07X_{11} - .16X_{12} + 2.52$$

## Factor Analysis

Results of the factor analysis for each group are shown in tables 7 through 10. The original correlation matrices and the matrices of residuals may be found in Appendix A. The Wherry (ref 25) clean-up technique was employed to improve the residuals slightly by reducing one .06 and a few .05s but further improvement was not possible.

Following the initial analyses two iterations were performed to refine the original communality estimates. For each variable the communality was estimated by the square of the multiple-correlation coefficient of that variable with the other 15 variables. According to Harman (ref 12) this method of estimating communalities has definite advantages over the next best method (or one of its modifications) recommended by Thomson (ref 23) and Fruchter (ref 10), ie, taking the highest correlation in each row or column to be the communality. Further iterations were deemed uneconomical in terms of the additional convergence that could be expected.

Eight factors were extracted for each group of data. After varimax rotation of these factor matrices, graphical rotations were performed as indicated below each table of loadings to achieve clearer psychological meaning and increase the similarity of factor structures. An interpretation of the factors will be considered under "Discussion and Conclusions."

TABLE 7

ROTATED ORTHOGONAL FACTOR LOADINGS (PHOTO GROUP I, STUDENTS)*

| Variable | Factor | | | | | | | | $h^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| 1. Confusing-object frequency | -.54 | -.04 | .24 | .13 | -.59 | .14 | -.20 | .06 | .80 |
| 2. Shape distinctiveness | .67 | .00 | -.15 | -.04 | .61 | .03 | .37 | .00 | .98 |
| 3. Picture detail | -.09 | .18 | .72 | .06 | -.02 | .12 | -.11 | .16 | .62 |
| 4. Contrast distinctiveness | .28 | .33 | -.07 | -.03 | .14 | -.08 | .80 | -.01 | .86 |
| 5. Relative size | .77 | .18 | -.22 | .05 | .25 | -.05 | .27 | -.16 | .84 |
| 6. Freedom of location | -.12 | -.03 | -.09 | .63 | -.04 | -.06 | -.09 | -.03 | .44 |
| 7. Picture homogeneity | .18 | -.02 | -.70 | .21 | .15 | -.02 | -.01 | -.23 | .64 |
| 8. Picture contrast | .01 | .63 | .09 | -.10 | -.03 | .03 | .46 | .26 | .70 |
| 9. Isolation from background | .35 | .14 | -.16 | -.20 | .21 | -.11 | .75 | -.05 | .83 |
| 10. Pattern distinctiveness | .64 | .11 | -.01 | .05 | .44 | -.18 | .42 | .07 | .83 |
| 11. Picture sharpness | .26 | .70 | .13 | .00 | .12 | -.01 | .11 | .03 | .60 |
| 12. Size distinctiveness | .86 | .23 | -.18 | -.02 | .30 | -.10 | .14 | .06 | .96 |
| 13. Size (cm) | .72 | .07 | .01 | -.29 | .04 | .16 | -.05 | .04 | .63 |
| 14. Distance from center (cm) | -.10 | .00 | .07 | -.06 | -.18 | .47 | -.07 | .04 | .28 |
| 15. Scaled difficulty | -.72 | -.21 | .03 | .35 | -.29 | .15 | -.28 | .33 | .99 |
| 16. Detection time (log sec.) | -.64 | -.06 | .16 | .20 | -.33 | .42 | -.29 | -.05 | .85 |

*Varimax solution with factors I, III, IV, VII, VIII reflected and four graphical rotations, viz , I vs. V 20° clockwise, V' vs. VI 15° clockwise, II vs. VIII 8° clockwise, III vs. VIII' 14° counterclockwise.

**TABLE 8**

ROTATED ORTHOGONAL FACTOR LOADINGS (PHOTO GROUP I, PHOTOINTERPRETERS)*

| Variable | Factor | | | | | | | | $h^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| 1. Confusing-object frequency | -.63 | .09 | .12 | -.06 | -.57 | .05 | -.08 | .19 | .78 |
| 2. Shape distinctiveness | .58 | .06 | -.04 | .15 | .70 | -.15 | .13 | -.14 | .91 |
| 3. Picture detail | -.19 | .14 | .65 | -.26 | .14 | .11 | -.13 | .09 | .56 |
| 4. Contrast distinctiveness | .14 | .25 | -.08 | .07 | .31 | -.11 | .83 | .00 | .89 |
| 5. Relative size | .31 | .16 | -.42 | -.29 | .52 | -.39 | .08 | .12 | .83 |
| 6. Freedom of location | .34 | .11 | -.24 | .55 | -.09 | -.02 | -.15 | .02 | .53 |
| 7. Picture homogeneity | .00 | -.04 | -.64 | -.02 | .25 | -.11 | .06 | .21 | .54 |
| 8. Picture contrast | .04 | .64 | .12 | -.10 | .07 | .07 | -.13 | .20 | .50 |
| 9. Isolation from background | .31 | .24 | -.11 | -.02 | .33 | -.10 | .84 | .08 | .95 |
| 10. Pattern distinctiveness | .47 | .06 | .04 | .16 | .64 | -.14 | .41 | .13 | .88 |
| 11. Picture sharpness | .06 | .81 | .15 | .10 | .00 | -.02 | .13 | .06 | .72 |
| 12. Size distinctiveness | .51 | .01 | -.28 | -.34 | .60 | -.31 | .17 | .16 | .94 |
| 13. Size (cm) | .53 | -.03 | -.11 | -.42 | .25 | .10 | -.05 | .38 | .67 |
| 14. Distance from center (cm) | -.05 | .04 | .11 | -.06 | .06 | .49 | -.08 | .05 | .27 |
| 15. Scaled difficulty | -.79 | -.14 | .22 | .25 | -.22 | .25 | -.26 | -.11 | .93 |
| 16. Detection time (log sec.) | -.46 | -.10 | .30 | .14 | -.30 | .23 | -.34 | .11 | .62 |

*Varimax solution with factors I, III, IV, V, VIII reflected and eight graphical rotations, viz , II vs. VIII 15° clockwise, III vs. VIII' 19° counterclockwise, IV vs. VIII" 23° counterclockwise, I vs. V 46° clockwise, V' vs. VIII"' 8° counterclockwise, V" vs. VII 7° counterclockwise, I' vs. VIII"" 13° counterclockwise, I" vs. IV' 29° clockwise.

TABLE 9

ROTATED ORTHOGONAL FACTOR LOADINGS (PHOTO GROUP II, STUDENTS)*

| Variable | Factor | | | | | | | | $h^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| 1. Confusing-object frequency | -.32 | -.04 | .09 | .16 | -.69 | .12 | -.17 | .05 | .66 |
| 2. Shape distinctiveness | .44 | .18 | -.12 | -.20 | .55 | .05 | .35 | .25 | .77 |
| 3. Picture detail | .05 | .10 | .70 | .10 | -.03 | .06 | -.09 | .07 | .53 |
| 4. Contrast distinctiveness | .25 | .36 | -.08 | .00 | .20 | -.10 | .75 | -.17 | .84 |
| 5. Relative size | .88 | -.17 | .06 | .07 | .20 | -.09 | .16 | .20 | .92 |
| 6. Freedom of location | -.11 | -.07 | .05 | .69 | -.09 | .11 | -.06 | .01 | .52 |
| 7. Picture homogeneity | .17 | -.22 | -.38 | .41 | .02 | -.04 | .02 | .42 | .57 |
| 8. Picture contrast | -.02 | .73 | .16 | -.02 | .06 | -.01 | .17 | -.10 | .59 |
| 9. Isolation from background | .26 | .21 | -.20 | -.14 | .20 | .02 | .75 | .19 | .81 |
| 10. Pattern distinctiveness | .37 | .34 | .04 | .23 | .51 | -.15 | .37 | .03 | .72 |
| 11. Picture sharpness | .20 | .76 | -.02 | -.17 | .09 | .01 | .21 | .13 | .72 |
| 12. Size distinctiveness | .90 | .14 | -.02 | -.09 | .25 | .02 | .23 | -.05 | .95 |
| 13. Size (cm) | .60 | .13 | -.02 | .01 | .30 | .19 | .05 | .08 | .50 |
| 14. Distance from center (cm) | .02 | -.02 | -.03 | .07 | -.05 | .53 | -.03 | .04 | .29 |
| 15. Scaled difficulty | -.71 | -.25 | .26 | .23 | -.25 | .15 | -.29 | -.10 | .86 |
| 16. Detection time (log sec.) | -.52 | -.23 | .45 | .17 | -.24 | .17 | -.39 | .11 | .80 |

*Varimax solution with factors II, III, V reflected and four graphical rotations, viz , III vs. VIII 17° clockwise, I vs. V 5° clockwise, IV vs. VIII′ 15° counter-clockwise, II vs. VIII″ 4° clockwise.

**TABLE 10**

ROTATED ORTHOGONAL FACTOR LOADINGS (PHOTO GROUP II, PHOTOINTERPRETERS)*

| Variable | Factor | | | | | | | | $h^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| 1. Confusing-object frequency | -.32 | .02 | -.01 | .21 | -.63 | .12 | -.26 | -.22 | .68 |
| 2. Shape distinctiveness | .21 | .04 | -.04 | -.07 | .75 | -.02 | .08 | .30 | .70 |
| 3. Picture detail | .03 | .09 | .65 | .04 | -.01 | .09 | -.10 | .01 | .45 |
| 4. Contrast distinctiveness | .08 | .25 | .03 | -.03 | .08 | .01 | .84 | .22 | .84 |
| 5. Relative size | .81 | -.18 | -.15 | .08 | .15 | -.01 | .00 | .34 | .86 |
| 6. Freedom of location | -.09 | -.08 | .03 | .68 | -.08 | -.03 | -.07 | -.01 | .50 |
| 7. Picture homogeneity | .26 | -.07 | -.49 | .47 | .03 | .09 | -.08 | -.05 | .55 |
| 8. Picture contrast | -.08 | .67 | .13 | -.04 | -.08 | -.16 | .14 | .30 | .62 |
| 9. Isolation from background | .28 | .12 | -.20 | -.12 | .23 | .12 | .76 | .22 | .83 |
| 10. Pattern distinctiveness | .39 | .24 | .05 | .23 | .55 | .14 | .33 | .13 | .71 |
| 11. Picture sharpness | .10 | .74 | .04 | -.11 | .09 | .07 | .22 | .02 | .64 |
| 12. Size distinctiveness | .74 | -.12 | -.04 | .10 | .39 | .00 | .15 | .31 | .85 |
| 13. Size (cm) | .76 | .13 | .13 | -.17 | .10 | .11 | .10 | .08 | .67 |
| 14. Distance from center (cm) | .01 | -.06 | .04 | .00 | -.04 | .51 | .03 | .02 | .27 |
| 15. Scaled difficulty | -.75 | -.19 | .06 | .10 | -.36 | .19 | -.38 | .18 | .97 |
| 16. Detection time (log sec.) | -.46 | -.14 | .22 | .20 | -.42 | .06 | -.46 | .08 | .71 |

*Varimax solution with factors I, II, III, VI reflected and four graphical rotations clockwise, viz., I vs. VIII 18°, VII vs. VIII' 11°, II vs. VIII" 14°, V vs. VIII"' 18°.

## DISCUSSION AND CONCLUSIONS

It is evident from inspection of the factor matrices for groups 1S, 1P, 2S, and 2P, shown in tables 7 through 10, that the factor structures for the four groups were quite similar in terms of number of factors, factor loadings, and obtained communalities ($\underline{h}^2$). This similarity was taken as representing a cross validation of the factor structure for the 16 variables investigated, both for different groups of raters and for different samples of pictures. It was thereby possible to view the four structures as variations of a single, basic structure, and to assign names to the eight factors based on their average relationships (as reflected by factor loadings) to the 12 judged image characteristics and the 2 physical measures.

Strictly speaking, of course, orthogonal factors are only independent components of variance explaining observed relationships among a particular set of variables. They achieve the status of underlying, psychologically meaningful parameters (and are therefore worthy of naming) only to the extent that the pattern of loadings in the factor matrix is unequivocal in its implications. This makes definitive naming of individual factors a risky business at best, and dictates that any factor name be viewed as only suggestive of the single dimension or group of covarying dimensions represented by that factor. Operationally, a factor is wholly and completely defined by a particular set of loadings in a particular matrix, and any name that is used to talk about the factor can rarely impart all of the information contained in its pattern of loadings.

With this admonition the reader's attention is directed to the descriptive names that were chosen for the eight factors appearing in tables 7, 8, 9, and 10. These factors were interpreted as representing:

I. Target Size
II. Picture Sharpness and Contrast
III. Picture Detail
IV. Freedom of Target Location
V. Target Shape and Pattern
VI. Target Location
VII. Target Isolation
VIII. Rater Bias

The discussion that follows describes those relationships among the 16 variables and the 8 orthogonal factors that were considered as most important in terms of contributing to factor meaning and predicting performance on the two criteria.

Of all of the factors, factor I (target size) consistently had the highest correlations with both criteria employed in the study, ie, scaled difficulty and detection time. This is not in agreement with the finding of Steedman and Baker (ref 22) that "both search time and errors remain invariant until the visual angle subtense of the targets falls below 12 minutes." Similarly, Harrison and Phoenix (ref 13) found little performance difference for objects exceeding 14 minutes of visual angle. The smallest target used in the present study subtended 35 minutes of arc at the minimum viewing distance of 25 cm.

The subjective judgments about target size (variables 5 and 12 in the tables of factor loadings) loaded higher on the first factor than did the physical measurement of size, reflecting the greater amount of information about the target contained in raters' evaluations of relative size and size distinctiveness than is present in a single measure of target diameter. The size variables always had moderate loadings on factor V, shape and pattern, while the defining variables for this factor (ie, those with the highest meaningful loadings—in this case variables 2 and 5) had secondary loadings on factor I. This would indicate that raters experienced considerable difficulty in distinguishing characteristics possessed by targets because of their size from those attributable to shape or pattern.

Factor II was said to represent the combined variables of judged picture sharpness and judged overall contrast. The fact that both variables had high loadings on the same factor was interpreted to mean that perceived sharpness and contrast were largely the same thing to raters, at least for the sample of pictures studied.

The correlations of factor II with detection time and scaled difficulty were very low and probably not significant. (The value of $\underline{r}$ required for significance at the 5% level is .20 for $\underline{N} = 100$. This value may be taken as a minimal estimate of the size of factor loading necessary to be considered significantly greater than zero.) These low criteria correlations confirm the findings of previous investigators as to the relative unimportance of contrast and sharpness in visual performance tasks compared with the effects of other variables. The Boston University Optical Research Laboratory (ref 3); Boynton and Bush (refs 4,5); and Boynton, Elworth, and Palmer (ref 6) found that variations in contrast have little effect upon performance except at very low contrasts, of which there were few examples in the present photographs. With regard to resolution, Baker, Morris, and Steedman (ref 1) have shown that this variable is of little significance as a determiner of target location time for a target recognition task similar to the one used in this study. Although it was recognized that resolution and perceived sharpness are only partially related, the latter being largely a function of acutance or edge gradient for resolutions greater than about twice that of the eye (ref 14), the Baker et al results were nevertheless considered to be especially relevant because of their direct concern with search time in a target recognition situation.

Factor III clearly represented variance having to do with judgments about picture detail and homogeneity. The loading for homogeneity of picture content (variable 7) was negative, reflecting the fact that this characteristic was rated low for pictures seen as being high in detail. Loadings on both criteria for this factor were generally low but significant.

Variable 6, freedom of target location (ie, the extent to which a target logically may be located anywhere in a picture), defined factor IV and was virtually independent of all other predictors except picture homogeneity. The latter variable loaded above .20 on factor IV for three of the four picture-rater groups. The factor's correlations with detection time were .20, .14, .17, and .20; its loadings on the secondary criterion were somewhat higher. The magnitude of the relationship of this factor to search time or other performance criteria could change greatly, of course, by selection of another sample of terrains or different types of targets, since the importance of logical restrictions on target location can vary drastically for the same target appearing in different terrain and vice versa.

The sixth factor represented almost entirely variance attributable to location of the target in the photograph, viz, its radial distance from the center. Criteria loadings exceeded .20 in only three out of eight instances. Baker et al (ref 1) found no pronounced differences in search time as a function of target position except for targets located in the periphery of the display, for which there was a marked increase in time.

For the factor representing isolation of target from background (factor VII) the defining variables were the direct judgment of target isolation (variable 9) and the judgment concerning distinctiveness of target contrast (variable 4). In addition to these high loadings, the only other significant loadings excepting those on the criteria resulted from judgments about target shape and pattern distinctiveness This leads to the conclusion that perceived isolation of a target from its background is primarily a function of the target's lightness contrast relative to it surround and secondarily a function of its shape-pattern distinctiveness. This confirms Conklin's (ref 8) opinion as to the importance of brightness contrast and complexity contrast as isolation variables. Factor VII had the highest loadings after the target size factor on both criteria.

The last factor, representing rater bias or halo effect, had, as would be expected, near-zero loadings on those variables that did not represent rating scale items. Loadings on individual scale items (variables 1-12) varied from group to group on factor VIII, indicating an absence of any consistent bias pattern for the four groups of raters.

From inspection of the tables of factor loadings it would appear that the factors contributing most to the prediction of target search time were I (size), V (shape-pattern), and VII (isolation). This also holds true for prediction of the secondary criterion, judged overall target difficulty. The remaining factors should not be dismissed, however, for they did (with the exception of the rater bias factor) contribute significantly to the total prediction. It is evident from table 5 that the variables chosen as best predictors by the stepwise regression technique represented the entire range of factors, not just I, V, and VII.

The multiple-correlation coefficients representing the prediction of detection time from the 12 rating scale items and two physical measures ranged in size from .75 to .87, with the average* $\underline{R}$ equal to .81. Essentially the same results were obtained when fewer predictors were used, ie, 6,7, or 8 instead of 14 variables. This prediction of detection or search time is somewhat better than that reported in

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*Obtained by using Fisher's $\underline{z}$ transformation.

two other multivariate studies in which multiple-regression techniques were employed. Christner et al (ref 7) obtained a multiple correlation of .46 for search time with two physical variables (ie, density and number of symbol types against a map background). Corbett et al*, using side-looking-radar imagery, reported a multiple R of .69 for detection time as predicted by four physical measures of image complexity.

The average multiple-correlation coefficient obtained when detection time was predicted from 14 variables was, as noted above, .81. The simple correlation of judged overall target difficulty with detection time was .73 (average), nearly as high as that obtained by combining in optimal fashion many judgments of individual image characteristics. Thus, the single complex judgment made by raters in answering the question, "How hard would it be to find this particular target in this photograph?" contained almost as much predictive information as several separate judgments about presumably relevant image characteristics.

*Corbett, D.G., N.D. Diamantides, and R.H. Krause, "Measurement and and Models for Relating the Physical Characteristics of Images to Target Detection, Goodyear Aerospace Corporation."

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# APPENDIX A

## INTERCORRELATIONS AND RESIDUALS OF CORRELATIONS

TABLE 11

INTERCORRELATIONS BETWEEN VARIABLES (PHOTO GROUP I, STUDENTS)

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | -82 | 29 | -46 | -72 | 18 | -34 | -06 | -56 | -75 | -23 | -75 | -39 | 26 | 72 | 71 |
| 2. Shape distinctiveness | | -20 | 57 | 79 | -14 | 30 | 15 | 67 | 84 | 27 | 82 | 48 | -19 | -76 | -75 |
| 3. Picture detail | | | -12 | -27 | -02 | -57 | 17 | -24 | -10 | 20 | -18 | -02 | 12 | 18 | 28 |
| 4. Contrast distinctiveness | | | | 57 | -12 | 09 | 57 | 83 | 66 | 40 | 51 | 18 | -14 | -58 | -54 |
| 5. Relative size | | | | | -07 | 37 | 17 | 60 | 74 | 33 | 87 | 53 | -21 | -79 | -68 |
| 6. Freedom of location | | | | | | 19 | -14 | -23 | -08 | -06 | -13 | -28 | -04 | 34 | 19 |
| 7. Picture homogeneity | | | | | | | -18 | 17 | 17 | -04 | 28 | 06 | -12 | -18 | -22 |
| 8. Picture contrast | | | | | | | | 41 | 26 | 52 | 19 | 06 | 00 | -17 | -17 |
| 9. Isolation from background | | | | | | | | | 68 | 28 | 54 | 26 | -20 | -65 | -63 |
| 10. Pattern distinctiveness | | | | | | | | | | 36 | 79 | 43 | -26 | -72 | -78 |
| 11. Picture sharpness | | | | | | | | | | | 41 | 24 | -05 | -40 | -27 |
| 12. Size distinctiveness | | | | | | | | | | | | 60 | -22 | -79 | -77 |
| 13. Size (cm) | | | | | | | | | | | | | 03 | -60 | -44 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 22 | 35 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | 77 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

Note.--Variables 1-12 are rating scale items; 13, 14 are physical measures; 15, 16 are criteria. N=100 photographs.

**TABLE 12**

INTERCORRELATIONS BETWEEN VARIABLES (PHOTO GROUP I, PHOTOINTERPRETERS)

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | -81 | 16 | -32 | -54 | 25 | -17 | 06 | -42 | -69 | 06 | -66 | -36 | 14 | 63 | 55 |
| 2. Shape distinctiveness | | -07 | 44 | 57 | -18 | 18 | 02 | 52 | 81 | 11 | 72 | 34 | -18 | -66 | -58 |
| 3. Picture detail | | | -12 | -32 | -18 | -44 | 14 | -20 | -08 | 18 | -21 | -08 | 16 | 29 | 26 |
| 4. Contrast distinctiveness | | | | 30 | -10 | 17 | 26 | 89 | 65 | 33 | 44 | 07 | -13 | -47 | -51 |
| 5. Relative size | | | | | -23 | 49 | -14 | 41 | 52 | -19 | 83 | 46 | -31 | -64 | -55 |
| 6. Freedom of location | | | | | | 14 | 07 | -24 | -18 | 09 | -35 | -39 | -02 | 40 | 25 |
| 7. Picture homogeneity | | | | | | | -03 | 23 | 21 | -10 | 40 | 18 | -14 | -23 | -28 |
| 8. Picture contrast | | | | | | | | 22 | 13 | 59 | -04 | 00 | 04 | -02 | 01 |
| 9. Isolation from background | | | | | | | | | 73 | 22 | 58 | 22 | -16 | -61 | -59 |
| 10. Pattern distinctiveness | | | | | | | | | | 17 | 69 | 37 | -20 | -62 | -56 |
| 11. Picture sharpness | | | | | | | | | | | 00 | -04 | 03 | -16 | -11 |
| 12. Size distinctiveness | | | | | | | | | | | | 60 | -26 | -81 | -66 |
| 13. Size (cm) | | | | | | | | | | | | | 03 | -60 | -34 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 22 | 22 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | 66 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

Note.--Variables 1-12 are rating scale items; 13, 14 are physical measures; 15, 16 are criteria. N=100 photographs.

TABLE 13

INTERCORRELATIONS BETWEEN VARIABLES (PHOTO GROUP II, STUDENTS)

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | -64 | 12 | -39 | -44 | 24 | 00 | -08 | -38 | -54 | -22 | -52 | -38 | 11 | 51 | 50 |
| 2. Shape distinctiveness | | -07 | 53 | 55 | -27 | 14 | 20 | 62 | 55 | 41 | 66 | 44 | 00 | -69 | -59 |
| 3. Picture detail | | | -10 | 07 | 11 | -23 | 17 | -17 | 06 | 05 | 01 | 05 | 07 | 18 | 36 |
| 4. Contrast distinctiveness | | | | 31 | -12 | -06 | 41 | 75 | 58 | 47 | 47 | 28 | -10 | -55 | -63 |
| 5. Relative size | | | | | -09 | 28 | -09 | 36 | 45 | 12 | 88 | 52 | -03 | -66 | -52 |
| 6. Freedom of location | | | | | | 28 | -07 | -25 | 02 | -23 | -18 | -14 | 14 | 29 | 28 |
| 7. Picture homogeneity | | | | | | | -26 | 13 | 11 | -11 | 18 | 06 | -04 | -10 | -12 |
| 8. Picture contrast | | | | | | | | 24 | 30 | 61 | 10 | 12 | -03 | -15 | -19 |
| 9. Isolation from background | | | | | | | | | 54 | 45 | 51 | 29 | -03 | -62 | -60 |
| 10. Pattern distinctiveness | | | | | | | | | | 44 | 57 | 43 | -12 | -55 | -49 |
| 11. Picture sharpness | | | | | | | | | | | 37 | 24 | 00 | -50 | -40 |
| 12. Size distinctiveness | | | | | | | | | | | | 65 | 00 | -82 | -65 |
| 13. Size (cm) | | | | | | | | | | | | | 10 | -53 | -38 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 14 | 13 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | 75 |
| 16. Detection time (log. sec.) | | | | | | | | | | | | | | | |

Note.--Variables 1-12 are rating scale items; 13, 14 are physical measures; 15, 16 are criteria. N=100 photographs.

TABLE 14

INTERCORRELATIONS BETWEEN VARIABLES (PHOTO GROUP II, PHOTOINTERPRETERS)

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | -65 | 04 | -36 | -40 | 23 | 05 | -05 | -48 | -50 | -16 | -59 | -37 | 07 | 56 | 54 |
| 2. Shape distinctiveness | | -03 | 23 | 39 | -16 | 04 | 06 | 38 | 57 | 15 | 54 | 26 | -04 | -42 | -45 |
| 3. Picture detail | | | -04 | -09 | 06 | -31 | 10 | -17 | 04 | 09 | -05 | 12 | 06 | 06 | 23 |
| 4. Contrast distinctiveness | | | | 10 | -10 | -11 | 36 | 78 | 44 | 38 | 26 | 22 | 02 | -42 | -49 |
| 5. Relative size | | | | | -02 | 32 | -10 | 32 | 39 | -06 | 81 | 59 | 01 | -59 | -40 |
| 6. Freedom of location | | | | | | 31 | -05 | -22 | 03 | -18 | 00 | -23 | 00 | 20 | 22 |
| 7. Picture homogeneity | | | | | | | -22 | 08 | 17 | -08 | 23 | 06 | 00 | -14 | -06 |
| 8. Picture contrast | | | | | | | | 15 | 15 | 54 | -08 | 08 | -11 | -03 | -08 |
| 9. Isolation from background | | | | | | | | | 52 | 34 | 46 | 34 | 04 | -59 | -57 |
| 10. Pattern distinctiveness | | | | | | | | | | 30 | 56 | 42 | 06 | -60 | -52 |
| 11. Picture sharpness | | | | | | | | | | | 06 | 20 | 02 | -36 | -28 |
| 12. Size distinctiveness | | | | | | | | | | | | 59 | 01 | -68 | -51 |
| 13. Size (cm) | | | | | | | | | | | | | 06 | -62 | -46 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 14 | 01 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | 75 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

Note. Variables 1-12 are rating scale items; 13, 14 are physical measures; 15, 16 are criteria. N=100 photographs.

**TABLE 15**

**RESIDUALS OF CORRELATIONS (PHOTO GROUP I, STUDENTS)***

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | 03 | 00 | -02 | -02 | 02 | 01 | 01 | 00 | -03 | 01 | 00 | 02 | 01 | -01 | -01 |
| 2. Shape distinctiveness | | 01 | -01 | -01 | 01 | -01 | -01 | 00 | 00 | -02 | -02 | -02 | 00 | 02 | 00 |
| 3. Picture detail | | | -01 | 00 | 00 | -02 | 00 | 00 | 00 | 01 | 00 | 01 | -01 | 00 | 02 |
| 4. Contrast distinctiveness | | | | 03 | 01 | -01 | 01 | 02 | 03 | -01 | 01 | -01 | 01 | -02 | -01 |
| 5. Relative size | | | | | 00 | -01 | 00 | 01 | 01 | -02 | 02 | 00 | -03 | 00 | 01 |
| 6. Freedom of location | | | | | | 01 | -01 | -01 | 01 | 01 | 00 | 00 | 00 | 00 | -01 |
| 7. Picture homogeneity | | | | | | | -01 | 00 | 00 | 01 | -02 | 00 | 00 | 01 | 01 |
| 8. Picture contrast | | | | | | | | -01 | -01 | 01 | -01 | -01 | -01 | 03 | 01 |
| 9. Isolation from background | | | | | | | | | 02 | 00 | 00 | 00 | -02 | 01 | 00 |
| 10. Pattern distinctiveness | | | | | | | | | | 00 | 00 | -02 | -01 | 00 | -03 |
| 11. Picture sharpness | | | | | | | | | | | -01 | 00 | 00 | 00 | 00 |
| 12. Size distinctiveness | | | | | | | | | | | | -03 | -01 | 02 | 01 |
| 13. Size (cm) | | | | | | | | | | | | | 01 | 01 | -01 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 01 | 02 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | 00 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

*Following extraction of eight factors by method of principal axes.

**TABLE 16**

RESIDUALS OF CORRELATIONS (PHOTO GROUP I, PHOTOINTERPRETERS)*

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | 00 | 01 | 01 | 01 | 02 | 01 | -03 | 00 | -01 | 02 | 00 | 02 | 00 | 00 | 00 |
| 2. Shape distinctiveness | | 02 | 00 | 01 | 01 | 00 | -01 | 00 | 00 | 00 | 00 | -01 | 01 | -01 | 00 |
| 3. Picture detail | | | 01 | 00 | -01 | -01 | -01 | -01 | 00 | 02 | 01 | 00 | 01 | 02 | 00 |
| 4. Contrast distinctiveness | | | | 01 | 01 | -01 | -01 | 00 | 01 | 00 | 01 | 00 | 02 | -01 | 00 |
| 5. Relative size | | | | | -01 | 01 | 01 | 00 | 00 | -01 | 00 | 00 | -01 | -01 | 01 |
| 6. Freedom of location | | | | | | 00 | -02 | -01 | 01 | 02 | 01 | 00 | 01 | 01 | 01 |
| 7. Picture homogeneity | | | | | | | 00 | 01 | 01 | 00 | 01 | -01 | 01 | 01 | 00 |
| 8. Picture contrast | | | | | | | | 02 | -01 | 02 | -01 | 00 | -02 | 02 | 02 |
| 9. Isolation from background | | | | | | | | | 01 | -02 | 00 | -02 | -01 | 00 | 00 |
| 10. Pattern distinctiveness | | | | | | | | | | 00 | 00 | 01 | -02 | 01 | -01 |
| 11. Picture sharpness | | | | | | | | | | | 00 | -01 | 01 | -02 | -02 |
| 12. Size distinctiveness | | | | | | | | | | | | 01 | -01 | 00 | 00 |
| 13. Size (cm) | | | | | | | | | | | | | 02 | 00 | -01 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 01 | 01 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | -02 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

*Following extraction of eight factors by method of principal axes.

TABLE 17

RESIDUALS OF CORRELATIONS (PHOTO GROUP II, STUDENTS)*

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confusing-object frequency | -03 | 02 | 00 | -01 | 00 | -02 | 00 | 01 | -01 | 00 | -01 | 01 | 00 | -02 | 00 |
| 2. Shape distinctiveness | | 02 | 02 | 00 | -01 | 01 | 03 | -01 | -03 | 01 | -01 | -03 | 02 | -01 | -01 |
| 3. Picture detail | | | -01 | 02 | 01 | -02 | 01 | 00 | 01 | 00 | -01 | 00 | -01 | 01 | 01 |
| 4. Contrast distinctiveness | | | | 02 | 03 | -01 | 01 | 02 | -02 | -01 | 00 | 00 | -02 | 00 | 00 |
| 5. Relative size | | | | | 00 | -01 | 02 | -01 | -01 | 01 | 01 | -02 | 02 | 02 | -03 |
| 6. Freedom of location | | | | | | 02 | 00 | -04 | 01 | -02 | 00 | -03 | 03 | -03 | 00 |
| 7. Picture homogeneity | | | | | | | 00 | 02 | 00 | 02 | 01 | 02 | -02 | 03 | -01 |
| 8. Picture contrast | | | | | | | | -01 | -03 | 03 | -02 | 00 | -02 | 04 | -01 |
| 9. Isolation from background | | | | | | | | | 03 | 00 | -01 | 01 | 01 | -01 | 02 |
| 10. Pattern distinctiveness | | | | | | | | | | 01 | 00 | 03 | -02 | -01 | 01 |
| 11. Picture sharpness | | | | | | | | | | | -01 | -03 | 02 | -02 | 01 |
| 12. Size distinctiveness | | | | | | | | | | | | 01 | 00 | 00 | 00 |
| 13. Size (cm) | | | | | | | | | | | | | 01 | -02 | 02 |
| 14. Distance from center (cm) | | | | | | | | | | | | | | 02 | -01 |
| 15. Scaled difficulty | | | | | | | | | | | | | | | -01 |
| 16. Detection time (log sec.) | | | | | | | | | | | | | | | |

*Following extraction of eight factors by method of principal axes.

## TABLE 18

### RESIDUALS OF CORRELATIONS (PHOTO GROUP II, PHOTOINTERPRETERS)*

| | Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Confusing-object frequency | -01 | 01 | 00 | 02 | -01 | 00 | 00 | 00 | 01 | -01 | -02 | -01 | 00 | 00 | -01 |
| 2. | Shape distinctiveness | | 01 | 00 | 01 | -02 | 01 | 00 | 01 | 02 | 00 | 00 | -02 | -02 | 01 | -01 |
| 3. | Picture detail | | | 00 | 00 | 02 | -02 | -02 | 01 | 00 | 02 | -02 | 01 | -01 | -01 | 05 |
| 4. | Contrast distinctiveness | | | | 00 | 01 | -01 | 02 | 02 | 01 | -01 | 00 | 01 | 00 | 00 | -03 |
| 5. | Relative size | | | | | 01 | 00 | 02 | 00 | -01 | -02 | 01 | -01 | 01 | -01 | 00 |
| 6. | Freedom of location | | | | | | 02 | 02 | -02 | 01 | -01 | 03 | -02 | 01 | 01 | -05 |
| 7. | Picture homogeneity | | | | | | | -03 | 03 | 01 | 02 | -01 | 03 | -02 | 00 | 04 |
| 8. | Picture contrast | | | | | | | | -02 | 02 | 02 | -01 | 02 | -01 | 03 | -03 |
| 9. | Isolation from background | | | | | | | | | 00 | 02 | 00 | -01 | -02 | -02 | 05 |
| 10. | Pattern distinctiveness | | | | | | | | | | -02 | -02 | 02 | 00 | -01 | 00 |
| 11. | Picture sharpness | | | | | | | | | | | 03 | -03 | 02 | -04 | 02 |
| 12. | Size distinctiveness | | | | | | | | | | | | -01 | 01 | -01 | 00 |
| 13. | Size (cm) | | | | | | | | | | | | | -01 | 02 | -02 |
| 14. | Distance from center (cm) | | | | | | | | | | | | | | 03 | -04 |
| 15. | Scaled difficulty | | | | | | | | | | | | | | | -01 |
| 16. | Detection time (log sec.) | | | | | | | | | | | | | | | |

*Following extraction of eight factors by method of principal axes.

# APPENDIX B

## TARGET DIFFICULTY SCALING DATA

TABLE 19

TARGET DIFFICULTIES AND Q VALUES (PHOTO GROUP I)

| Photo | Difficulty | Q | Photo | Difficulty | Q | Photo | Difficulty | Q |
|---|---|---|---|---|---|---|---|---|
| A5 | 3.7 | 1.8 | F11 | 6.8 | 2.1 | M13 | 3.7 | 1.4 |
| A7 | 4.8 | 4.1 | F13 | 6.4 | 1.7 | M14 | 5.4 | 2.0 |
| A10 | 4.1 | 2.0 | F17 | 4.6 | 2.6 | M16 | 3.5 | 2.7 |
| A13 | 5.9 | 2.5 | F19 | 2.1 | 1.0 | M17 | 5.8 | 2.6 |
| A14 | 1.9 | 0.3 | G2 | 4.3 | 2.3 | M19 | 6.1 | 2.6 |
| A18 | 3.0 | 2.8 | G8 | 3.4 | 2.8 | N2 | 7.1 | 2.3 |
| B2 | 7.6 | 1.3 | G12 | 7.0 | 1.7 | N19 | 5.5 | 2.0 |
| B8 | 3.9 | 2.5 | G20 | 3.9 | 2.4 | O5 | 4.8 | 1.6 |
| B12 | 4.9 | 2.6 | H6 | 3.4 | 1.7 | O7 | 7.2 | 2.6 |
| B14 | 7.6 | 1.8 | H11 | 3.9 | 1.9 | O9 | 5.0 | 1.6 |
| B17 | 3.5 | 1.9 | H15 | 6.6 | 1.3 | O12 | 7.5 | 2.3 |
| C2 | 4.8 | 2.4 | H18 | 2.7 | 2.2 | O15 | 4.4 | 2.0 |
| C3 | 8.2 | 1.1 | I3 | 4.6 | 2.6 | O19 | 7.8 | 1.5 |
| C5 | 7.2 | 2.5 | I15 | 6.4 | 2.5 | O20 | 6.1 | 2.1 |
| C6 | 6.9 | 1.6 | J6 | 4.2 | 2.8 | P2 | 7.1 | 2.7 |
| C15 | 6.0 | 2.0 | J9 | 6.6 | 2.4 | P6 | 4.7 | 2.4 |
| D3 | 3.0 | 2.4 | J13 | 5.2 | 1.7 | P9 | 7.2 | 1.6 |
| D9 | 7.0 | 1.6 | J17 | 6.1 | 1.6 | P10 | 7.8 | 2.7 |
| D11 | 5.7 | 1.6 | J18 | 4.2 | 2.8 | P13 | 1.5 | 0.6 |
| D13 | 3.7 | 1.8 | J19 | 3.3 | 2.4 | P16 | 4.2 | 2.5 |
| D15 | 6.3 | 1.0 | K3 | 7.7 | 1.9 | P17 | 5.8 | 2.1 |
| D19 | 8.7 | 0.3 | K6 | 4.4 | 2.6 | Q1 | 7.1 | 2.1 |
| D20 | 4.8 | 1.9 | K7 | 5.4 | 1.6 | Q7 | 6.3 | 2.0 |
| E4 | 3.9 | 1.7 | K9 | 7.3 | 1.8 | Q9 | 6.0 | 2.1 |
| E5 | 3.4 | 2.1 | K16 | 6.4 | 1.1 | Q11 | 6.7 | 2.3 |
| E9 | 4.3 | 2.4 | K17 | 6.8 | 1.6 | Q12 | 8.0 | 1.8 |
| E12 | 8.1 | 0.4 | K20 | 5.7 | 2.6 | Q17 | 4.7 | 1.9 |
| E14 | 5.4 | 2.2 | L2 | 7.8 | 2.6 | Q20 | 3.7 | 1.6 |
| E19 | 5.9 | 2.6 | L5 | 5.0 | 2.8 | R2 | 7.1 | 1.6 |
| F1 | 7.9 | 1.2 | L6 | 7.5 | 2.4 | R4 | 3.7 | 2.2 |
| F2 | 4.6 | 2.1 | L8 | 4.1 | 2.6 | R8 | 5.4 | 2.7 |
| F3 | 7.2 | 2.4 | L11 | 7.2 | 1.6 | R9 | 5.1 | 2.5 |
| F4 | 5.9 | 2.5 | M1 | 6.2 | 2.6 | R16 | 6.1 | 2.5 |
| | | | | | | R19 | 6.9 | 2.3 |

TABLE 20

TARGET DIFFICULTIES AND Q VALUES (PHOTO GROUP II)

| Photo | Diffi-culty | Q | Photo | Diffi-culty | Q | Photo | Diffi-culty | Q |
|---|---|---|---|---|---|---|---|---|
| A1 | 7.5 | 0.8 | G13 | 6.6 | 1.4 | N9 | 4.3 | 2.6 |
| A3 | 5.0 | 2.7 | G14 | 2.7 | 2.3 | N11 | 4.3 | 2.5 |
| A6 | 3.6 | 1.5 | G15 | 3.6 | 2.2 | N13 | 7.1 | 2.0 |
| A9 | 2.2 | 0.9 | H4 | 3.7 | 2.8 | N14 | 8.2 | 1.1 |
| A16 | 6.2 | 2.0 | H7 | 5.8 | 1.7 | N15 | 3.4 | 1.9 |
| B7 | 4.5 | 2.4 | H10 | 3.4 | 2.5 | N16 | 5.7 | 2.6 |
| B9 | 6.6 | 1.8 | H20 | 5.0 | 2.8 | N17 | 6.3 | 2.7 |
| B15 | 4.9 | 2.3 | I7 | 4.1 | 2.2 | N20 | 6.5 | 1.7 |
| C9 | 3.1 | 1.4 | I9 | 8.0 | 1.0 | O2 | 6.1 | 1.6 |
| C13 | 6.5 | 1.6 | I10 | 6.4 | 1.8 | O4 | 7.5 | 2.4 |
| C14 | 6.1 | 2.6 | I18 | 6.5 | 2.6 | O6 | 8.9 | 1.2 |
| C19 | 4.5 | 1.5 | J3 | 6.8 | 2.1 | O10 | 7.1 | 1.4 |
| C20 | 2.5 | 0.9 | J5 | 3.9 | 2.7 | O11 | 4.2 | 1.9 |
| D1 | 2.0 | 0.6 | J11 | 5.4 | 2.4 | O16 | 6.4 | 1.7 |
| D2 | 6.4 | 1.6 | K5 | 3.5 | 1.8 | O17 | 3.8 | 1.6 |
| D7 | 3.4 | 1.5 | K8 | 6.6 | 1.7 | O18 | 7.4 | 1.9 |
| D8 | 6.8 | 1.6 | K11 | 4.8 | 2.9 | P4 | 6.9 | 2.5 |
| D14 | 4.1 | 2.6 | K13 | 3.6 | 1.7 | P5 | 8.7 | 0.7 |
| D16 | 5.1 | 1.4 | K18 | 5.0 | 1.3 | P14 | 5.6 | 2.4 |
| D18 | 7.0 | 1.5 | K19 | 7.9 | 1.3 | P18 | 4.6 | 2.2 |
| E1 | 5.6 | 2.6 | L1 | 6.6 | 2.1 | P20 | 6.5 | 2.2 |
| E3 | 3.8 | 2.5 | L4 | 5.2 | 2.1 | Q2 | 6.1 | 2.1 |
| E8 | 4.8 | 1.9 | L9 | 5.2 | 2.2 | Q4 | 6.9 | 1.3 |
| E11 | 3.7 | 1.9 | L10 | 7.5 | 1.4 | Q10 | 7.6 | 2.2 |
| E13 | 5.4 | 2.2 | L15 | 7.5 | 1.8 | Q13 | 5.6 | 2.2 |
| E16 | 1.7 | 0.7 | L20 | 4.8 | 2.6 | Q14 | 7.0 | 2.2 |
| E17 | 6.2 | 1.5 | M6 | 2.4 | 1.2 | Q15 | 5.4 | 2.7 |
| F9 | 7.2 | 1.6 | M10 | 4.6 | 2.7 | Q19 | 7.7 | 1.4 |
| F12 | 4.3 | 2.4 | M15 | 3.9 | 2.0 | R5 | 6.1 | 1.9 |
| F15 | 5.8 | 2.3 | M18 | 5.8 | 2.6 | R7 | 8.4 | 0.8 |
| F20 | 4.1 | 2.0 | N1 | 5.6 | 2.4 | R12 | 4.0 | 1.7 |
| G1 | 6.5 | 2.1 | N5 | 4.0 | 2.0 | R13 | 4.7 | 2.4 |
| G4 | 5.8 | 1.6 | N6 | 5.0 | 2.4 | R14 | 6.4 | 2.5 |
| | | | | | | R20 | 6.5 | 1.8 |

## TABLE 21

## TEST-RETEST RELIABILITIES FOR STUDENTS

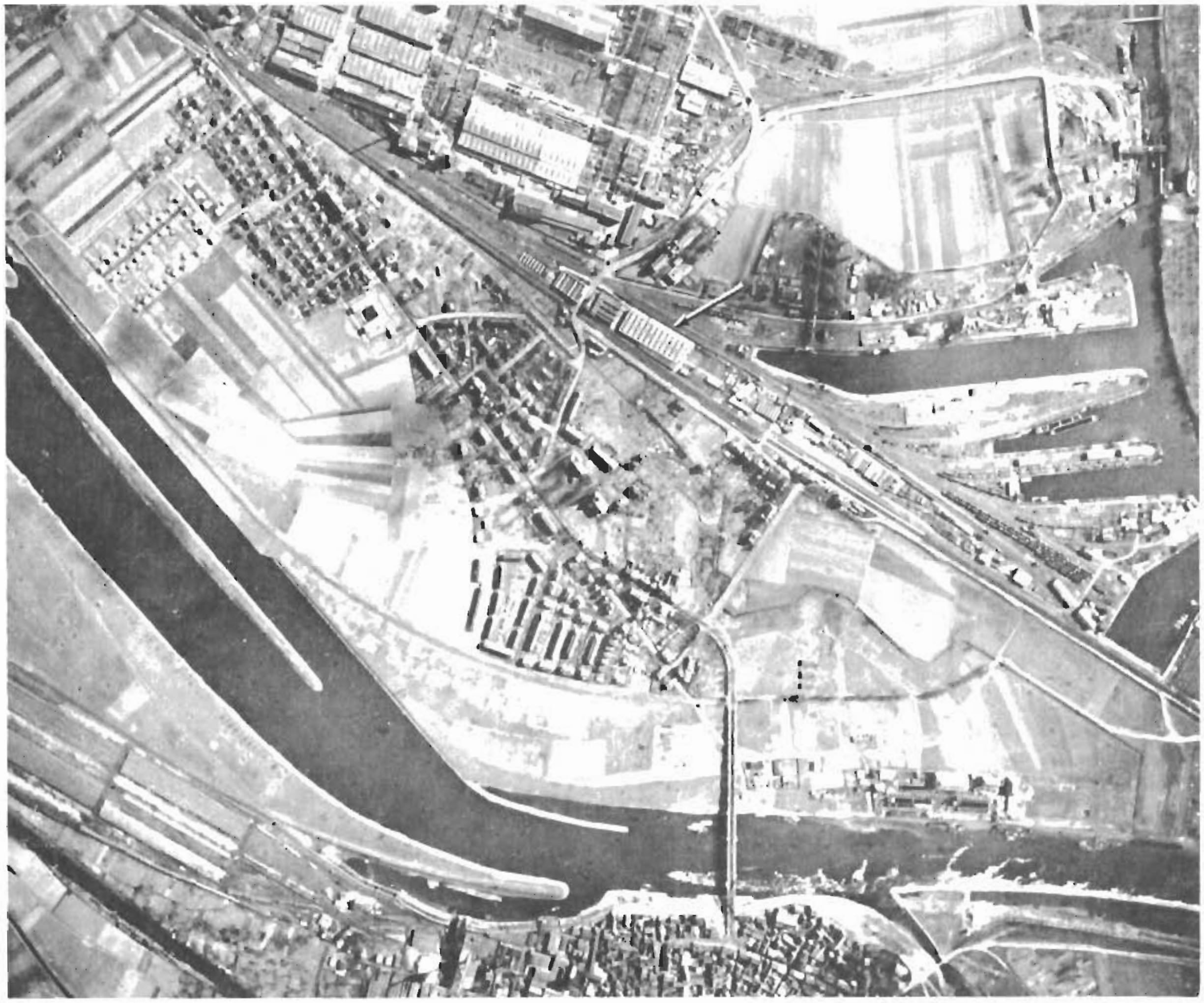
| Student | Photo group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| 1 | .88 | .91 | .88 | .89 | .91 | .93 | .88 | .79 | .92 | .98 | .96 | .79 | .96 | .78 | .89 | .85 | .85 | .85 |
| 2 | -.13 | -.19 | .17 | .12 | .14 | .15 | .38 | .18 | .28 | -.07 | .06 | .20 | .33 | .80 | -.01 | .75 | .04 | .85 |
| 3 | .66 | .77 | .83 | .83 | .88 | .81 | .72 | .83 | .54 | .76 | .72 | .66 | .65 | .54 | .89 | .87 | .81 | .82 |
| 4 | .81 | .76 | .94 | .95 | .98 | .95 | .82 | .88 | .94 | .75 | .93 | -- | -- | -- | -- | -- | -- | -- |
| 5 | .88 | .91 | .88 | .90 | .93 | .88 | .89 | .84 | .56 | .87 | .93 | .88 | .83 | .93 | .97 | .87 | .93 | .85 |
| 6 | .86 | .97 | .64 | .98 | .89 | .97 | .94 | .91 | .86 | .91 | .98 | .88 | .94 | .91 | .88 | .98 | .94 | .87 |
| 7 | .75 | .80 | .89 | .94 | .66 | .80 | .84 | .77 | .79 | .30 | .78 | .90 | .46 | .89 | .90 | .92 | .89 | .73 |
| 8 | .60 | .92 | .81 | .73 | .65 | .86 | .76 | .83 | .63 | .92 | .76 | .72 | .86 | .73 | .75 | .92 | .91 | .98 |
| 9 | .78 | .81 | .94 | .98 | .87 | .96 | .73 | .92 | .90 | .28 | .95 | .77 | .73 | .74 | .90 | .88 | .82 | .86 |
| 10 | .88 | .70 | .82 | .92 | .91 | .90 | .83 | .83 | .69 | .87 | .87 | .87 | .86 | .82 | .90 | .94 | .92 | .93 |
| 11 | .42 | .19 | .82 | .51 | .91 | .84 | .27 | .27 | .86 | .79 | .64 | .66 | .83 | .61 | .78 | .58 | .79 | .54 |
| 12 | .83 | .94 | .89 | .92 | .95 | .86 | .86 | .82 | .50 | .89 | .79 | .86 | .80 | .75 | .89 | .93 | .94 | .88 |
| 13 | .48 | .89 | .86 | .93 | .58 | .71 | .74 | .48 | .70 | .35 | .70 | .71 | .54 | .84 | .89 | .88 | .84 | .94 |
| 14 | .93 | .85 | .92 | .84 | .90 | .91 | .79 | .43 | .75 | .69 | .83 | .74 | .89 | .80 | .93 | .86 | .82 | .69 |
| 15 | .91 | .83 | .95 | .84 | .69 | .87 | .78 | .86 | .88 | .76 | .91 | .90 | .79 | .84 | .93 | .95 | .88 | .88 |
| 16 | .83 | .82 | .88 | .87 | .91 | .74 | .84 | .96 | -.12 | .70 | .96 | .82 | .87 | .88 | .82 | .66 | .74 | .85 |
| 17 | .55 | .83 | .78 | .74 | .93 | .85 | .91 | .84 | .72 | .77 | .87 | .81 | .83 | .66 | .85 | .94 | .83 | .66 |
| 18 | .78 | .91 | .92 | .92 | .88 | .91 | .90 | .92 | .78 | .62 | .92 | .92 | .95 | .95 | .92 | .93 | .96 | .94 |
| 19 | .86 | -- | -- | .86 | -- | -- | -- | .72 | -- | .80 | .62 | -- | .87 | .81 | .85 | .95 | -- | .94 |
| 20 | -- | -- | -- | -- | -- | -- | -- | -- | -- | .87 | .93 | .92 | -- | .92 | -- | -- | -- | -- |
| 21 | .96 | .81 | .92 | .96 | .86 | .92 | .91 | .87 | .92 | .95 | -- | -- | -- | .98 | -- | .95 | -- | .96 |
| 22 | .67 | .83 | -- | -- | .81 | .96 | .86 | .80 | .73 | .85 | .88 | .82 | .73 | .83 | .96 | -- | .77 | .88 |
| 23 | -- | .77 | -- | .07 | -- | .94 | .89 | .92 | .95 | .39 | .94 | .86 | .84 | .87 | .87 | .83 | -- | .55 |

Note.--Correlations are Spearman rhos. N=20.

# APPENDIX C

## EXAMPLES OF STIMULUS PHOTOGRAPHS

Following are 10 examples of the aerial photographs and target cue cards used by subjects in the detection task. The photographs have been reproduced at 3/4 their original size, but the target inserts are shown at the same size as used in the study. The arrows designating targets were included for illustrative purposes only and did not appear in the original photographs.



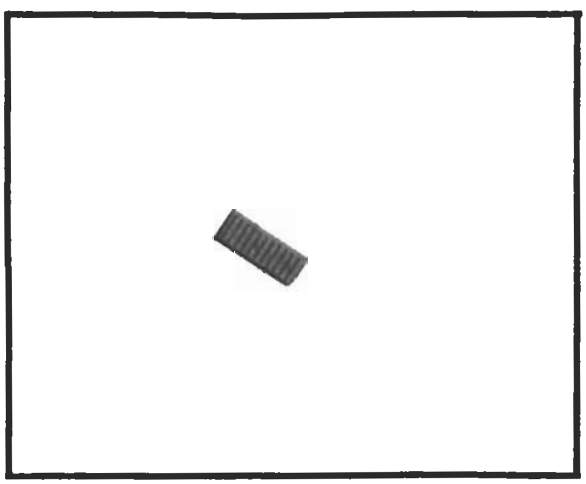
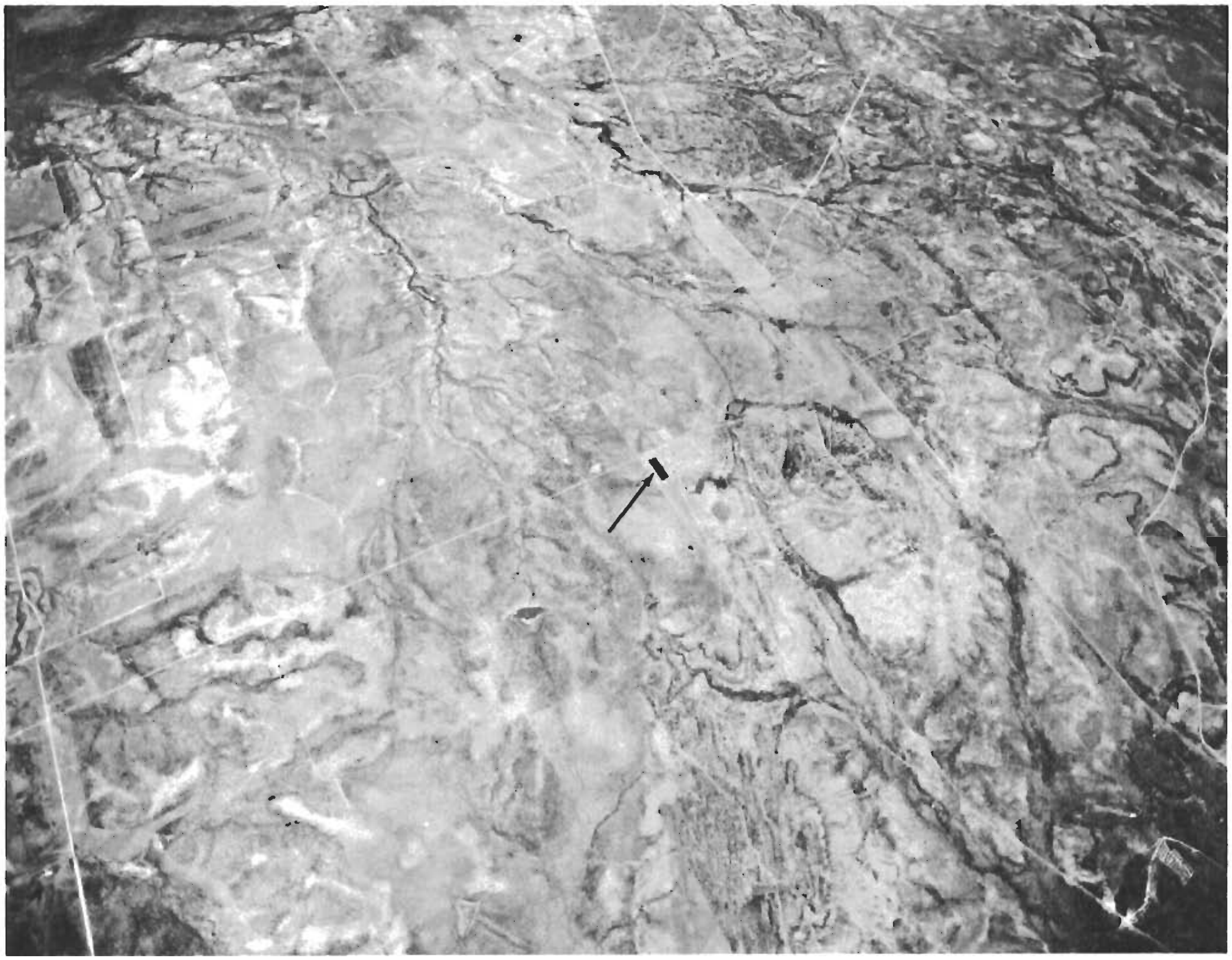


Figure 1

Photo A7-1: Judged Difficulty = 3.7, Median Search Times = 2.5 sec. (Photointerpreters) and 4.0 sec. (Students)



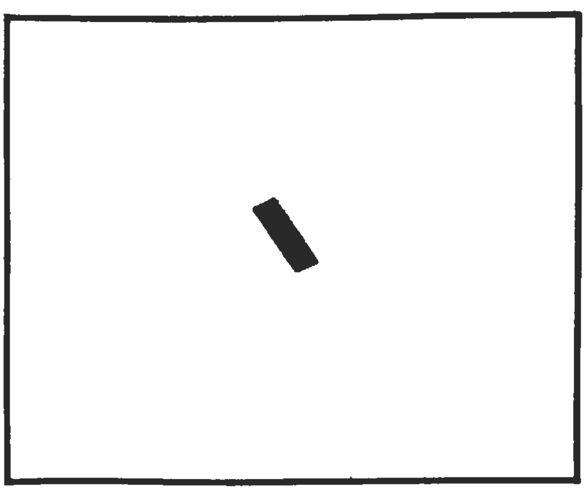
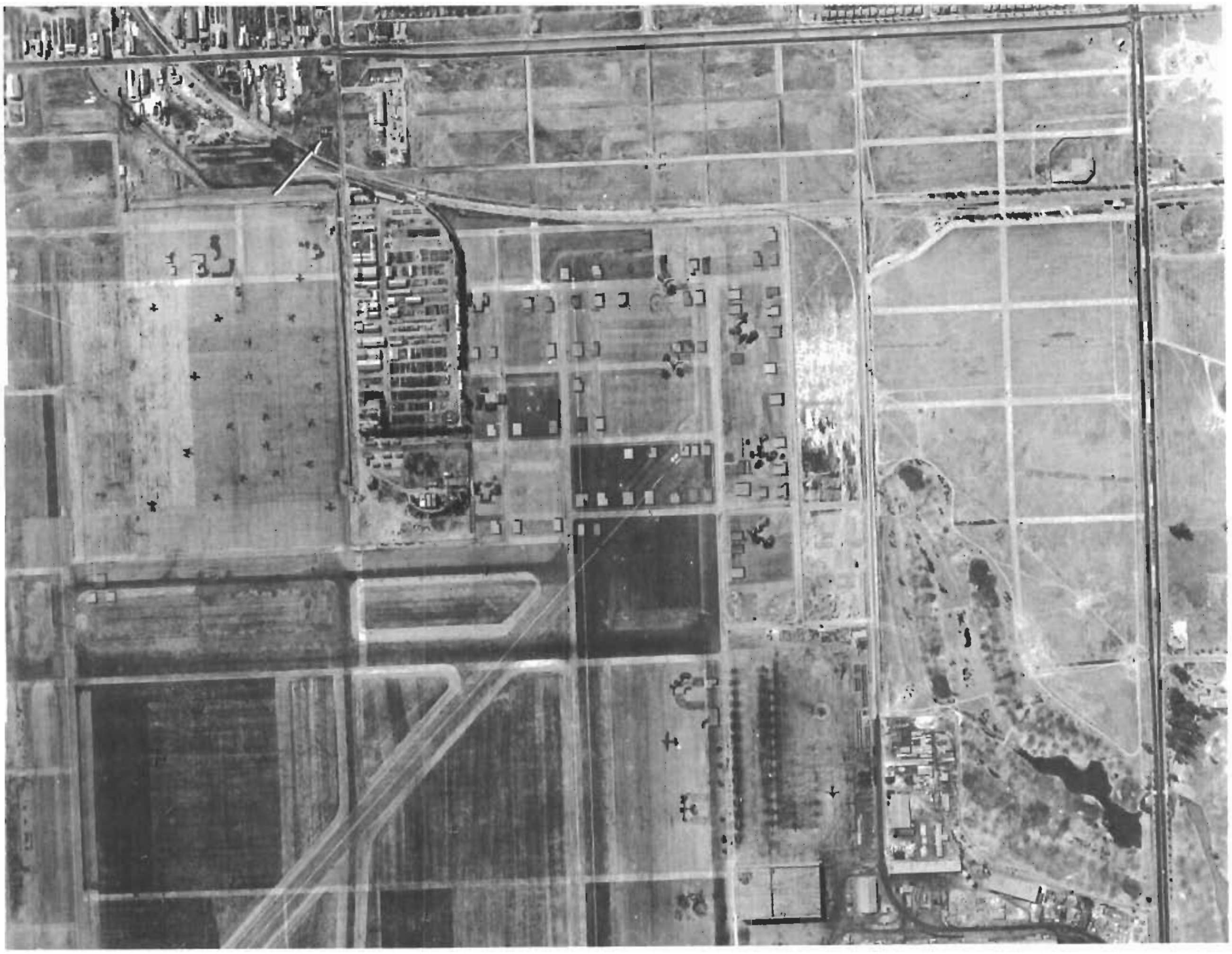


Figure 2

Photo A14-1: Judged Difficulty = 1.9, Median Search Times = 1.0 sec. (Photo-interpreters) and 1.0 sec. (Students)



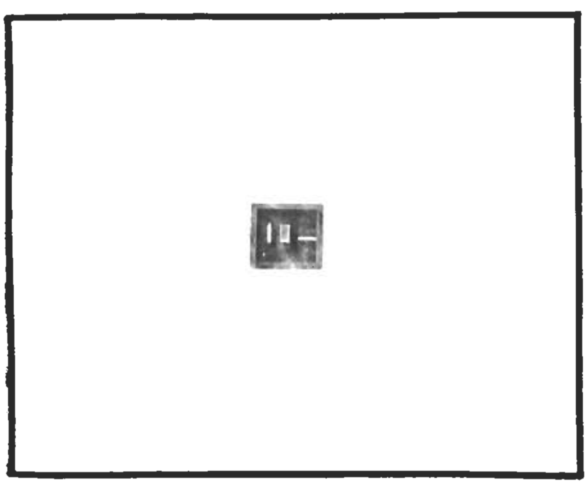
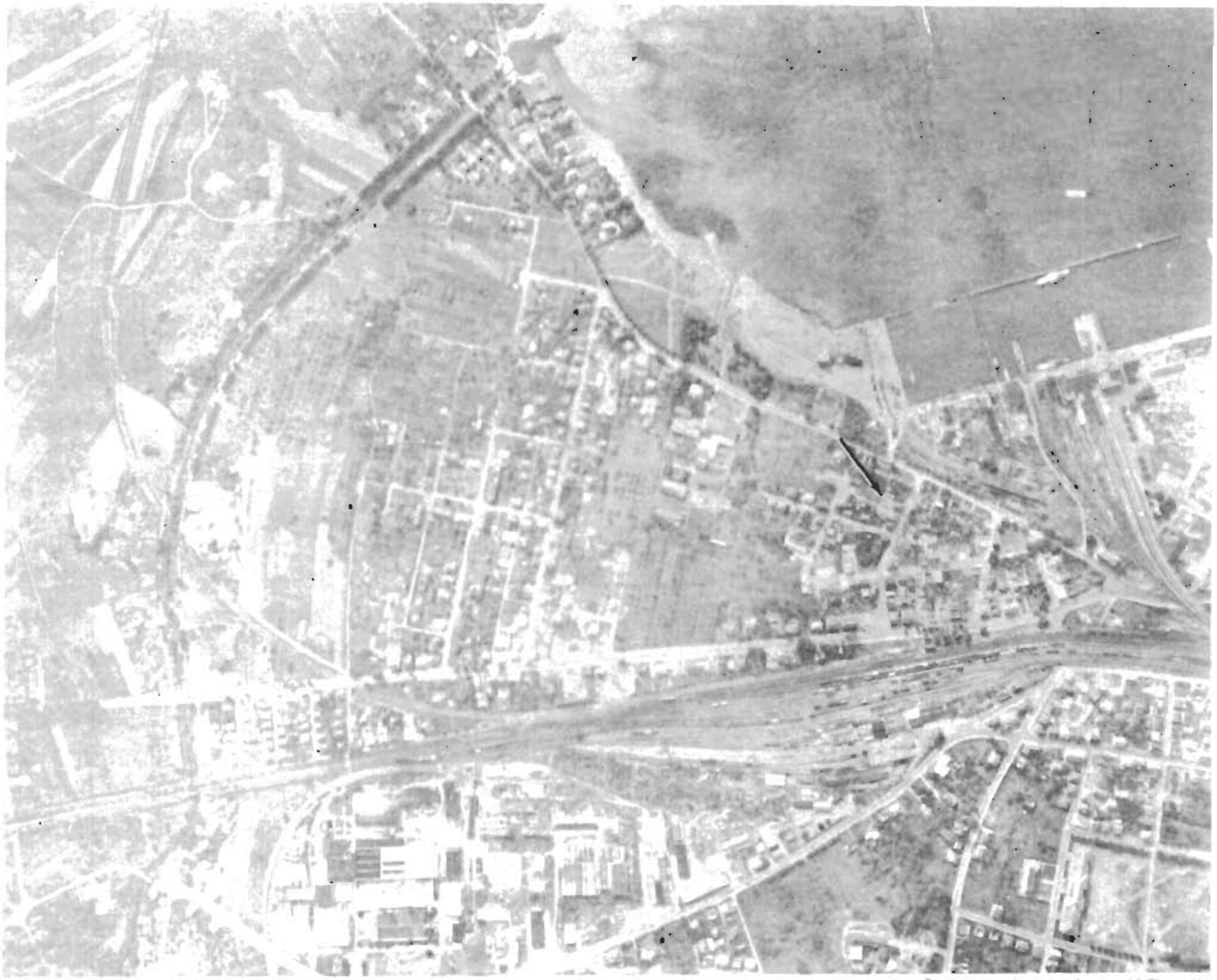


Figure 3

Photo B14-1: Judged Difficulty = 7.6, Median Search Times = 39.0 sec. (Photo-interpreters) and 121.0 sec. (Students)



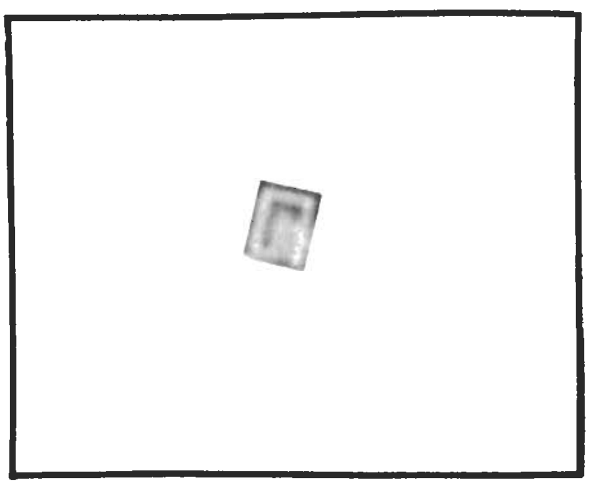
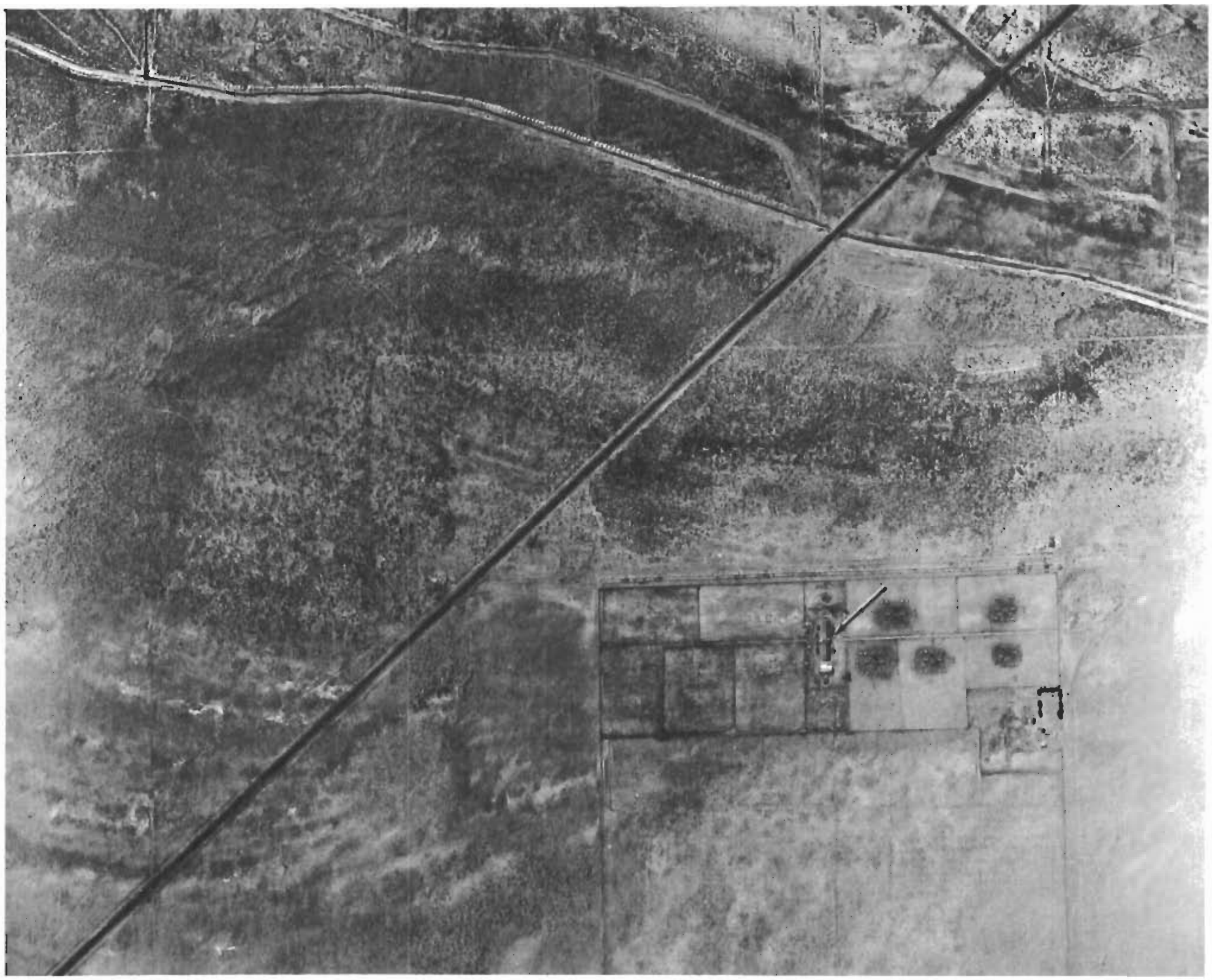


Figure 4

Photo D19-1: Judged Difficulty = 8.7, Median Search Times = 98.0 sec. (Photointerpreters) and 57.0 sec. (Students)



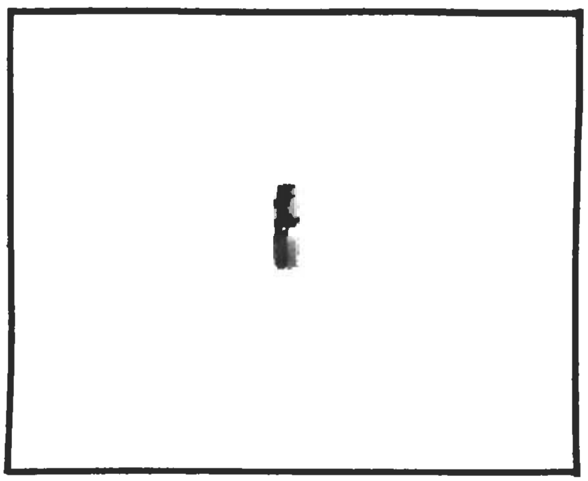
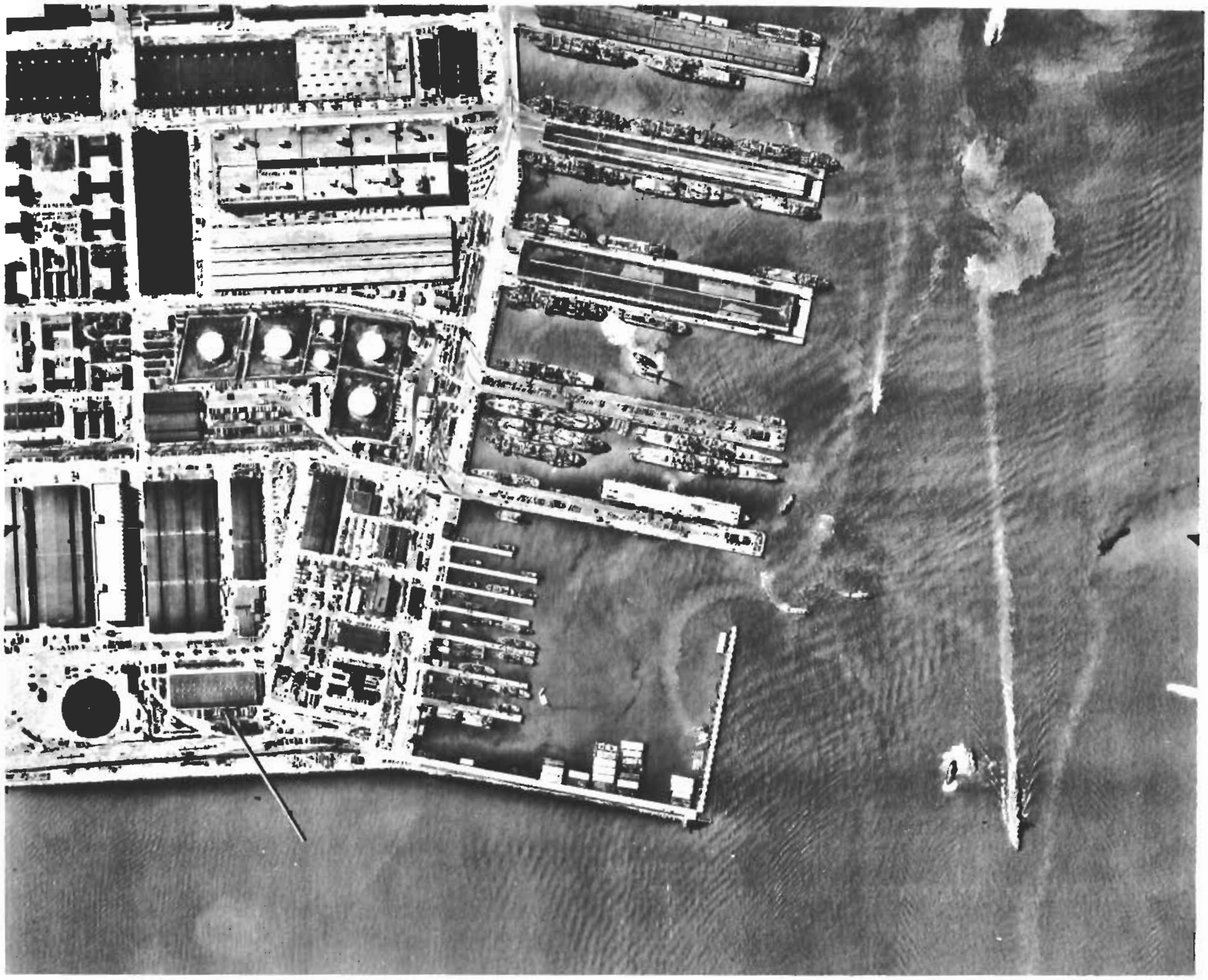


Figure 5

Photo H6-1: Judged Difficulty = 3.4, Median Search Times = 1.5 sec. (Photo-interpreters) and 2.0 sec. (Students)



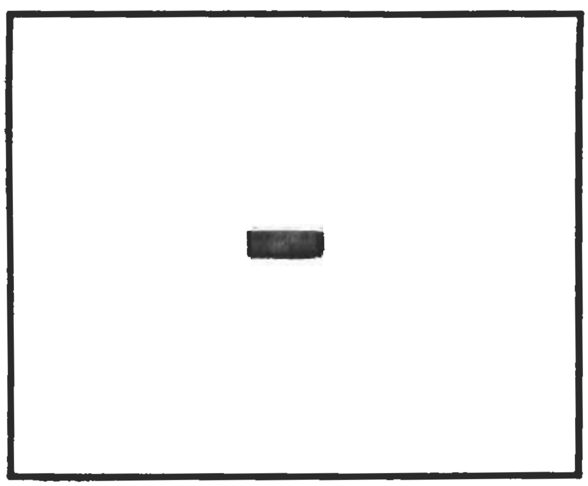


Figure 6

Photo J6-1: Judged Difficulty = 4.2, Median Search Times = 3.0 (Photointerpreters) and 4.5 sec. (Students)

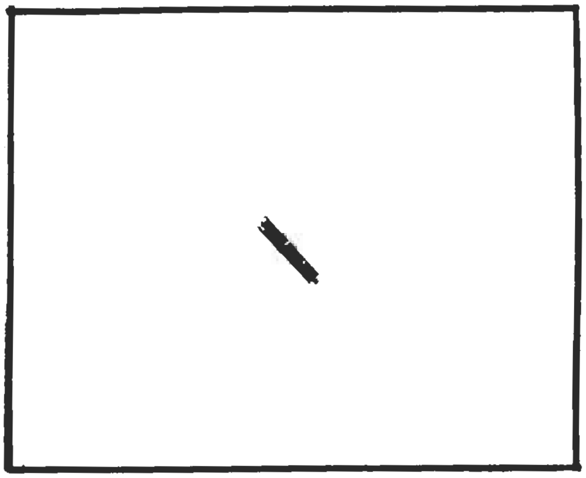
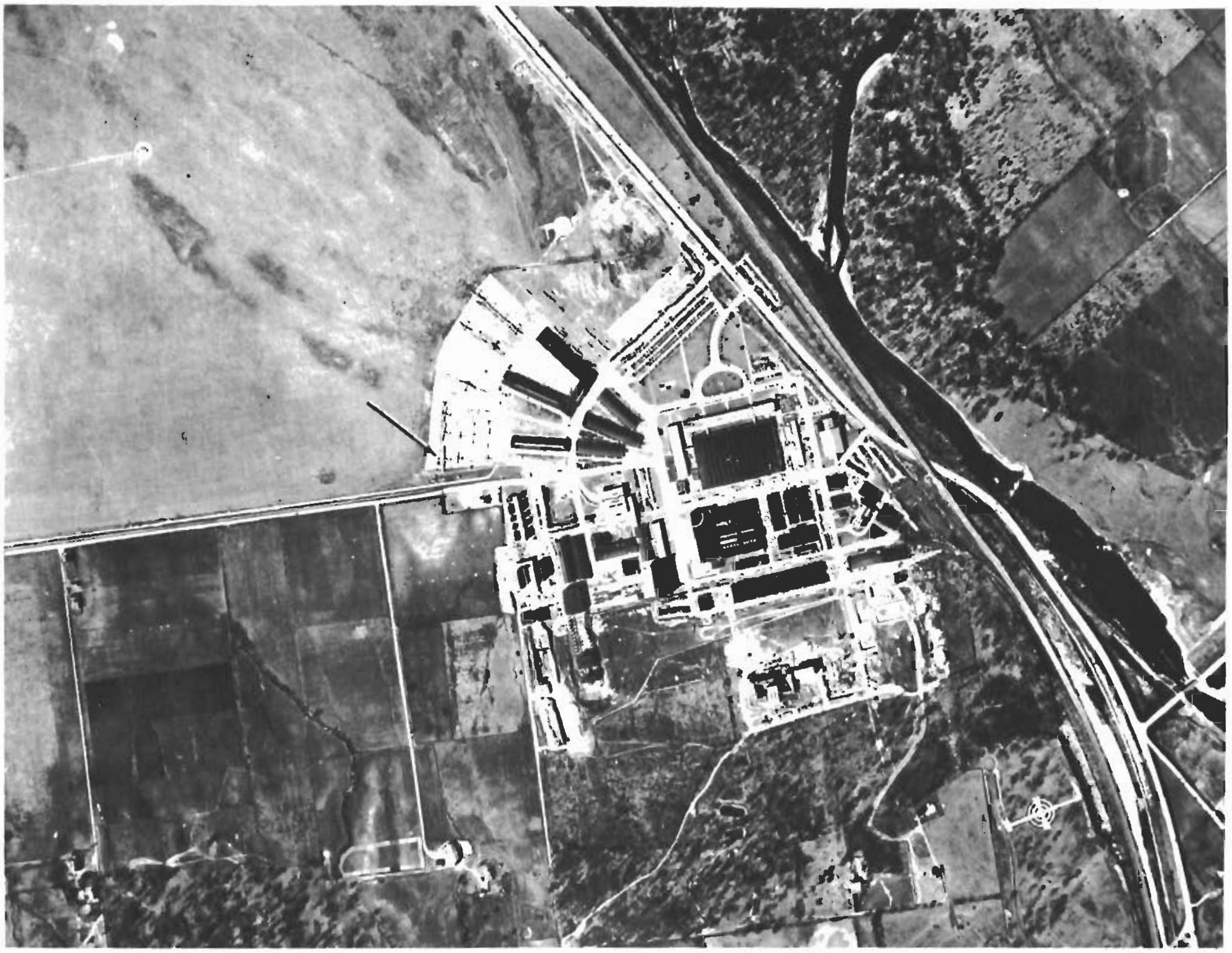


Figure 7

Photo 09-1: Judged Difficulty = 5.0, Median Search Times = 3.0 sec. (Photo-interpreters) and 4.0 sec. (Students)



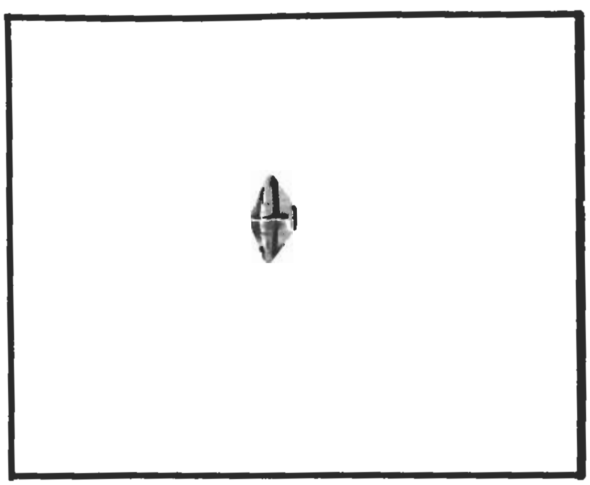
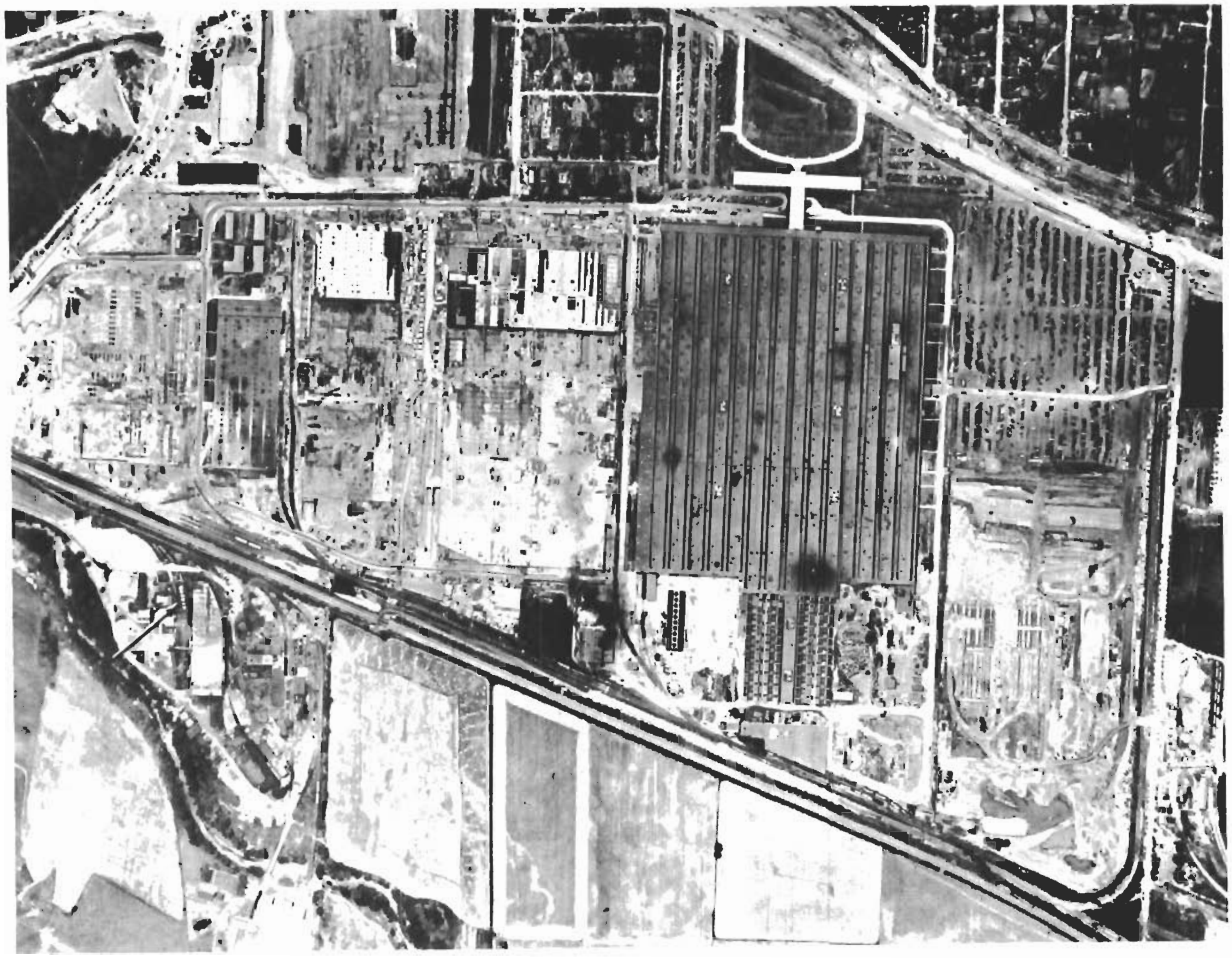


Figure 8

Photo Q13-2: Judged Difficulty = 5.6, Median Search Times = 5.5 sec. (Photointerpreters) and 9.0 sec. (Students)



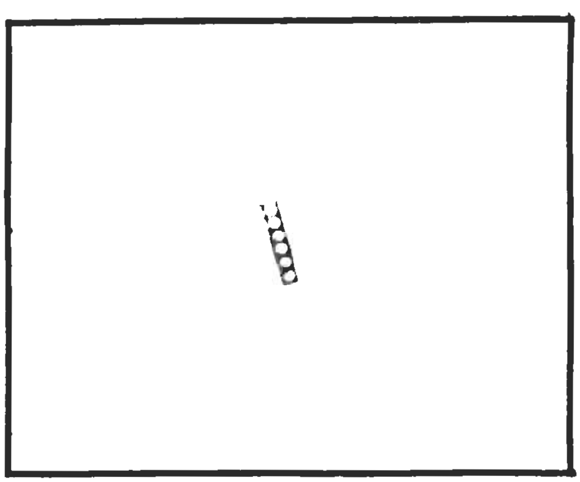
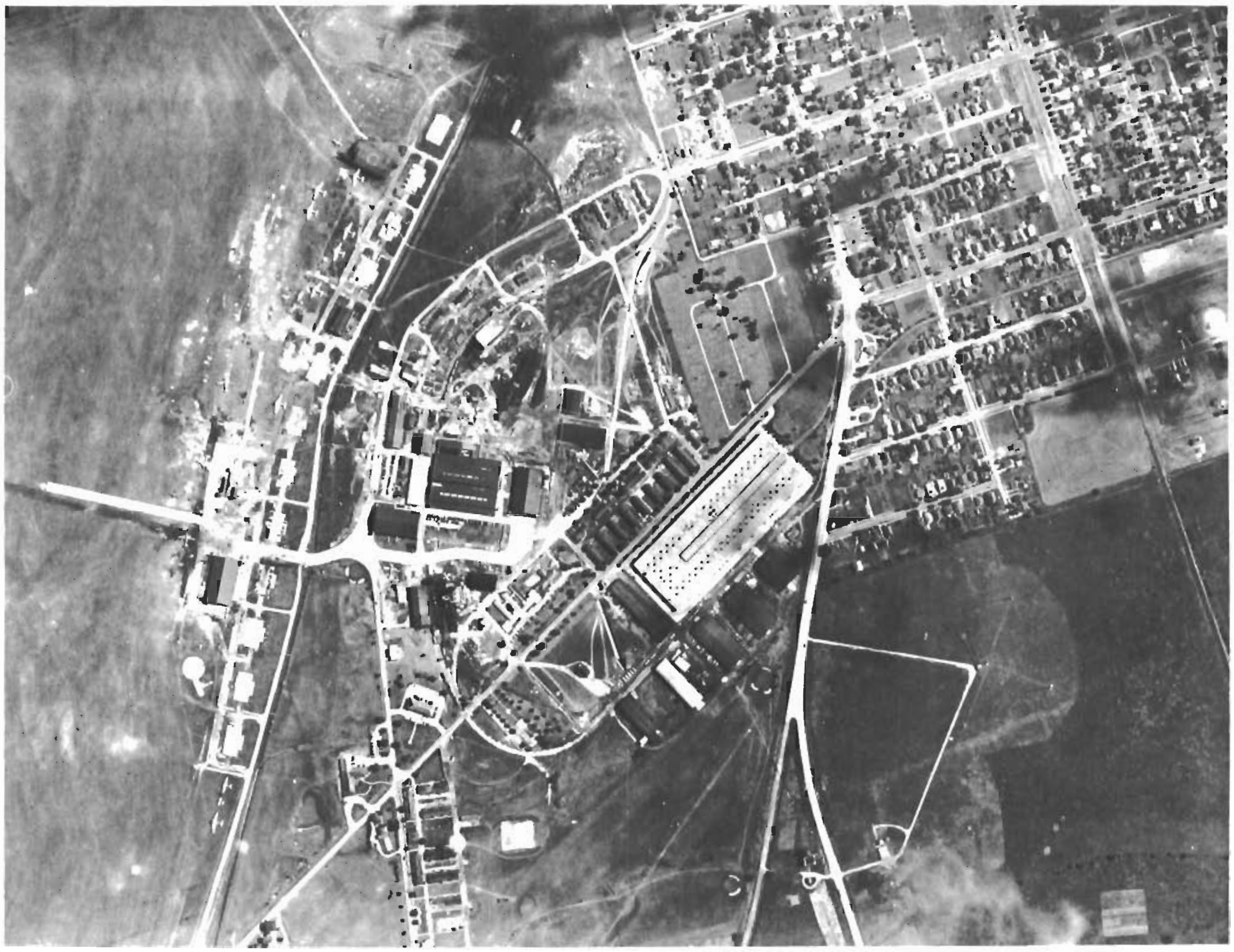


Figure 9

Photo Q19-2: Judged Difficulty = 7.7, Median Search Times = 7.0 sec. (Photointerpreters) and 22.0 sec. (Students)



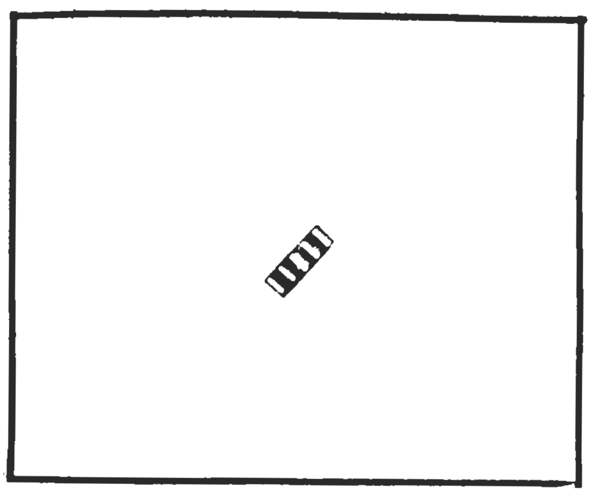


Figure 10

Photo R19-1: Judged Difficulty = 6.9
Median Search Times = 39.5 sec.
(Photointerpreters) and 16.5 sec.
(Students)