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EVALUATION OF SELECTED PICTORIAL CHARACTERISTICS OF REFERENCE MATERIALS FOR USE IN IMAGE INTERPRETATION

Marshall A. Narva

Army Behavior and Systems Research Laboratory
Arlington, Virginia

November 1972

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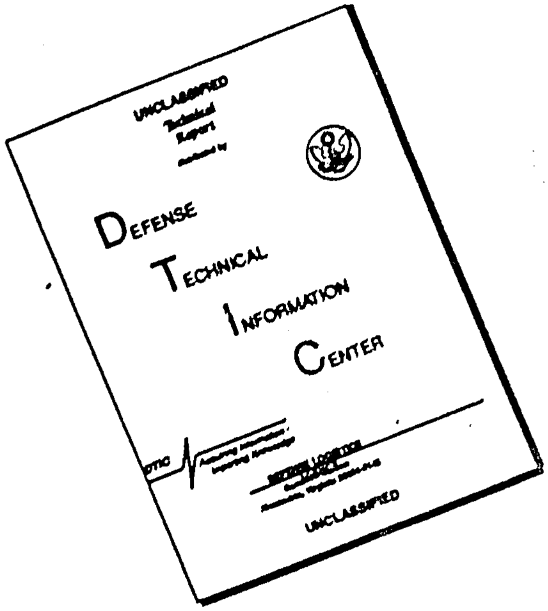

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Technical Research Note 233

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SUPPORT SYSTEMS RESEARCH DIVISION

BESRL

U. S. Army

Behavior and Systems Research Laboratory

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BEHAVIOR AND SYSTEMS RESEARCH LABORATORY

An activity of the Chief, Research and Development

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BESRL Technical Research Note 233

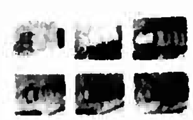
ERRATA SHEET

Page 2. Paragraph 3.

In the sentence beginning in line 5,

"work descriptions" should read "word descriptions".

Page 16. The photographs in Figure 7 should appear as follows:



Page 17. The illustrations in Figure 8 should appear as follows:

Page 44. Paragraph 1, lines 4-6. The last two sentences of this paragraph should read as follows:

. . . . For a difficult discrimination, as with a degraded image, redundancy may facilitate discrimination [23]. The amount of information presented must complement the task at hand.

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13. ABSTRACT - Continued

in greater accuracy. A net result of the experimentation is to permit greater leeway in the materials included in keys and in the manner of presentation.

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13. ABSTRACT

The present Technical Research Note reports on three related experiments conducted by the BESRL Work Unit "Influence of Displays on Image Interpreter Performance" to investigate the characteristics of pictorial content of reference materials (keys) used by image interpreters with a view to determining the most effective way of representing objects in the key. The set of experiments was concerned with obtaining information pertaining to the optimal manner of presenting recognition features in a key so as to aid an interpreter in final identification of an object seen in imagery. Each experiment involved different combinations of the characteristics under study--1) type of presentation (use of photographs or outline drawings, or both), 2) viewing angle (vertical, oblique, or both), and 3) scale of the image in the key (large or small). In the first experiment, computer-aided procedures for selecting the category of the object imaged were included. In experiments two and three, no computer aids were employed. The interpreter used only the key which contained no textual material. In each experiment, recently graduated image interpreters identified a series of 16 vehicles organized into four sets and presented in a balanced research design. Two levels of quality were used in the test imagery.

Performance was more rapid with photographs than with line drawings when the key was used with a computer-assisted category selection procedure. When the key was used alone, no difference between photographs and drawings was found in speed or in number of correct identifications. No advantage was obtained in presenting more than one viewing angle nor by presenting photographs and schematic representations together. Reduced scale in the key images required greater identification time, but did not result

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Image interpretation						
*Laboratory facilities						
*image interpreter references						
*Imagery Keys						
Image quality						
Photo quality						
Computer-aided target category selection						
*Photographic representations						
*Schematic representations						
*vertical view						
*oblique view						
Target identification						
imagery scale						
Interpreter performance						
Interpreter training						
*Photointerpretation Keys						
*Key Characteristics						
Experimentation - design						
Imagery displays						
Visual perception						
Pattern recognition						

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FOREWORD

The SURVEILLANCE SYSTEMS research program of the Behavior and Systems Research Laboratory has as its objective the production of scientific data bearing on the extraction of information from surveillance displays, and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. Research results are used in future systems design and in the development of enhanced techniques for all phases of the interpretation process. Research is conducted under Army RDT&E Project No. 2Q662704A721, "Surveillance Systems," FY 1972 Work Program.

The BESRL Work Unit, "Influence of Displays on Image Interpreter Performance" conducts research to determine how interpreter performance is affected by variations in the character of the image. The present publication reports on three related experiments dealing with variations in the way objects are represented in reference materials or keys and the resulting effectiveness of the keys for image interpretation.

J. E. UHLANER, Director
Behavior and Systems
Research Laboratory

IV

EVALUATION OF SELECTED PICTORIAL CHARACTERISTICS OF REFERENCE MATERIALS FOR USE IN IMAGE INTERPRETATION

BRIEF

Requirement:

To investigate the characteristics of the pictorial content of reference materials (keys) used by image interpreters with a view to determining the most effective way of representing objects in the key.

Procedure:

Selected pictorial characteristics of image interpretation keys were varied, and the effect of the variations on performance in identifying military vehicles was determined. Variations were: 1) photographs or line drawings or both, 2) angle of view--vertical, oblique, or both, and 3) scale of the image in the key. Three experiments were conducted, each concerned with different combinations of the variations. In the first, a computer, in response to inputs from the interpreter, derived the three categories most likely to include the vehicle to be identified. The interpreter then referred to the key (in the form of a loose-leaf notebook) to make the final identification. In the other two experiments, the interpreter used only the key, which contained no textual material. In each experiment, recently graduated image interpreters identified a series of 16 vehicles organized into four sets and presented in a balanced research design. Two levels of quality were used in the test imagery.

Findings:

When the key was used with a computer-assisted category selection procedure, performance was more rapid with photographs than with line drawings. When the key was used alone, no difference in speed was found. No difference between photographs and drawings in number of correct identifications was found.

No advantage was obtained by presenting the photographic and schematic representations together as compared to photographs alone. There was some indication that use of photographs and line drawings together can reduce differences between targets with respect to difficulty of identification.

No advantage was found in presenting both vertical and oblique views in a key, nor did either view presented alone show any advantage. The vertical view was found to require more time with degraded test imagery when the key was used with a computer-assisted category selection procedure but not when the key was used alone.

With the smaller scale images in the key, more time was required to make an identification, possibly because of the tendency of interpreters to use a magnifier with the small scale.

Utilization of Findings:

The experiments have contributed information bearing on questions which arise in the development and use of keys. The net result is to permit greater leeway both in the materials included in keys and in the way they are presented. For example, either a photograph or a line representation may be used. The view in the key need not correspond to that shown in the imagery to be interpreted. No advantage is gained by presenting more than one viewing angle. Reduced scale in the key images may require greater identification time but not result in greater accuracy.

EVALUATION OF SELECTED PICTORIAL CHARACTERISTICS OF REFERENCE MATERIALS FOR USE IN IMAGE INTERPRETATION

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EVALUATION OF SELECTED PICTORIAL CHARACTERISTICS OF REFERENCE MATERIALS FOR USE IN IMAGE INTERPRETATION

BACKGROUND

Reference materials in image interpretation are designed to facilitate rapid and accurate identification and determination of the significance of objects in imagery to be interpreted [1,2]. Such materials are referred to as keys.

Depending upon a particular assignment, an interpreter may be able to operate independently of any keys. However, even the most experienced interpreter may need to supplement his memory by use of a key if he is to meet certain requirements; for example, he may be reassigned to a new geographic area or encounter a new class of objects or activities [3,4,5].

Image interpretation keys are used not only for reference in interpreting imagery but also in interpreter training. The Image Interpretation Handbook[2] considers an image interpretation key both for training the interpreter to recognize certain objects and conditions and for refreshing the memory of the interpreter on distinguishing characteristics and general appearance of objects and conditions to be identified. In a survey, Bigelow [2,3] points out that keys may serve three purposes, as a training aid for students, as orientation to new areas or items for trained interpreters, and as a comprehensive reference for the experienced interpreter. In training or orientation, the object being viewed is usually made known to the interpreter, the aim being to teach him the distinguishing characteristics of the object with its associated label or category. In actual interpretation, the identification of the object being viewed is not known, and comparative viewing of the reference materials is an aid to identification. In training, learning to discriminate is the objective, while on the job, recognition or discrimination is the objective.

---

[1] Strandberg, C. H. Aerial Discovery Manual. New York: John Wiley and Sons, 1967.

[2] U. S. Naval Reconnaissance and Technical Support Center. Image Interpretation Handbook. Vol. 1, TM 30-245, NAVAIR 10-35-685, AFM 200-50. December 1967.

[3] Bigelow, G. F. Photographic interpretation keys--a reappraisal. Photogrammetric Engineering, 1963, 29. 1042-1051.

[4] Bigelow, G. F. Human factors problems in the development and use of image interpretation keys. Research Study 66-4. Behavior and Systems Research Laboratory. Arlington, Va. May 1966.

[5] Rabben, E. L. (Ed.). Fundamentals of photographic interpretation. In Manual of Photographic Interpretation. Washington D. C.: American Society of Photogrammetry. 1960.

Since World War II, more than 200 photointerpretation keys have been prepared[1]. Inasmuch as the interpreter may be concerned with any of the natural or man-made features on the surface of the earth, these keys may take many forms and deal with a variety of interests. Keys have been categorized according to scope, technical level, intrinsic character, and manner of organization or presentation[1,2]. In scope, keys may depict an individual object or condition, the principal objects or conditions within a particular category, or the particular objects or conditions characteristic of a particular region.

The technical level of a key may be suitable primarily for use by interpreters who have had professional or technical training or experience in the subject covered, or by interpreters who have no such background. The intrinsic character of the key refers to the distinction between a "direct" key designed for identification of objects or conditions directly discernible on the imagery and an "associative" key designed for deduction of information not directly discernible on the imagery. The key may take on any combination of these conditions. However, it should include specific information judged to be required for the purpose it is to serve.[6] The level of analysis required may range from detection through recognition to interpretation[7]. Bigelow[2,3] has reviewed much of the discussion among practicing interpreters concerning utilization of keys and problems associated with them, as well as the history of key development.

All keys, by their nature, are concerned with the diagnostic features of objects or conditions to be identified. That is, they aim to present the elements of information that will permit the interpreter to make the identification. Keys involve the use of text and pictorial materials in varying degrees. As Colwell[8] has indicated, work descriptions alone are usually insufficient to convey different impressions; photographs alone are also insufficient, as word descriptions are needed to direct attention to salient features useful for identification. This opinion is supported by recent experimental findings[9].

See footnotes (1,2 and 3) on page (1).

[6] Simontacchi, A. A., G. A. Choate, and D. A. Bernstein. Considerations in the preparation of keys to natural vegetation. Photogrammetric Engineering, 1955, 21, 582-588.

[7] Narva, M. A., and F. A. Muckler. Visual reconnaissance and surveillance from space vehicles. Human Factors. 1963, 5, 295-315.

[8] Colwell, R. N. Photointerpretation for civil purposes. In Manual of Photogrammetry. Washington, D. C.: American Society of Photogrammetry, 1953.

[9] Harrison, P., and D. Rochford. Photointerpretation key conversion study. RADC-TR-65-5. U. S. Air Force, Rome Air Development Center, 1966.

With respect to the organization of diagnostic features, interpreters generally classify keys in two general types--selective keys and elimination keys. With a selective key, the interpreter selects the example corresponding most closely to the image being interpreted. Such a key usually consists of various combinations of selected photographs and descriptive text. In an elimination key, the interpreter is led through a process that enables him to eliminate all items except the one he is trying to identify. Elimination keys may consist of mechanical arrangements such as disks or punch cards in which selected recognition features are arranged so that various combinations lead to one possible object or group as satisfying the identification. Weiner[10] has described such a key. In another type of elimination key, the dichotomous key, the interpreter is led through a series of decisions concerning various characteristics until only one object or condition survives all the comparisons.

While many keys have been developed, comparatively little attention has been given to the human factors involved in the content and use of keys as indicated by Bigelow in his survey.[3] In research on the development and use of keys, performance has been evaluated with reference materials organized in various ways[11] -- with variations in the placement and combination of textual and pictorial materials[9], with "error" keys in which typical errors are shown[12], and with various computer-compatible procedures involving use of recognition features much as in an elimination key[13].

See footnote 3 on page 1 and footnote 9 on page 2.

[10] Weiner, H. The mechanical aspect of photo interpretation keys. Photogrammetric Engineering, 1955, 21, 708-711.

[11] DeLancie, R., W. W. Steen, R. E. Pippin, and A. Shapiro. Quantitative evaluation of photo interpretation keys. Technical Research Report 57-130C, U. S. Air Force, Rome Air Development Center. May 1957. (Also Photogrammetric Engineering, 1957, 23, 858-864).

[12] Martinek, H. and R. Sadacca. Error keys as reference aids in image interpretation. Technical Research Note 153 (AD619 225). Behavior and Systems Research Laboratory. Arlington, Va. June 1965.

[13] Laymon, R. S. Evaluation of three computer-compatible procedures for using image interpreter keys. Technical Research Note 186 (AD655 856). Behavior and Systems Research Laboratory. Arlington, Va. June 1967.

However, much remains unknown about the major component in most keys, the pictorial representations, and how to present this material most effectively to aid the interpreter in arriving at the identification of an object. As was pointed out at a meeting of interpreters several years ago, "A fundamental problem is, how do you identify something that you have never seen before?[14]

The efficiency with which an object can be identified through use of a key is a function of a number of characteristics of both the key and the imagery on which the object appears. In the operational situation, the characteristics of the key are usually constant, while the characteristics of the imagery are subject to change. It is also to be expected that updating of the reference materials will lag behind changes encountered in imagery. There may be considerable discrepancy between the appearance of an object on the imagery and what is presented in the key. As it may not be feasible or desirable to have key material available to match all possible appearances of an object, the key materials must be designed to have maximum generalization to imagery likely to be viewed.

In addition to the main objective of improving interpreter performance, other benefits could accrue from key content which will best generalize to imagery encountered operationally and yet require minimal information content. Such content would facilitate identification of objects viewed in imagery obtained over a wide range of conditions and yet permit a saving in space requirements. This objective has pertinence for development of reference materials to be presented on chips (slides) where it may be desirable for all pertinent information to be presented on one chip[15]. In many systems calling for retrieval of information, particularly in the field, data base requirements must be kept to a minimum. In addition, elimination of superfluous or redundant materials in keys will facilitate their use in situations calling for rapid interpretation. Information concerning the most effective manner of presentation of pictorial materials is also of interest relative to the use of electronic or electro-optical display devices. Readout with such devices can usually be activated more rapidly and they may have greater input-output utility than a conventional slide projector or other optical system. However, with such displays, tones on a gray scale may not appear; rather, line or pattern configurations may be shown[16].

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[14] Seymour, T. D. The interpretation of unidentified information: A basic concept. Photogrammetric Engineering, 1957, 23, 115-121.

[15] Nelson, A., K. McClure, J. Polgreen, and R. Sadacca. Organization and presentation of image interpreter reference and auxiliary information. Technical Research Note 173 (AD641 326). Behavior and Systems Research Laboratory. Arlington, Va. June 1966.

[16] Murray, A. E. Perceptron applications in photo interpretation. Photogrammetric Engineering. 1961, 27, 627-637.

OBJECTIVE

The present set of experiments was an inquiry into the pictorial content of reference materials (keys). It was concerned with obtaining information pertaining to the optimal manner of presenting recognition features in a key so as to aid an interpreter in final identification of an object seen in imagery. The effects of variations in selected pictorial characteristics of reference materials on interpreter performance were studied: 1) use of photographs or outline drawings, or both, 2) viewing aspect of the object presented--vertical, oblique, or both, and 3) scale of the image in the key. The reference materials were used with imagery of two levels of quality in order to obtain an indication of the generality of the findings. A discussion of the pictorial characteristics studied is presented in Appendix A.

SCOPE OF THE PRESENT RESEARCH

Three experiments were conducted, each involving different combinations of the characteristics of interest--type of presentation, viewing angle, and scale. In the first experiment, various computer-aided procedures for selecting the category of the object imaged were included. In the remaining experiments, no computer aids were used.

Experiment One

Key Characteristics. The relative effectiveness of various representations, views, and scales in keys for identification of motorized vehicles was examined. Two types of representation were used for the key materials. One was a photograph of the vehicle taken from a crane so that a clear representation was obtained showing the vehicle in detail (Figure 1). The other was an outline drawing, or schematic, made from the photograph of the vehicle and including the recognition features judged by a group of experienced interpreters to be important for identification (Figure 2).

Two views, vertical and oblique, and a combination of the two were used. The vertical view was from directly above a vehicle, as in Figure 1 and Figure 2. The oblique view was taken at approximately a 45-degree angle so as to show both side and top of the vehicle. As attempt was made to show all the pertinent features on the top (Figure 3). Schematics made from the photographs are shown in Figure 4. The appearance of the key when the views were presented together is shown in Figures 5 and 6.

Two scales were used. The views shown in Figures 1-6 are of the larger scale. To approximate the scale at which a target would be shown in imagery, the views were reduced photographically as shown in Figure 7 for the photograph and Figure 8 for the schematic. Scale for each vehicle on the small scale key is given for the vertical view in Appendix B. No textual material was included in the keys.

Organization of Keys. Twelve experimental keys, each containing the desired combination of the three key characteristics under investigation, were constructed. Each key provided the appropriate view or views of 23 vehicles, and each view in a key incorporated the same combination of the experimental variables. Each of the keys covered the same vehicles, listed in Table 1. The vehicles were divided into six categories. Each category occupied a separate page of the key, or two facing pages if both vertical and oblique views were provided. Each view was accompanied by an identification number. The military designation was not presented on the key. Each page had a tab bearing the category number. The pages were put together in a loose-leaf notebook to constitute the key.

Table 1

VEHICLES SHOWN IN THE KEYS

Category	Category No.	Designation	Ident. No.
Tank	10	M60	11
		M48	12
		M41	13
SPG	20	M55	21
		M52	22
		M44	23
		M108	24
		M42	25
APC	30	M114	31
		M113	32
		M577	33
		M75	34
Recovery vehicle	40	M88	41
		M74	42
		M578	43
Cargo truck	50	M151	51
		M37	52
		M35	53
		M54	54
		M36	55
		M55	56
Special truck	60	M49	61
		M62	62

Test Imagery. A series of positive transparencies containing vehicles to be identified was prepared. The imagery was divided into a practice set of four frames and four test sets of four frames each, as shown in Table 2. Each of the test sets was reproduced at two levels of quality. The poor quality level was produced photographically by processing through layers of plexiglass. All features except those felt to be necessary for identification of the vehicle were blurred. The good quality imagery was clear. The four test sets were organized into four test rolls, representing four test sequences, to permit the presentation of each set at the desired combination of image quality, key scale, and trial block, as required for the experimental design. Only vertical imagery was used. As the task of the subject was restricted to identification, one vehicle to be identified on each frame was annotated by an arrow.

Experimental Design. Independent groups of eight subjects each worked with a particular combination of key representation and view condition (Figure 9). Each subject worked with both key scales, changing halfway through the test trials. Half the subjects worked with the large scale first, half with the small scale first. Each group of subjects, therefore, used one of the six experimental key representation/view combinations at both key scales. The presentation schedule for the imagery sets and quality levels is also shown in Figure 9. Each subject identified sixteen vehicles which had been grouped into four sets of four vehicles each. The order of presentation of the four sets defined four sequences. A group of subjects taking the four sequences under one of the conditions was thus balanced by trial block for the four sets of imagery and the two quality levels. Key scale was also balanced over the trial blocks, the four sets of imagery, and the two quality levels. For a group of subjects taking the four sequences under one of the key representation/view conditions, imagery set, quality, and key scale were thus balanced over the trial blocks. Use of four sets of imagery permitted each subject to be exposed to all four combinations of key scale and image quality without repeating the same targets.

Procedure. The experiment was performed in conjunction with another experiment on computer-aided target category selection methods[17/]. Each subject went through two main sequential activities: 1) making the decision as to which category the vehicle belonged, and 2) making the subsequent specific identification of the vehicle. Four target category selection methods were included. In one method, the interpreter was given only the names of the vehicle categories. In another, the name of each category was embellished with a composite representation of the category in sketch form. Significant recognition features for each of the categories was highlighted by pointing them out on the sketch. In a third method of

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[17/] The research on computer-aided target category selection was conducted as a separate experiment by R. Laymon.

Table 2

COMPOSITION OF THE FOUR TEST SETS OF IMAGERY

Test Set	Ident. No.	Designation	Category	Scale
1	12	M48	Tank	1:1200
	34	M75	APC	1:1200
	52	M37	Cargo truck	1:1400
	22	M52	SPG	1:1200
2	21	M55	SPG	1:1225
	51	M151	Cargo truck	1:1400
	32	M113	APC	1:1300
	13	M41	Tank	1:1225
3	42	M74	Recovery veh.	1:2400
	33	M577	APC	1:1300
	11	M60	Tank	1:1300
	62	M62	Spec. truck	1:1400
4	41	M88	Recovery veh.	1:1100
	53	M35	Cargo truck	1:1400
	24	M108	SPG	1:1200
	31	M114	APC	1:1300

category selection, the subject was given a grouping of displays of target signatures, some with accompanying sketches. He selected the signatures he believed to be represented in the vehicle being identified. In the fourth method, the subject also assigned a weight to each signature selected, indicating his degree of certitude of the presence of the signature in the vehicle. All these methods were carried out by use of an appropriate configuration of pushbotton/displays on a console in the Information Systems Laboratory of the Behavior and Systems Research Laboratory. For each of the methods, based on the inputs from the subject via the keyboard, a computer selected three possible vehicle categories ranked from most probable to least probable. These three category numbers were displayed on the console.

Aided by the category numbers displayed, the subject then turned to the key to make his identification. As indicated previously, the keys were in the form of loose-leaf notebooks, with the category numbers on tabs on each page. The key was kept closed until the subject had gone through the category selection procedure. He then opened the key to the category indicated as the most probable category by the console display.

Through comparison of the target on the imagery with the key representations in the category selected, the subject decided which representation was the correct identification. If the subject found that he could not make the identification from the first category selected, he could then go on to the next most probable category. If, after going through the three categories displayed on the console, no identification had been made, the subject could then turn to any portion of the key. Upon deciding which vehicle was shown in the imagery, he recorded the identification number by means of a keyboard. Time elapsing from presentation of the three categories to input of the identification number by the subject was recorded by the computer. The subject then closed the key, which was held on a clipboard on the light table, and went on to the next trial. Halfway through the trials, the scale of the key was changed.

Before going through the 16 test trials, each subject went through the four practice trials. He could clear up any questions about procedure during this time. 3X and 8X magnifiers were available to him.

Subjects. Subjects were 48 image interpreters recently graduated from the U. S. Army Intelligence School at Fort Holabird, Maryland. These subjects could not depend on their experience for identification of the vehicles. Also, they were not likely to have developed any biases toward key materials or particular techniques for using the keys. They were assigned to four proficiency groups of twelve subjects each based on performance in identifying foreign equipment during training at Fort Holabird. Six groups of eight subjects each were formed, matched as evenly as possible on the test scores. In each group, there were two subjects who had been exposed to each of the category selection procedures included in the experiment. Thus, each of the six independent groups of subjects had been equally exposed to the four category selection methods.

Dependent Measures. Three dependent measures of performance were derived: time to make an identification, number of correct identifications, and efficiency.

Time is a measure of the time taken by a subject to make either a correct or an incorrect identification after having made his category decision. Time was measured from the display of the three categories to the recording of the identification number--the time the subject was actually viewing the key materials. A time score for each subject was calculated for each of the four sets of four targets each.

For each identification, the subject was given a score of 1 if he was correct and 0 if he was incorrect. The number of correct identifications was summed across a set of four vehicles.

The efficiency score was a combined measure of speed and accuracy. It was calculated by dividing the number of correct identifications per set by the time score for that set. Therefore, the more correct identifications made or the less time required to make the identifications, the higher the efficiency score.

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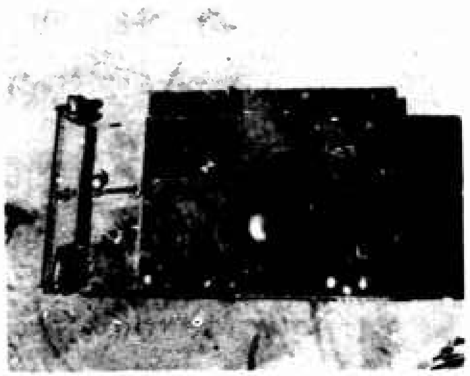

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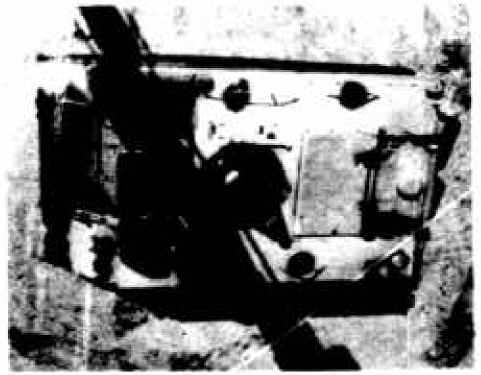

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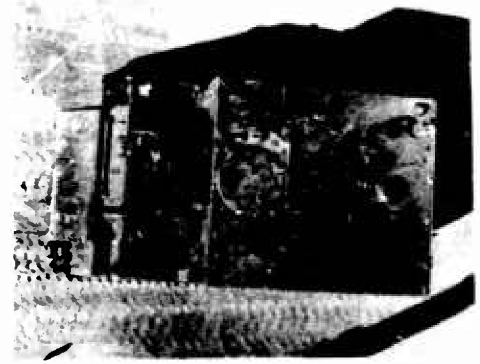

Figure 1. Page from an experimental key showing examples of photographic vertical large-scale representations

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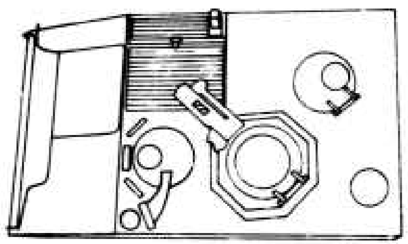
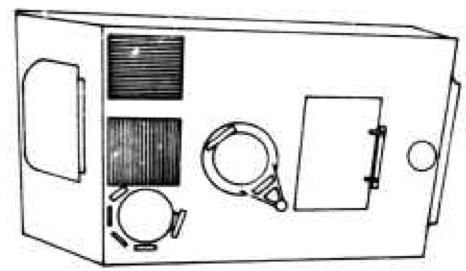
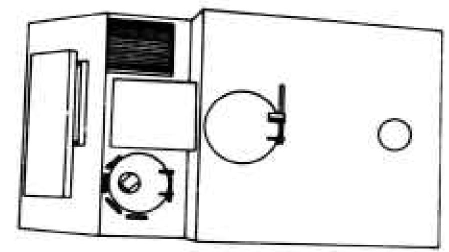


32



33



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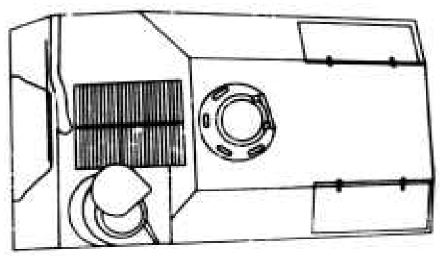

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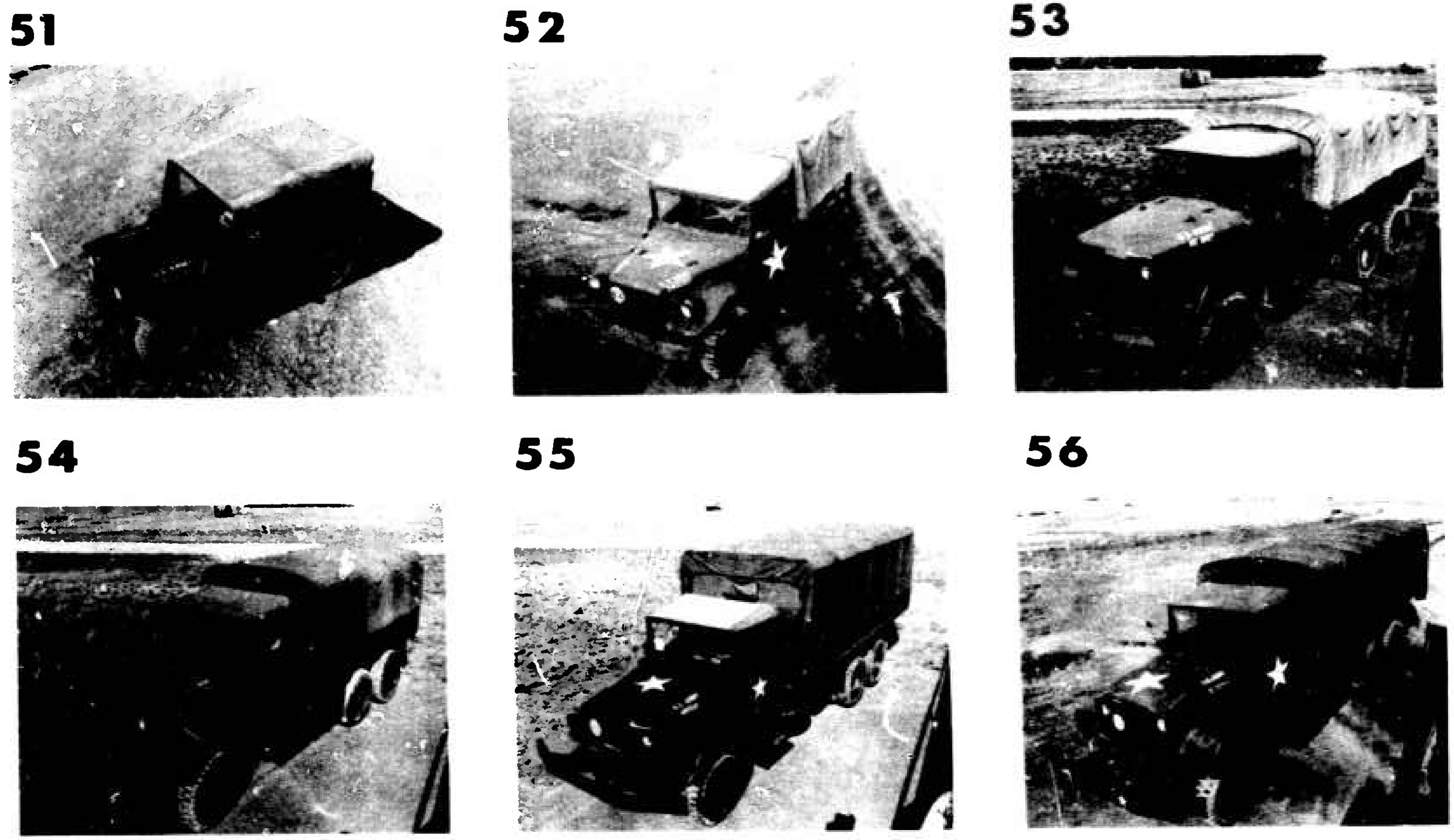
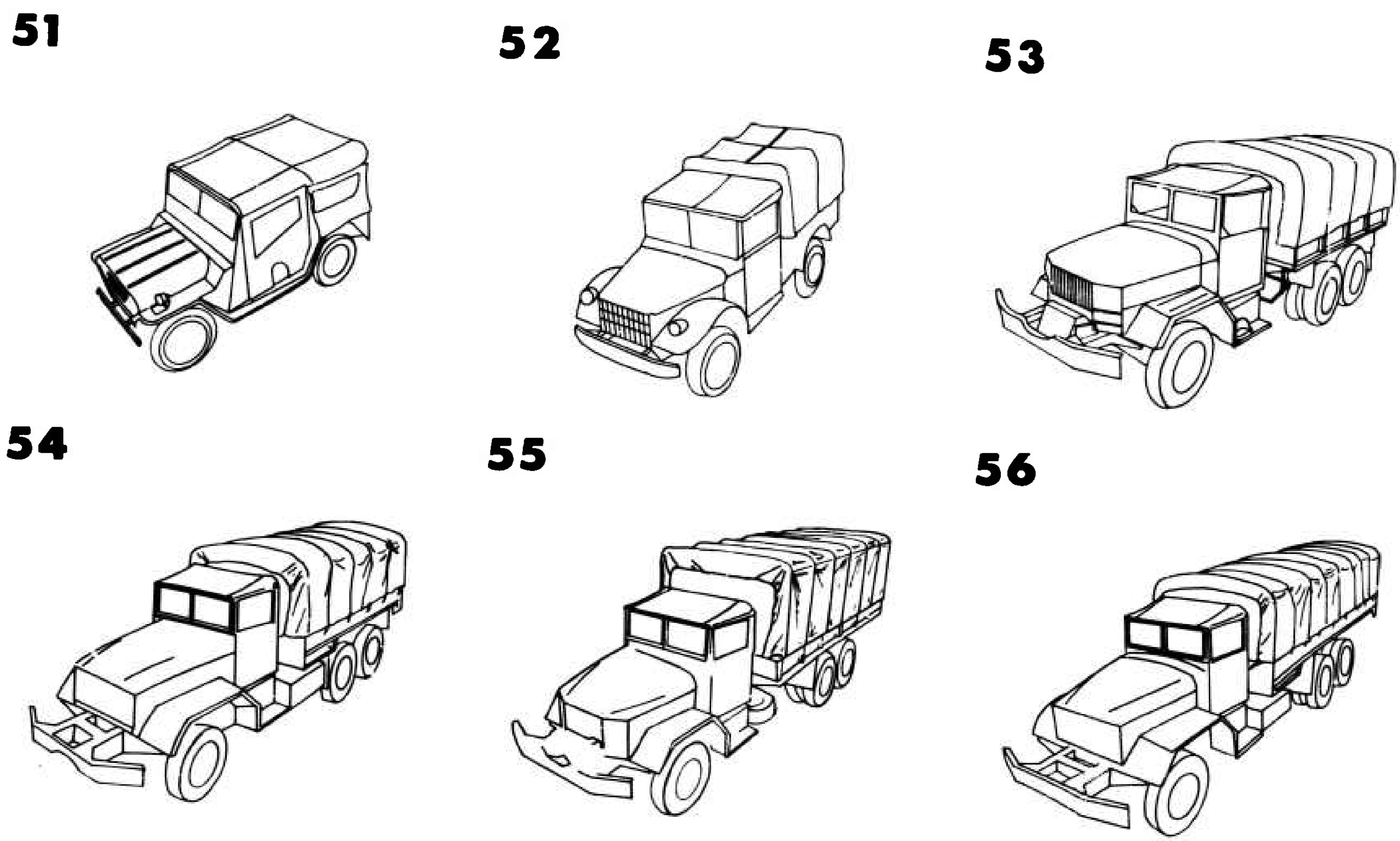
Figure 2. Page from an experimental key showing examples of schematic vertical large-scale representations



50

Figure 3. Page from an experimental key showing examples of photographic oblique large-scale representations



50

Figure 4. Page from an experimental key showing examples of schematic oblique large-scale representations

11 12 13

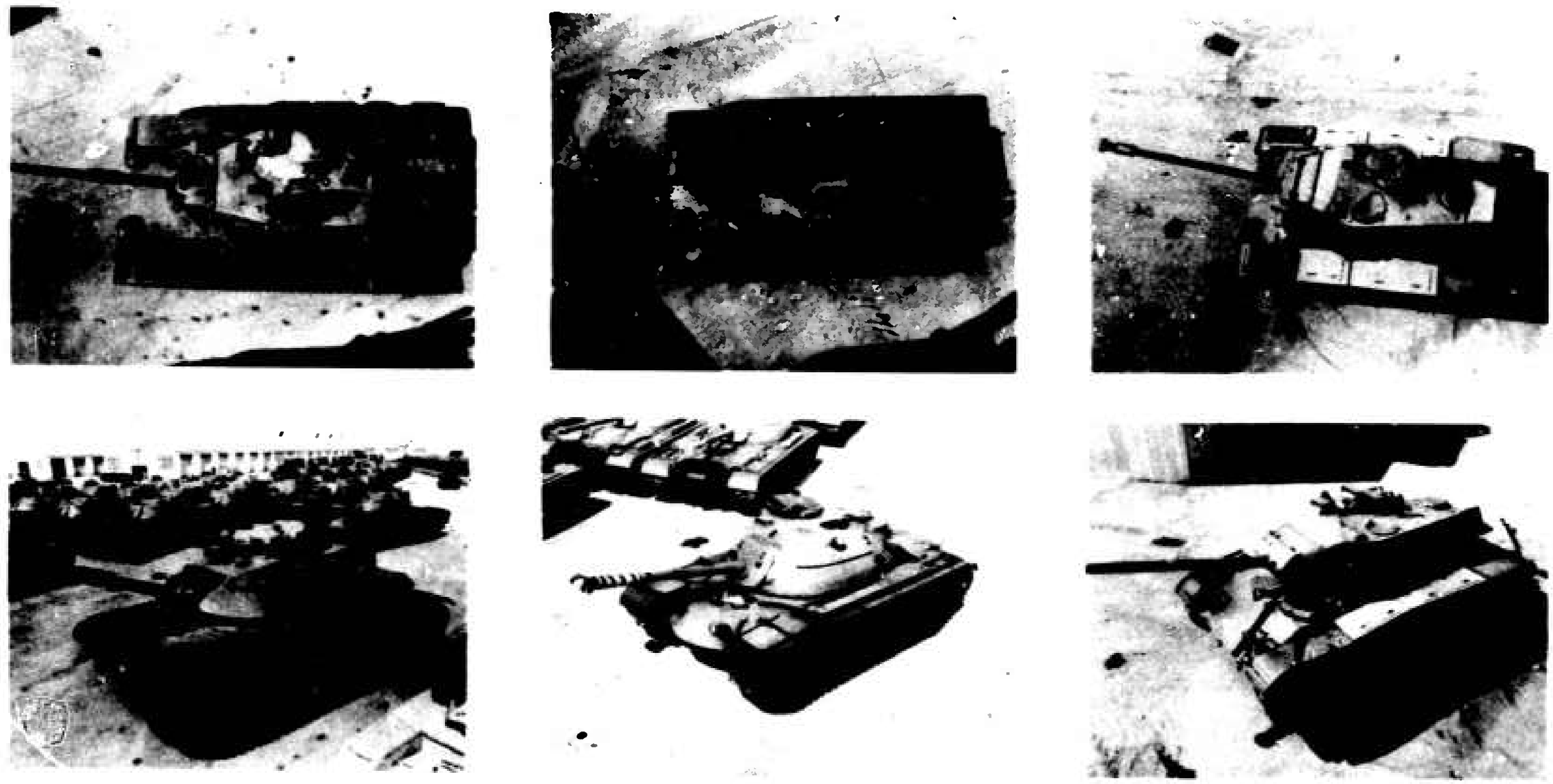


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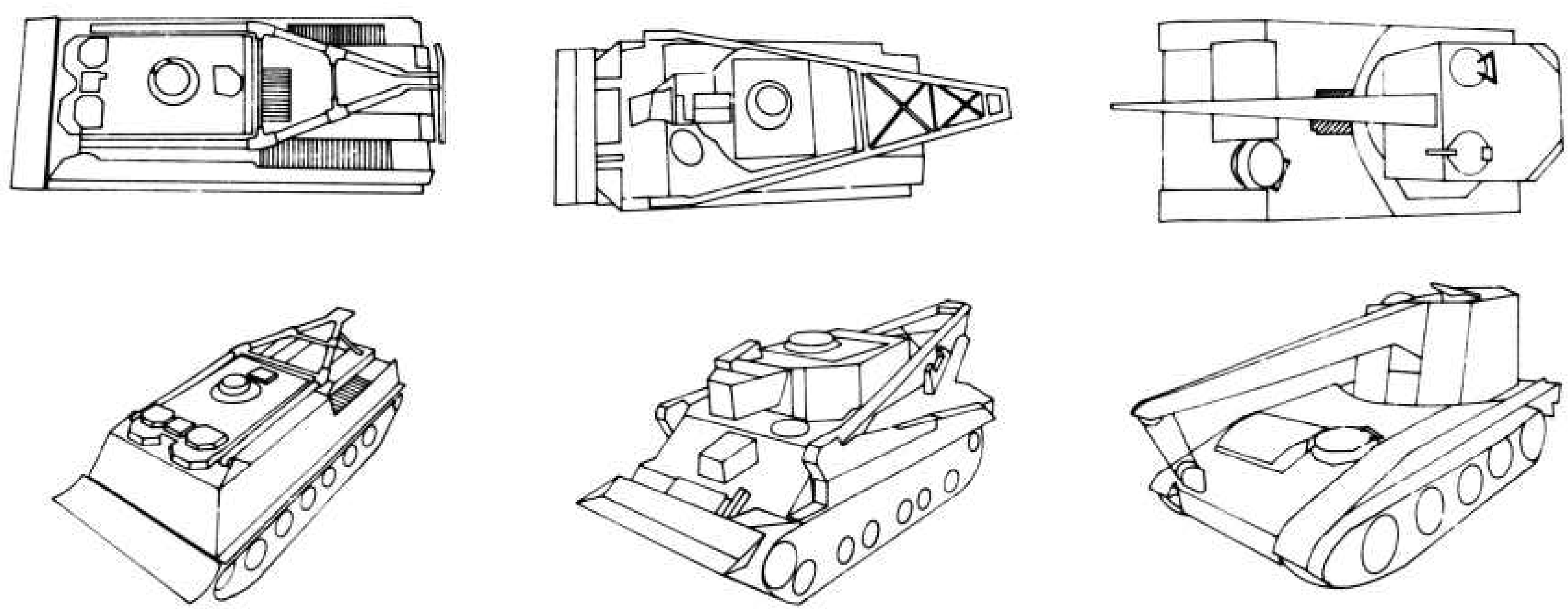
Figure 5. Page from an experimental key showing examples of photographic large-scale vertical and oblique views used togethe

41 42 43



40

Figure 6. Page from an experimental key showing examples of schematic large-scale vertical and oblique views used together

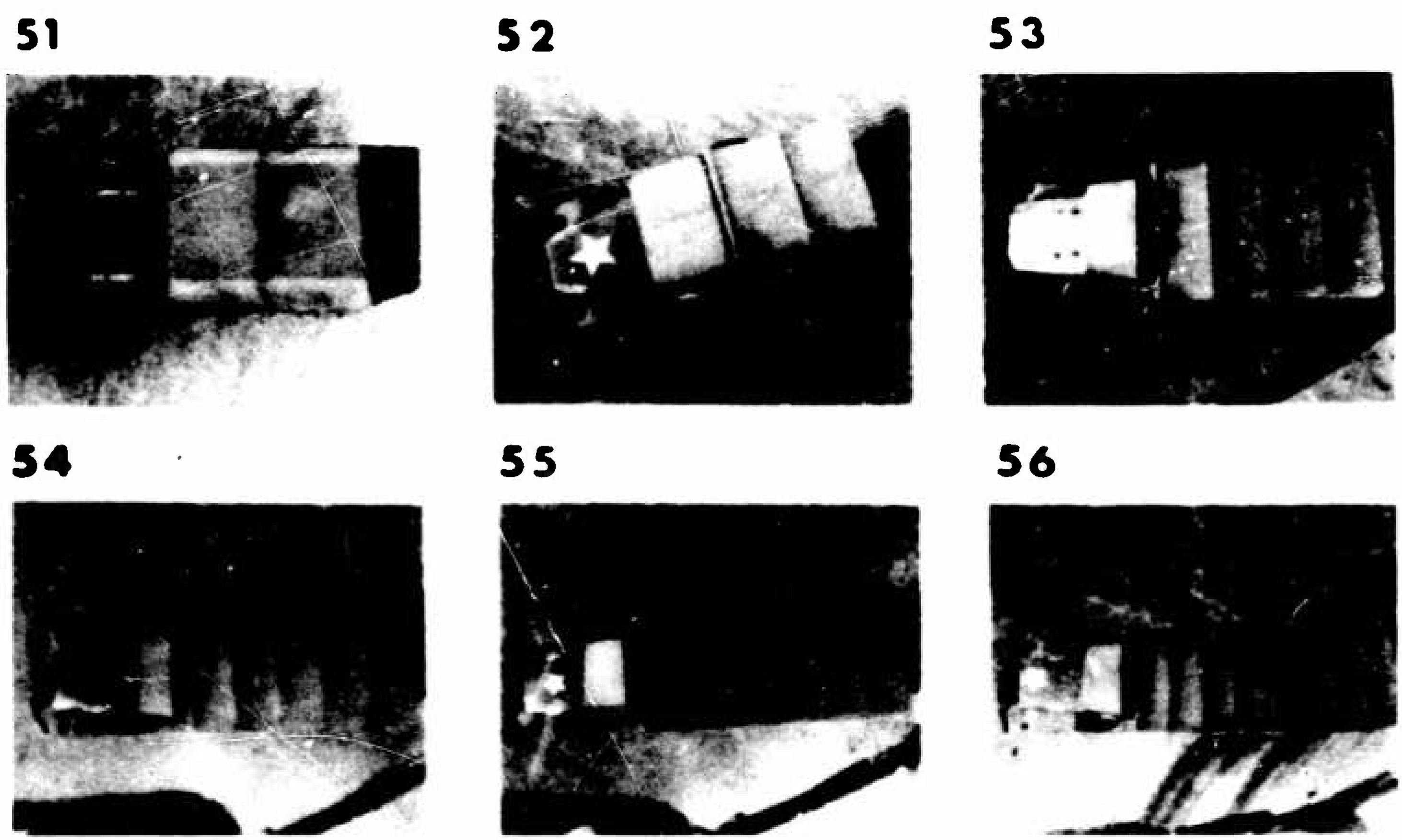


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Figure 7. Page from an experimental key showing examples of photographic vertical small-scale representations

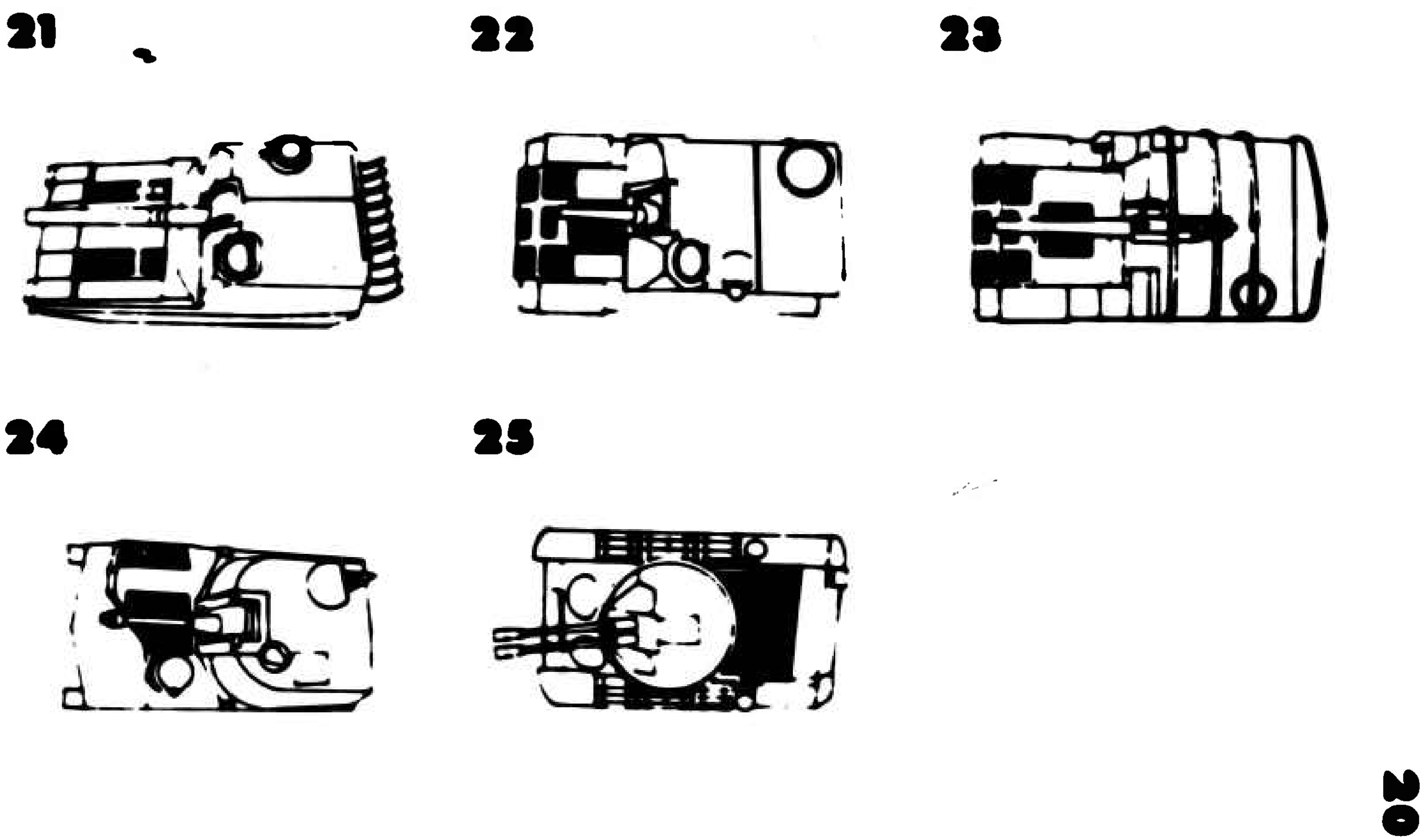

Figure 8. Page from an experimental key showing examples of schematic vertical small-scale representations

Key Representation	Key View	Subjects	Sequence	Trial Block 1 Key Scale	Trial Block 1 Imagery Set	Trial Block 1 Imagery Quality	Trial Block 2 Key Scale	Trial Block 2 Imagery Set	Trial Block 2 Imagery Quality	Trial Block 3 Key Scale	Trial Block 3 Imagery Set	Trial Block 3 Imagery Quality	Trial Block 4 Key Scale	Trial Block 4 Imagery Set	Trial Block 4 Imagery Quality
Photographic	Vertical	1, 4	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		19,22	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		25,28	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		43,46	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good
	Oblique	5, 8	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		14,23	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		29,32	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		38,47	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good
	Both	9,12	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		15,18	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		33,36	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		39,42	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good
Schematic	Vertical	7,10	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		13,16	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		31,34	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		37,40	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good
	Oblique	2,11	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		17,20	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		26,35	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		41,44	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good
	Both	3, 6	A	Small	1	Poor	Small	2	Good	Large	4	Poor	Large	3	Good
		21,24	B	Small	3	Good	Small	4	Poor	Large	2	Good	Large	1	Poor
		27,30	C	Large	4	Good	Large	3	Poor	Small	1	Good	Small	2	Poor
		45,48	D	Large	2	Poor	Large	1	Good	Small	3	Poor	Small	4	Good

Figure 9. Experimental design for Experiment One

Experiment Two

The computer-aided procedures used in conjunction with Experiment One could have reduced identification time by narrowing possible choices to the three categories selected as probable. However, the procedure could also have increased identification time if the wrong categories were selected. It was also possible that the procedures followed in selecting the categories could have interacted with effects of the pictorial variables under study. The experiment was therefore partially replicated without using computer-aided procedures. Subjects made their identifications strictly through comparison of the imagery with the representations in the key.

Key Characteristics. Two types of representation and two views were used. The two types of representation were the same as in Experiment One--a photograph and a line drawing or schematic representation of recognition features made from the photograph (Figures 1 and 2). The keys presented a vertical view, shown in Figures 1 and 2 or an oblique view, shown in Figures 3 and 4. The two views were not used together. All the keys were of large scale. The small scale was not used because of the significantly longer time required to use this scale, as found in Experiment One. As before, no text was used on the keys.

Organization of Keys. Four experimental keys, each containing the desired combination of the two key characteristics under investigation, were constructed. The keys were organized as for Experiment One.

Test Imagery. The test imagery was the same as that used in Experiment One.

Experimental Design. Independent groups of 20 subjects each worked with each of the key view conditions (Figure 10). Each subject worked with both key representations, changing halfway through the test trials. Half the subjects worked with the photographic representation first, half with the schematic representation first. Each group of subjects thus used one of the key views with both key representations, sequentially, to make a series of identifications.

Since the same test imagery was used as in Experiment One, the presentation schedule for the imagery sets and quality levels was the same as that shown previously. As before, each subject identified 16 vehicles grouped into four sets of four vehicles each.

Procedure. The subject was dependent on the key alone to make his identifications. As there was no text or listing of recognition features, the subject had to go through a series of comparisons of the key representations with the imaged vehicle to be identified and make a decision as to which presented the closest match. The key was divided into various categories which were presented on separate pages. Upon turning to a frame showing an annotated vehicle to be identified, the subject turned on a counter which recorded the time in seconds. At the same time, he

Key View	Subjects	Sequence	Trial Block 1 Key Representation	Trial Block 1 Imagery Set	Trial Block 1 Quality	Trial Block 2 Key Representation	Trial Block 2 Imagery Set	Trial Block 2 Quality	Trial Block 3 Key Representation	Trial Block 3 Imagery Set	Trial Block 3 Quality	Trial Block 4 Key Representation	Trial Block 4 Imagery Set	Trial Block 4 Quality
Vertical	1,5,9 13,17	A	Photographic	1	Poor	Photographic	2	Good	Schematic	4	Poor	Schematic	3	Good
	2,6,10 14,18	B	Photographic	3	Good	Photographic	4	Poor	Schematic	2	Good	Schematic	1	Poor
	3,7,11 15,19	C	Schematic	4	Good	Schematic	3	Poor	Photographic	1	Good	Photographic	2	Poor
	4,8,12 16,20	D	Schematic	2	Poor	Schematic	1	Good	Photographic	3	Poor	Photo graphic	4	Good
Oblique	21,25,29 33,37	A	Photographic	1	Poor	Photographic	2	Good	Schematic	4	Poor	Schematic	3	Poor
	22,26,30 34,38	B	Photographic	3	Good	Photographic	4	Poor	Schematic	2	Good	Schematic	1	Poor
	23,27,31 35,39	C	Schematic	4	Good	Schematic	3	Poor	Photographic	1	Good	Photographic	2	Poor
	24,28,32 36,40	D	Schematic	2	Poor	Schematic	1	Good	Photographic	3	Poor	Photo graphic	4	Good

Figure 10. Experimental design for Experiment Two

opened the key. He had available 3X and 8X magnifiers. When he had decided on the identification, he stopped the counter and recorded the identification number on a form, together with the elapsed time in seconds. The counter was set back to 0 for use on the next trial, and the key was closed. The key was attached to a clipboard mounted on the light table. Halfway through the test trials, type of representation was changed.

Before starting the 16 test trials, the subject went through four practice frames, each of which contained a vehicle to be identified. Any questions concerning procedure were answered during this time. It was ascertained that the subject understood the procedure before he was permitted to go on to the test frames.

The subjects were told that the aim of the experiment was to provide information that might be useful in the design of reference materials.

Subjects. Forty image interpreters recently graduated from the U. S. Army Intelligence School at Fort Holabird were used as subjects. These mer .ld not depend upon their experience for the identification of the vehicles. To the extent possible, assignment to the independent groups was based on matching scores on the General Technical Aptitude Area, a composite of the Verbal and Arithmetic Reasoning tests of the Army Classification Battery.

Dependent Measures. The same three measures of performance as in Experiment One were used. Time was obtained by readout of the counter at each identification by a subject.

Experiment Three

In Experiment Three, as in Experiment Two, identification was made strictly by comparing the target in the imagery with the representations in the key. However, instead of comparing performance with photographic representations and schematic representations, performance with photographs was compared to that with combined photographic and schematic representations.

Key Characteristics. The combined photographic and schematic representation with which the photograph alone was compared presented a photograph of the vehicle together with recognition characteristics indicated on a line drawing. (Figure 11). Only the vertical view was used, and all views were large scale.

Organization of Keys. Keys were organized as in Experiment One.

Test Imagery. The test imagery was the same as that used in Experiment One.

11 12 13

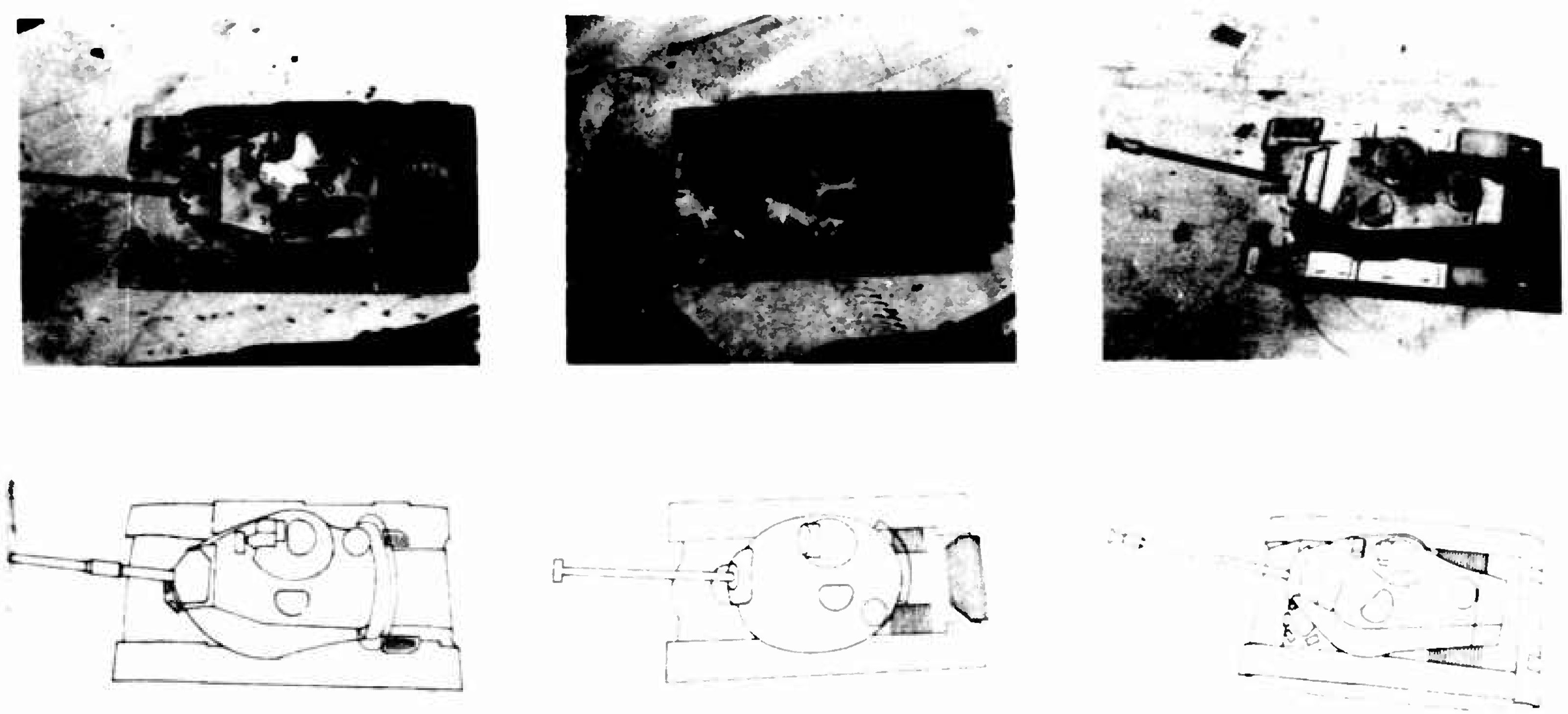

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Figure 11. Page from an experimental key showing examples of photographic and schematic representations used together

Experimental Design. The experimental design is shown in Figure 12. Each of the 20 subjects worked with both types of representation, changing halfway through the test trials. Half the subjects worked with the photographic representation first, half with the combined photographic and schematic representation first. As the same test imagery was used as in the previous experiments, the presentation schedule for the imagery sets and quality levels was the same as in the previous experiments. As before, each subject identified 16 vehicles grouped in four sets of four vehicles each.

Procedure. As in Experiment Two, the subject was dependent on the key alone for making the identifications. Procedure was the same as in Experiment Two.

Subjects. Twenty image interpreters recently graduated from the U. S. Army Intelligence School were the subjects. These subjects could not depend on their experience for identification of the vehicles.

Dependent Measures. Evaluation was in terms of the same three measures of performance as in Experiment One and Two. Time was obtained in the same manner as in Experiment Two.

Summary of Experimental Variables

To facilitate presentation of the comparisons made, the key variables of representation, angle of view, and scale as combined in the three experiments are presented in Table 3. This table shows which dimensions were varied and which were held constant in each of the studies. Since the same test imagery was used in all three experiments, the quality of imagery was either good or degraded, and the same four sets of four different vehicles were involved.

RESULTS

Treatment of the Data

An analysis of variance was performed for each of the dependent measures. An additional analysis was performed for the time measure using a log transformation to offset possible effects of skewness in the data[18/]. Thus, there were four analyses of variance for each of the

[18/] As Experiment One was one of the earlier experiments conducted in the Information Systems Laboratory, problems with the hardware were encountered. Several time scores were distorted through improper functioning of the response keyboard. Out of the 768 data points, 26 were so affected, as were data collected on 21 of the 48 subjects. However, because of the small number of data points involved and lack of concentration on any one subject, it was decided to use these data in the analyses. The data points in question were reconstituted by using the average of the other data points in the image set affected.

		Trial Block											
		1			2			3			4		
Subjects	Sequence	Key Representation	Imagery Set	Quality	Key Representation	Imagery Set	Quality	Key Representation	Imagery Set	Quality	Key Representation	Imagery Set	Quality
1,5,9 13,17	A	Photographic	1	Poor	Photographic	2	Good	Photographic plus Schematic	4	Poor	Photographic plus Schematic	3	Good
2,6,10 14,18	B	Photographic	3	Good	Photographic	4	Poor	Photographic plus Schematic	2	Good	Photo graphic plus Schematic	1	Poor
3,7,11 15,19	C	Photographic plus Schematic	4	Good	Photographic plus Schematic	3	Poor	Photographic	1	Good	Photographic	2	Poor
4,8,12 16,20	D	Photographic plus Schematic	2	Poor	Photographic plus Schematic	1	Good	Photographic	3	Poor	Photographic	4	Good

Figure 12. Experimental design for Experiment Three

Table 3

SUMMARY OF KEY VARIABLES IN THE THREE EXPERIMENTS

Representation	View	Scale
	Experiment One[a]	
Photographic	Vertical	Large
Schematic	Oblique	Small
	Both	
	Experiment Two	
Photographic	Vertical	Large[b]
Schematic	Oblique	
	Experiment Three	
Photographic	Vertical[b]	Large[b]
Photographic plus Schematic		

[a]In conjunction with computer-assisted category selection

[b]Not varied

three experiments. Summary tables of these analyses are presented as Appendix D.[19]

The means in Tables 4 through 7 are for a set of four images to be identified, as the analyses were based on this test unit. All four image sets were involved in calculation of the means, and all 16 vehicles were thus included. Mean time per identification is shown in Appendix E, together with mean number and proportion of correct identifications made under each experimental condition.

Performance as a Function of Key Representation

The only significant difference was for the transformed time measure in Experiment One, a difference in favor of photographic representation in the key (Table 4). That the same measure did not show a significant difference in Experiment Two may indicate that the photograph permitted more rapid identification within category, once the category was initially selected. However, when the category had to be selected solely from the key, without computer aid, there was no difference in performance between photographic and schematic representation, indicating that the procedure involved in category selection in Experiment One interacted with the final identification of the target. In three of the four procedures involved in selection of target category, the interpreter was directed by the computer input/output device to particular features distinguishing the various categories before he had access to the key itself. When the interpreter had gone through these procedures, the photographic representation appeared to facilitate final identification. It is possible that with photographs, the interpreter can extract information to supplement

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[19] In Experiment One, there was a possibility that the category selection procedure executed initially by the subject before he turned to the key would not give the correct category. The subject would then have to go through the other ranking categories. In any case, the category selection could have an effect on the time required to make a decision about the vehicle identification independent of the characteristics of the keys. A tabulation was therefore made of the number of targets which had been correctly categorized into each of the rankings for each of the subjects. This tabulation indicates that the accuracy achieved in selection of the category was fairly evenly distributed over the six groups of subjects subsequently using the various combinations of representation and view in the keys. Also, in most cases, the category selected for the first rank was correct. Therefore, this possible artifact does not appear to have occurred. However, there was the possible interaction between category selection and target identification procedures, and this was one factor dictating the conduct of Experiment Two. (The tabulation appears as Appendix C)

adequately the information derived during the category selection procedure. The schematic representation may not have complemented the category selection procedure as readily. In Experiment Two, where the key material alone was used from the beginning of the identification procedure, selection of a category was not specifically carried out separately from the identification of the target. For this integrated procedure, it would appear that the photographic and schematic presentations were equally effective. With the photograph, the interpreter was able to extract pertinent features as needed; he attained an equal level of performance with the schematic type of presentation. These findings indicate the presence of a possible interaction between procedure used and key characteristics. Also, different types of information may be needed at different stages in the identification process.

Performance as a Function of Angle of View

No differences in performance were found as a function of the view of the object presented in the key (Table 5). Evidently, interpreters were able to compensate for the discrepancy between an oblique view in the key and the vertical view in the test imagery. Nor was any advantage obtained by presenting the vertical and oblique views together in the key materials. Since only the vertical view was used in the key for Experiment Three, comparisons in Table 5 derive only from the first two experiments.

A significant interaction was found between view and image quality for the transformed time data in Experiment One. Additional analyses were therefore performed in an attempt to localize the reason for the interaction. The analysis is presented in Appendix F. For each level of image quality, no differences were found among the three levels of the view variable. However, when the difference in performance as a function of image quality for each view was ascertained, a significant difference was found for the vertical view but not for the oblique view or for the two views used together. When the vertical view key was used, a significant decrement in identification time was found when poor quality test imagery was used, as indicated in the pattern of means. Thus, performance with the vertical view suffered when a more difficult discrimination had to be made, while with the oblique view no significant change in performance occurred as a function of difference in quality of key imagery. This effect occurred only in Experiment One where the key was used subsequent to category selection.

Performance as a Function of Key Scale

Only in Experiment One was a reduced scale on the key compared with large scale. The reduced scale corresponded to the scale of the test imagery. In Experiments Two and Three, only the large scale was used.

Table 4

IDENTIFICATION PERFORMANCE AS A FUNCTION OF TYPE OF KEY REPRESENTATION

Dependent Measure	Type of Presentation: Photographic	Schematic	Photographic and Schematic
Mean Time (seconds) per image set to make an identification		Experiment One	
	148.46	* 177.34	-----
		Experiment Two	
	108.94	106.40	-----
		Experiment Three	
	113.52	-----	115.40
Mean Number of correct identifications per image set		Experiment One	
	2.63	2.83	-----
		Experiment Two	
	2.82	2.67	-----
		Experiment Three	
	3.00	-----	2.87
Mean efficiency score per image set		Experiment One	
	.023	.020	-----
		Experiment Two	
	.037	.032	-----
		Experiment Three	
	.035	-----	.030

*Significant difference (P < .05) (log transform)

Table 5

IDENTIFICATION PERFORMANCE AS A FUNCTION OF KEY VIEW

Dependent Measure	View: Vertical	View: Oblique	View: Vertical and Oblique
		Experiment One	
Mean time (seconds) per image set to make an identification	164.20	151.39	173.11
		Experiment Two	
	102.57	112.76	-----
		Experiment One	
Mean number of correct identifications per image set	2.77	2.67	2.77
		Experiment Two	
	2.84	2.66	-----
		Experiment One	
Mean efficiency score per image set	.020	.024	.021
		Experiment Two	
	.038	.030	-----

Table 6

IDENTIFICATION PERFORMANCE AS A FUNCTION OF KEY SCALE
(EXPERIMENT ONE ONLY)

Dependent Measure	Large Scale		Small Scale
Mean time (seconds) per image set to make an identification	150.15	**	175.66
Mean number of correct identifications per image set	2.85		2.61
Mean efficiency score per image set	.024	**	.019

**Significant Difference (P <.01)

Results of the comparison between the two scales in Experiment One are given in Table 6. A significant difference was found in time, both untransformed and transformed, and in the efficiency score. No differences were found in number of correct identifications.

Observation of the interpreters at work showed that they used their magnifiers with the reduced scale keys as they did with the test imagery. Of course, this practice slowed them down and caused the significant decrement in time. No difference occurred in accuracy of identification. Since the reduced scale of the keys was obtained through photographic reduction, there was minimal loss of detail, as would not be the case with reduced scale due to altitude as with the test imagery. The detail presented through the magnifier approximated that on the large-scale keys. It is possible that the presence in a key of imagery at reduced scale, taken from altitude, may enhance performance through similarity in appearance to objects in the imagery. However, there remains the possibility of slower identification through the use of magnifiers.

There was no interaction of key scale with any other variables.

Performance as a Function of Image Set

As discussed previously, the test imagery consisted of 16 vehicles which had been divided into four sets of four each, in keeping with the experimental design. Mean performance with each of the image sets is presented in Table 7.

All the analyses except one gave a significant effect as a function of image set. This result would indicate that the sets varied in difficulty depending on their composition. The number of correct identifications for each of the vehicles is given in Appendix G. The experimental design exposed the variables equally to each of the image sets.

The one comparison in which no difference was found among the image sets was for number of correct identifications made in Experiment Three, possibly because the introduction of photographic and schematic representations in combination reduced differences in the difficulty of discrimination among the various vehicles and enabled the subject to use the most effective aid for each identification. This differential use of types of representation was mentioned by several of the interpreters in interviews after testing. However, the difference in effectiveness was not reflected in mean performance over all image sets (shown in Table 4).

There was no interaction of image set with the other variables.

Performance as a Function of Image Quality

For all the experiments, mean performance on all measures was found to suffer as a result of degraded quality of test imagery. Mean performance on the two quality levels for the several experiments is given in Appendix H. The only interaction of imagery quality with the other variables was in Experiment One with angle of view in the case of transformed time data, as discussed previously.

SUMMARY OF FINDINGS

Overall results concerning the relative effectiveness of photographic and schematic representation in the keys indicate that the two are equally effective in aiding identification as required in the present research. Interpreters appeared able to extract pertinent recognition features from the photographic representations. However, schematic representation such as may be required in using electronic media may be as effective as photographic keys.

The photographic representation permitted more rapid identification when the key was used in conjunction with a computer-assisted category selection procedure. However, no differences in performance between photographic and schematic representation were found when the keys were used alone. These findings indicate possible interaction between procedure used and the resulting difficulty of discrimination with type of representation in the key. The most effective representation may vary as a function of the stage of the discrimination process involved.

Table 7

IDENTIFICATION PERFORMANCE AS A FUNCTION OF IMAGE SET

Dependent Measure	Image Set 1	2	3	4
	Experiment One **			
Mean time per image set to make an identification (sec.)	186.60	133.75	187.48	143.77
	Experiment Two **			
	122.27	80.47	125.10	102.82
	Experiment Three **			
	135.40	82.60	124.40	115.45
	Experiment One **			
Mean number of correct identifications per image set	2.65	3.15	2.27	2.87
	Experiment Two **			
	2.55	3.10	2.35	3.00
	Experiment Three			
	2.85	3.05	2.80	3.05
	Experiment One **			
Mean efficiency score per image set	.018	.028	.015	.025
	Experiment Two **			
	.026	.050	.024	.035
	Experiment Three **			
	.024	.049	.030	.029

**Significant Effect ($P < .01$)

With the particular task involved, no advantage was attained by presenting the photographic and schematic representations together. However, several of the interpreters using this combination key indicated that they used different representations depending on the difficulty of the identification encountered. Also, introduction of both representations together reduced differences among the image sets in number of correct identifications made, indicating that the particular target involved and its associated difficulty of discrimination may dictate which type of representation is most effective. The presence of both photographic and schematic representations may have enabled the interpreters to use the most effective view.

Mean performance did not vary as a function of the angle of view used in the key. Interpreters appeared able to compensate for the discrepancy between an oblique view in the key and vertical imagery. No advantage was found with presenting both vertical and oblique views in the key. When the key was used in conjunction with a computer-assisted category selection procedure, the vertical view required more time in the case of degraded imagery. However, no such effect was found when the key was used alone, indicating an interaction between level of required discrimination and the view used.

With a reduced scale on the key, more time was taken to make an identification, perhaps because interpreters tended to use a magnifier with the small-scale key.

IMPLICATIONS OF FINDINGS

Since a schematic representation may be as effective an aid to identification as a photograph, the compiler of a key may use either type of presentation, taking into account other considerations such as availability of photographic imagery and costs of production of illustrations. Of course, any application of this and other findings to the design of operational keys must be tempered by the realization that a key may involve other elements than the pictorial. The associated text and accession procedures may interact with the effectiveness of any one presentation. However, the very nature of a key would indicate that the pictorial component is an important determinant of a key's effectiveness.

The effectiveness of the schematic type of presentation also has important implications for the presentation of reference information through the use of such media as the cathode ray tube, a practice which may become increasingly common as computer-based capabilities find greater use in military information processing systems. Such media may require line figures if the range of gray scale required to display a photograph can not be reproduced.

While no increment in identification performance was obtained by use of both photographic and schematic representations together, there is some indication that difficulty of identification of certain targets is reduced when both representations are present in the key. The target involved and associated degree of difficulty may dictate which type of presentation should be used or if it is desirable to present both. Further research into how photographic and various schematic presentations may be integrated is needed, and the effectiveness of such integrated presentations should be assessed empirically.

The designer of a key has been accustomed to select with great care the view to be included so as to emphasize the salient characteristics of the object in question. However, present findings indicate that an interpreter is able to compensate for discrepancies between the view of the image he is interpreting and the view in the key. For example, a vertical view in the key may not be essential to identification of an object shown in vertical imagery. The findings also indicate that there is no advantage to presenting more than one view in the key. Therefore, a saving in storage space requirements may be achieved with no decrement in the effectiveness of the keys.

Incorporation of illustrations at reduced scale in a key--to save space or to match the imagery scale--may increase the time required to use the key--and with no attendant increase in accuracy--because of the need to use a magnifier. An optimal scale or range of scales to present the appearance of a target adequately and still permit use of the key without magnification remains to be determined. In any case, it may not be desirable to present the illustration in the key at a scale that requires magnification.

LITERATURE CITED

Bigelow, G. F. Photographic interpretation keys--a reappraisal. Photogrammetric Engineering, 1963, 29. 1042-1051.

Bigelow, G. F. Human factors problems in the development and use of image interpretation keys. Research Study 66-4. Behavior and Systems Research Laboratory. Arlington, Va. May 1966.

Colwell, R. N. Photointerpretation for civil purposes. In Manual of Photogrammetry. Washington, D. C.: American Society of Photogrammetry, 1953.

DeLancie, R., W. W. Steen, R. E. Pippin, and A. Shapiro. Quantitative evaluation of photo interpretation keys. Technical Research Report 57-130C, U. S. Air Force, Rome Air Development Center. May 1957. (Also Photogrammetric Engineering, 1957, 23, 858-864).

Harrison, P., and D. Rochford. Photointerpretation key conversion study. RADC-TR-65-5. U. S. Air Force, Rome Air Development Center, 1966.

Laymon, R. S. Evaluation of three computer-compatible procedures for using image interpreter keys. Technical Research Note 186 (AD655 856). Behavior and Systems Research Laboratory. Arlington, Va. June 1967.

Martinek, H., and R. Sadacca. Error keys as reference aids in image interpretation. Technical Research Note 153 (AD619 225). Behavior and Systems Research Laboratory. Arlington, Va. June 1965.

Murray, A. E. Perceptron applications in photo interpretation. Photogrammetric Engineering. 1961, 27, 627-637.

Narva, M. A., and F. A. Muckler. Visual reconnaissance and surveillance from space vehicles. Human Factors. 1963, 5, 295-315.

Nelson, A., K. McClure, J. Polgreen, and R. Sadacca. Organization and presentation of image interpreter reference and auxiliary information. Technical Research Note 173 (AD641 326). Behavior and Systems Research Laboratory. Arlington, Va. June 1966.

Rabben, E. L. (Ed.). Fundamentals of photographic interpretation. In Manual of Photographic Interpretation. Washington D. C.: American Society of Photogrammetry. 1960.

Seymour, T. D. The interpretation of unidentified information: A basic concept. Photogrammetric Engineering, 1957, 23, 115-121.

Simontacchi, A. A., G. A. Choate, and D. A. Bernstein. Considerations in the preparation of keys to natural vegetation. Photogrammetric Engineering, 1955, 21, 582-588.

Strandberg, C. H. Aerial Discovery Manual. New York: John Wiley and Sons, 1967.

U. S. Naval Reconnaissance and Technical Support Center. Image Interpretation Handbook. Vol. 1, TM 30-245, NAVAIR 10-35-685, AFM 200-50. December 1967.

Weiner, H. The mechanical aspect of photo interpretation keys. Photogrammetric Engineering, 1955, 21, 708-711.

ADDITIONAL SELECTED REFERENCES CITED IN APPENDIX A

Anderson, Nancy S., and J. A. Leonard. The recognition, naming, and reconstruction of visual figures as a function of the contour redundancy. Journal of Experimental Psychology, 1958, 56, 262-270.

Birnbaum, A. H. Exploratory study in interpretation of vertical and high oblique photographs. Technical Research Note 174. (AD643 242). Behavior and Systems Research Laboratory. Arlington, Va. June 1966.

Colwell, R. N. Photointerpretation for civil purposes. In: Manual of Photogrammetry. Washington, D. C.: American Society of Photogrammetry. 1953.

Dalton, W. A. J., S. H. Levine, J. H. Logan, and P. L. Taylor. Usefulness of aspect angle viewing in photo intelligence extraction. Report EN-614. St. Louis, Missouri: McDonnell Douglas Corporation. March 1968.

Fitts, P. M., M. Weinstein, M. Rappaport, N. Anderson, and J. A. Leonard. Stimulus correlates of visual pattern recognition: A probability approach. Journal of Experimental Psychology, 1956 51, 1-11.

Fraisse, P. and E. H. Elkin. Étude génétique de l'influence des modes de présentation sur le seuil de reconnaissance d'objets familiers. L'Année Psychologique, 1963, 63, 1-12.

Gagne, R., and J. J. Gibson. Research on the recognition of aircraft. In J. J. Gibson (Ed.). Motion picture training and research. Report No. 7. Washington, D. C.: U. S. Army Air Force Aviation Psychology Program. 1947.

Gavurin, E. I. An evaluation of various tachistoscopic and WEFT techniques in aircraft recognition. Technical Report NAVTRADEVCEN IH-40. Port Washington, N. Y.: U. S. Naval Training Device Center. November 1965.

Gibson, Eleanor J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts. 1969.

Gibson, J. Proposals for a theory of pictorial perception. HFORL Memo Report 35. Washington, D. C.: Human Factors Operations Research Laboratories. May 1953.

Hake, H. W. Contributions of psychology to the study of pattern vision. U. S. Air Force, WADC Technical Report 57-621. Wright Air Development Center. October 1957.

Klingberg, C. L., C. L. Elworth (The Boeing Co.), and A. H. Birnbaum (USABESRL). Effect of disparity in photo scale and orientation on change detection. Technical Research Note 206 (AD688 967). Behavior and Systems Research Laboratory. Arlington, Va. January 1969.

Leibowitz, H. W. _Visual perception_. New York: MacMillan. 1965.

Leibowitz, H. W. The human visual system and image interpretation. Research paper P-319. Arlington, VA: Institute for Defense Analysis. June 1967.

Neisser, U. _Cognitive psychology_. New York: Appleton-Century-Crofts. 1967.

Rappaport, M. The role of redundancy in the discrimination of visual forms. _Journal of Experimental Psychology_, 1957, _53_, 3-10.

Ryan, T. A., and Carol B. Schwartz. Speed of perception as a function of mode of representation. _American Journal of Psychology_. 1956, _69_, 60-69.

Sadacca, R., J. E. Ranes, and A. I. Schwartz. Human factors studies in image interpretation: Vertical and oblique photos. Technical Research Note 120 (AD 281 423). Behavior and Systems Research Laboratory. Arlington, VA. December 1961.

Sternberg, S. Two operations in character recognition: Some evidence from reaction-time measurement. _Perception and Psychophysics_, 1967 _2_, 45-53.

Whitmore, P. G., J. A. Cox, and D. J. Friel. A classroom method of training aircraft recognition. Technical report 68-1. Fort Bliss, Texas. Human Resources Research Office, Division No. 5. January 1968.

Wright, A. D. Applied perceptual problems in aircraft recognition and situation recognition. In Pattern identification by man and machine. Technical Memo 17-68. Aberdeen Proving Ground, Maryland: U. S. Army Human Engineering Laboratories. December 1968.

Zusne, L. Moments of area and the perimeter of visual form as predictors of discrimination performance. _Journal of Experimental Psychology_, 1965. _69_, 213-220.

APPENDIXES

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APPENDIX A

PICTORIAL ASPECTS OF IMAGE INTERPRETATION KEYS

While in most keys recognition features are categorized in physical terms based on the characteristics of the objects depicted, the underlying process through which the object is identified falls in the area of visual perception. It follows that the manner of presenting the pictorial information in a key, to be used either as reference or in discrimination training, should be such as to facilitate or enhance the perceptual processes taking place. The objective is to present the perceptually relevant characteristics of the objects to be identified in imagery. If this can be done while satisfying operational and practical considerations, the performance of the interpreter could be improved. Leibowitz[20] has discussed the importance of an understanding of the underlying perceptual processes involved in image interpretation. Research in this area having pertinence for image interpretation has been surveyed by Gibson[21] and Neisser[22]. In the discrimination process, the perceptually pertinent qualities of objects which permit their rapid and accurate recognition are extracted from the changeable representations of these objects. The perceptual apparatus is constantly operating on the physical stimulation. A mental representation is formed of the object--designated by such terms as "schema", "prototype", "template", or in broader terms as "percept". This representation consists of the critical invariant properties of the object which permit it to be recognized or discriminated from other objects. Presumably, the mental representation also is reduced to the minimal set of features which permit recognition of the object under all conditions encountered. It has been suggested that the visual system selects those parts of stimulation which lead to the greatest "coherence", and that these aspects are those which produce the greatest resemblance between past and present stimulation and lead to the most efficient predictions about future stimulation[23]. A new object is then recognized by comparison with the basic mental representation. It has been pointed out, however, that a skilled image interpreter is not able to describe the processes underlying the making of an identification[20].

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[20] Leibowitz, H. W. The human visual system and image interpretation. Research paper P-319. Arlington, VA.: Institute for Defense Analysis. June 1967

[21] Gibson, Eleanor J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts. 1969.

[22] Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts. 1967.

[23] Hake, H. W. Contributions of psychology to the study of pattern vision. U. S. Air Force, WADC Technical Report 57-621. Wright Air Development Center. October 1957.

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Further, an individual need not be aware of the stimuli to which he is responding[24/]. In essence, therefore, this mental representation is a mental key. In the training situation, the aim may be said to be to develop a mental representation which will yield the correct identification in the face of the changing conditions of presentation encountered in the imagery. Where the interpreter refers to a key, the design of the key materials should be such as to facilitate the operation of the perceptual processes involved. The key, in essence a substitute for the mental representation, must permit a correct discrimination decision relative to the changeable stimulus represented in the imagery.

A great number of laboratory experiments, usually with abstract materials which lend themselves to easy control, have been performed on the perceptual processes involved in discrimination. An article in 1965[25/] indicated that between 70 and 80 physical measures of visual form had been defined and used in form perception experiments since 1948. Of most direct pertinence is work concerned with training in the recognition of aircraft during World War II, as reviewed by Gagne and Gibson[26/]. It was found that students tended to memorize the various aircraft in terms of features which served to distinguish each from the others--in other words, the perceptually relevant characteristics. These characteristics did not necessarily conform to a standard set of features presented to the students in the way keys are usually organized. Results of the studies indicated a need for the students to know features which primarily distinguish one aircraft from another rather than a standard set of features. In an attempt to isolate the perceptually relevant features, remembered shapes of the aircraft as shown by drawings made by the students were examined. The students had evidently learned to visualize the aircraft as unique entities, the main characteristics of each being differentiated in the drawings. In many cases, the features were exaggerated so that the drawings were almost caricatures. Additional work on

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[24/] Leibowitz, H. W. Visual perception. New York: MacMillan. 1965.

[25/] Zusne, L. Moments of area and the perimeter of visual form as predictors of discrimination performance. Journal of Experimental Psychology, 1965. 69, 213-220.

[26/] Gagne, R., and J. J. Gibson. Research on the recognition of aircraft. In J. J. Gibson (Ed.). Motion picture training and research. Report No. 7. Washington, D. C.: U. S. Army Air Force Aviation Psychology Program. 1947.

aircraft recognition conducted by Gavurin[27] and Whitmore[28] indicated that comparison viewing during training is advantageous for discrimination training. In both studies, specific recognition features were pointed out to the student, in one case through use of the wings-engine-fuselage-tail (WEFT) nomenclature system, in the other through use of specific recognition features selected judgmentally.

In a key, views of an object may vary along several continua relative to the imagery being viewed. One such variable, and the first to be considered in the present experimentation, is the pictorial fidelity with which the object is shown on the key. Fidelity may range from a clear photograph to an abstract representation. The objective was to determine how best to present features required for identification of an object. As Gibson[29] has indicated, the observer may need to be presented only those properties which are relevant or significant. A photograph reproduces all without differentiation, while a drawing may be selective. The selective emphasis of the drawing may clarify the observer's perception of the object. Indeed, as indicated in the aircraft recognition training, an emphasis of some feature in the form of a caricature may facilitate discrimination, providing enhancement by exaggeration of distinctive features[21]. On the other hand, there is a danger that a drawing or anything less than a high fidelity reproduction may omit a feature which is important for recognition of the object. On anything other than a true photograph, a decision must be made as to what to include in the representation. The problem is to eliminate what is superfluous, retaining what is necessary to meet all requirements for identification. Work on abstract forms in the laboratory has indicated that the observer 'filters' his input and selects only those aspects required to perform

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21/ Gibson, Eleanor J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts. 1969.

27/ Gavurin, E. I. An evaluation of various tachistoscopic and WEFT techniques in aircraft recognition. Technical Report NAVTRADEVCEN IH-40. Port Washington, N. Y.: U. S. Naval Training Device Center. November 1965.

28/ Whitmore, P. G., J. A. Cox, and D. J. Friel. A classroom method of training aircraft recognition. Technical report 68-1. Fort Bliss, Texas. Human Resources Research Office, Division No. 5. January 1968.

29/ Gibson, J. Proposals for a theory of pictorial perception. HFORL Memo Report 35. Washington, D. C.: Human Factors Operations Research Laboratories. May 1953.

the task. In identification, classification, and learning tasks, only distinctive features may be used[30], [31]. However, there may be an interaction between the nature and difficulty of the task and the amount of information required. For a difficult discrimination, as with a degraded image, redundancy may hamper rapid discrimination[32]. The amount of information presented must complement the task at hand.

Recent theory has hypothesized that there are two operations in recognition and classification[22], [33]. In the first, there is a 'preprocessing' or encoding of the visual stimulus as an abstracted representation of its physical properties. In essence, this process "cleans up" the input or reduces the redundancy present. The second operation then compares such a stimulus representation to a memory representation, producing either a match or a mismatch and consequent acceptance or rejection of identification. Presumably, a representation other than a photograph but one which includes all pertinent features would facilitate the recognition process, as the first operation would not be required.

Therefore, the question of what degree of fidelity to use in a key representation requires investigation. Ryan and Schwartz[34] have compared the accuracy of discriminative judgments of the same objects in four modes of presentation. The four modes were photographs, shaded drawings, line drawings (tracings of outlines of the photographs), and caricature or cartoon drawings of the object. The representations were presented tachistoscopically. However, the task was not identification or discrimination of the object, but rather specification of the position of a

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[22] Neisser, U. Cognitive Psychology. New York: Appleton-Century-Crofts. 1967

[30] Anderson, Nancy S., and J. A. Leonard. The recognition, naming, and reconstruction of visual figures as a function of the contour redundancy. Journal of Experimental Psychology, 1958, 56, 262-270.

[31] Fitts, P. M., M. Weinstein, M. Rappaport, N. Anderson, and J. A. Leonard. Stimulus correlates of visual pattern recognition: A probability approach. Journal of Experimental Psychology, 1956 51, 1-11.

[32] Rappaport, M. The role of redundancy in the discrimination of visual forms. Journal of Experimental Psychology, 1957, 53, 3-10.

[33] Sternberg, S. Two operations in character recognition: Some evidence from reaction-time measurement. Perception and Psychophysics, 1967 2, 45-53.

[34] Ryan, T. A., and Carol B. Schwartz. Speed of perception as a function of mode of representation. American Journal of Psychology. 1956, 69, 60-69.

part of the object. For a representation of a hand, for example, the subject was to specify the position shown; for an assembly of switches, he was to name the particular switch that was open; and for a representation of a steam valve, he was to name the stage of the cycle shown. It was found that, for the objects and poses used, line drawings required the longest time for perception while cartoons were interpreted in the shortest time. Photographs and shaded drawings were about equal and fell between line drawings and cartoons. Fraisse and Elkin[35] presented tachistoscopically eight common objects in four modes--the real object, a photograph, an outline drawing, and a drawing in which certain features were accentuated by heavier lines. The subject was to recognize and name the object presented. The accented drawings were most easily recognized, with real objects, photographs, and outline drawings following in the order of ease of recognition. However, it was pointed out that this effect may vary somewhat as a function of the particular object and its angle of presentation.

In the present research, two levels on the continuum for fidelity of representation were chosen, a clear photograph and an outline drawing. No supplementary text was involved. In the case of the photograph, the interpreter had to abstract the pertinent recognition features from the key photograph and match them with the object in the imagery. With the outline drawings a previous decision had been made by experienced interpreters as to what to include, and the interpreter then had to match the object in the imagery against this representation.

Another variable along which a key representation may vary and which may affect its effectiveness is the angle of regard at which the object is shown. The view at which an object is shown may vary from a ground view (showing it as seen from the ground) to a view looking directly down on the object, as in vertical imagery. As Colwell[36] has indicated, an interpreter trainee must learn that features of an object that are most conspicuous on the ground view may be inconspicuous on the imagery and vice versa. He has suggested exposing the trainee to a series of photographs of the object showing ground, oblique, and vertical views to train the interpreter to relate the oblique and vertical views to the more familiar orientation seen in a ground view. Work has been conducted

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[35] Fraisse, P. and E. H. Elkin. Étude génétique de l'influence des modes de présentation sur le seuil de reconnaissance d'objets familiers. L'Année Psychologique, 1963, 63, 1-12.

[36] Colwell, R. N. Photointerpretation for civil purposes. In Manual of Photogrammetry. Washington, D. C.: American Society of Photogrammetry. 1953.

into the minimum number of training views of an aircraft that will permit uniform recognition performance across all possible views[37]. It appears that the view used in training can lead to various degrees of generalization to other views. Training views of various combinations have been selected which provide a relatively flat generalization gradient, and therefore somewhat equivalent recognition performance across all possible views which may be encountered by the observer. Interpretation performance as a function of viewing vertical or oblique imagery has also been investigated[38] [39] [40].

The present experiment dealt with the relative effectiveness of a vertical view, an oblique view, and the two used together in key presentation to identify an object on vertical imagery. The vertical view on the key presented the same aspect as that of the imagery. The oblique view, while not presenting the same view as on the imagery, presented information concerning the appearance of both the top and side of the object in one view, together with an indication of the relative height and spatial arrangement of the features on the top of the object. The oblique view was also closer to the familiar ground orientation.

Large and small scale views of the image in the key were compared. The large scale permitted the object to be shown in detail; the small scale was the same as that of the imagery. The effect of discrepancy in scale on performance in detecting changes in comparative cover imagery

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37/ Wright, A. D. Applied perceptual problems in aircraft recognition and situation recognition. In: Pattern identification by man and machine. Technical Memo 17-68. Aberdeen Proving Ground, Maryland: U. S. Army Human Engineering Laboratories. December 1968.

38/ Birnbaum, A. H. Exploratory study in interpretation of vertical and high oblique photographs. Technical Research Note 174. (AD 643242). Behavior and Systems Research Laboratory. Arlington, VA. June 1966.

39/ Dalton, W. A. J., S. H. Levine, J. H. Logan, and P. L. Taylor. Usefulness of aspect angle viewing in photo intelligence extraction. Report EN-614. St. Louis, Missouri: McDonnell Douglas Corporation. March 1968.

40/ Sadacca, R., J. E. Ranes, and A. I. Schwartz. Human factors studies in image interpretation: Vertical and oblique photos. Technical Research Note 120 (AD 281 423). Behavior and Systems Research Laboratory. Arlington, VA. December 1961.

has previously been examined[41]. In that experiment, it was found that scale disparity did adversely influence performance. However, the largest scale used in the prior research was equivalent to the smaller scale used in the present experiment. Also, a different task was involved.

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[41] Klingberg, C. L., C. L. Elworth (The Boeing Co.), and A. H. Birnbaum (USABESRL). Effect of disparity in photo scale and orientation on change detection. Technical Research Note 206 (AD 688 967). Behavior and Systems Research Laboratory. Arlington, VA. January 1969.

APPENDIX B

Table B-1

SCALE FOR EACH VEHICLE ON THE SMALL-SCALE KEY
(Vertical View)

Vehicle	Scale
M-60 Tank	1:1400
M-48 Tank	1:1450
M-41 Tank	1:1350
M-55 SPG	1:1150
M-52 SPG	1:960
M-44 SPG	1:1100
M-108 SPG	1:1200
M-42 SPG	1:1200
M-75 APC	1:960
M-112 APC	1:880
M-114 APC	1:980
M-577 APC	1:880
M-88 Recovery vehicle	1:1350
M-74 Recovery vehicle	1:1250
M-578 Recivery vehicle	1:1100
M-151 Cargo truck	1:780
M-37 Cargo truck	1:880
M-35 Cargo truck	1:1100
M-54 Cargo truck	1:1300
M-36 Cargo truck	1:1300
M-55 Cargo truck	1:1550
M-49 Special truck	1:1150
M-62 Special truck	1:1350

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APPENDIX C

Table C-1

NUMBER OF TARGETS CORRECTLY CATEGORIZED, BY RANKING, IN THE CATEGORY SELECTION PROCEDURE IN EXPERIMENT ONE

Subsequent Key Use		Rank 1	Rank 2	Rank 3	Beyond 3	Subsequent Key Use		Rank 1	Rank 2	Rank 3	Beyond 3
Photographic	S 1	14	1	1	-	Schematic	S 7	9	4	2	1
Vertical	4	12	3	-	1	Vertical	10	11	4	-	1
	19	11	4	1	-		13	14	2	-	-
	22	9	4	2	1		16	12	3	1	-
	25	15	-	-	1		31	8	4	2	2
	28	14	-	-	2		34	14	1	1	-
	43	12	3	1	-		37	12	1	1	2
	46	11	3	1	1		40	15	-	-	1
		98	18	6	6			95	19	7	7
Photographic	S 5	16	-	-	-	Schematic	S 2	10	2	3	1
Oblique	8	13	3	-	-	Oblique	11	14	2	-	-
	14	14	2	-	-		17	14	1	-	1
	23	11	3	1	1		20	15	1	-	-
	29	15	-	-	1		26	13	2	-	1
	32	10	3	2	1		35	13	3	-	-
	38	15	-	-	1		41	14	1	-	1
	47	12	2	1	1		44	12	3	-	1
		106	13	4	5			105	15	3	5
Photographic	S 9	10	5	1	-	Schematic	S 3	11	3	1	1
Both	12	10	3	2	1	Both	6	13	2	1	-
	15	14	2	-	-		21	12	4	-	-
	18	14	2	-	-		24	10	4	1	1
	33	12	3	-	1		27	15	-	-	1
	36	15	-	-	1		30	14	-	2	-
	39	13	1	-	2		45	12	2	-	2
	42	13	-	-	3		48	7	3	3	3
		101	16	3	8			94	18	8	8

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APPENDIX D ANALYSIS OF VARIANCE SUMMARY TABLES

Table D-1
ANALYSIS OF VARIANCE SUMMARY -- TIME (PER IMAGE SET)
FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Key representation	40049.630	1	40049.630	3.809
Key view	15257.292	2	7628.646	.725
Key representation X key view	7289.042	2	3644.521	.347
Sequence	109273.807	3	36424.602	3.464 *
Sequence X groups	207868.224	15	13857.882	1.318
Error 1 (Subj. w/groups X sequence)	252348.875	24	10514.536	
Within subjects				
Key scale	31237.505	1	31237.505	8.399 **
Key representation X key scale	190.005	1	190.005	.051
Key view X key scale	3412.792	2	1706.396	.457
Key representation X key view X key scale	2213.167	2	1106.583	.297
Imagery set	114320.182	3	38106.727	10.246 **
Key representation X imagery se	5059.682	3	1686.561	.452
Key view X imagery set	11894.708	6	1982.451	.532
Key representation X key view X imagery set	16152.708	6	2692.118	.722
Imagery quality	67988.380	1	67988.380	18.281 **
Key representation X imagery quality	5386.922	1	5386.922	1.448
Key view X imagery quality	22910.792	2	11455.396	3.080
Key scale X imagery quality	112.547	1	112.547	.030
Key representation X key view X imagery quality	6382.125	2	3191.062	.856
Key representation X key scale X imagery quality	360.255	1	360.255	.097
Key view X key scale X imagery quality	2981.625	2	1490.812	.400
Key representation X key view X key scale X imagery quality	12562.667	2	6281.333	1.689
Trial block	33229.516	3	11076.505	2.978 *
Trial block X groups	19323.516	15	1288.234	.345
Square residual	28151.099	3	9383.700	2.523
Square residual X groups	55733.432	15	3715.562	.996
Error 2	268496.625	72	3729.120	
Total	1340187.120	191		

*p < .05
**p < .01

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Table D-2
ANALYSIS OF VARIANCE SUMMARY -- LOG TIME (PER IMAGE SET)
FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Key representation	1.463478	1	1.463478	4.597 *
Key view	.615367	2	.307683	.966
Key representation X key view	.403820	2	.201910	.634
Sequence	3.316489	3	1.105496	3.472 *
Sequence X groups	7.610495	15	.507366	1.594
Error 1 (Subj. w/groups X sequence)	7.640635	24	.318360	
Within subjects				
Key scale	1.166761	1	1.166761	11.423 **
Key representation X key scale	.035334	1	.035334	.346
Key view X key scale	.192775	2	.096387	.944
Key representation X key view X key scale	.059422	2	.029711	.291
Imagery set	3.789279	3	1.263093	12.366 **
Key representation X imagery set	.317529	3	.105843	1.036
Key view X imagery set	.170663	6	.028444	.278
Key representation X key view X imagery set	.866174	6	.144362	1.413
Imagery quality	1.799096	1	1.799096	17.613 **
Key representation X imagery quality	.219885	1	.219885	2.153
Key view X imagery quality	.785702	2	.392851	3.846 *
Key scale X imagery quality	.022364	1	.022364	.219
Key representation X key view X imagery quality	.270009	2	.135004	1.322
Key representation X key scale X imagery quality	.006725	1	.006725	.066
Key view X key scale X imagery quality	.257470	2	.128735	1.260
Key representation X key view X key scale X imagery quality	.275248	2	.137624	1.347
Trial block	.667836	3	.222612	2.179
Trial block X groups	.865223	15	.057682	.565
Square residual	.242463	3	.080821	.791
Square residual X groups	1.983471	15	.132231	1.295
Error 2	7.354447	72	.102145	
Total	42.398160	191		

*p < .05
**p < .01

Table D-3
ANALYSIS OF VARIANCE SUMMARY -- NUMBER CORRECT
(PER IMAGE SET) FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	
<u>Between subjects</u>					
Key representation	1.880208	1	1.880208	2.039	
Key view	.375000	2	.187500	.203	
Key representation X key view	.291667	2	.145833	.158	
Sequence	2.182292	3	.727431	.789	
Sequence X groups	6.348958	15	.423264	.459	
Error 1 (Subj. w/groups X sequence)	22.125000	24	.921875		
<u>Within subjects</u>					
Key scale	2.755208	1	2.755208	3.862	
Key representation X key scale	1.505208	1	1.505208	2.110	
Key view X key scale	.541667	2	.270833	.380	
Key representation X key view X key scale	.541667	2	.270833	.380	
Imagery set	19.765625	3	6.588542	9.234	**
Key representation X imagery set	2.682292	3	.894097	1.253	
Key view X imagery set	4.875000	6	.812500	1.139	
Key representation X key view X imagery set	3.958333	6	.659722		
Imagery quality	34.171875	1	34.171875	47.893	**
Key representation X imagery quality	1.505208	1	1.505208	2.110	
Key view X imagery quality	2.625000	2	1.312500	1.840	
Key scale X imagery quality	.130208	1	.130208	.182	
Key representation X key view X imagery quality	.791667	2	.395833	.555	
Key representation X key scale X imagery quality	.130208	1	.130208	.182	
Key view X key scale X imagery quality	.541667	2	.270833	.380	
Key representation X key view X key scale X imagery quality	2.041667	2	1.020833	1.431	
Trial block	7.182292	3	2.394097	3.355	*
Trial block X groups	11.348958	15	.756597	1.060	
Square residual	5.515500	3	1.838500	2.577	
Square residual X groups	12.265500	15	.817700	1.146	
Error 2	51.375000	72	.713542		
Total	199.453125	191			

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

Table D-4
ANALYSIS OF VARIANCE SUMMARY -- EFFICIENCY SCORE
(PER IMAGE SET) FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	
Between subjects					
Key representation	374.0833	1	374.0833	1.857	
Key view	491.0729	2	245.5365	1.219	
Key representation X key view	256.0729	2	128.0365	.635	
Sequence	1018.9375	3	339.6458	1.686	
Sequence X groups	3404.8125	15	226.9875	1.127	
Error 1 (Subj. w/groups X sequence)	4835.5000	24	201.4792		
Within subjects					
Key scale	1463.0208	1	1463.0208	9.616	**
Key representation X key scale	30.0833	1	30.0833	.198	
Key view X key scale	618.4479	2	309.2240	2.032	
Key representation X key view X key scale	136.5729	2	68.2865		
Imagery set	5139.3542	3	1713.1180	11.260	**
Key representation X imagery set	25.5417	3	8.5139	.056	
Key view X imagery set	893.5521	6	148.9253	.979	
Key representation X key view X imagery set	513.5521	6	85.5920	.562	
Imagery quality	4125.5208	1	4125.5208	27.116	**
Key representation X imagery quality	2.0833	1	2.0833	.014	
Key view X imagery quality	452.8854	2	226.4427	1.488	
Key scale X imagery quality	2.5208	1	2.5208	.016	
Key representation X key view X imagery quality	380.6354	2	190.3177	1.251	
Key representation X key scale X imagery quality	96.3333	1	96.3333	.633	
Key view X key scale X imagery quality	214.8854	2	107.4427	.706	
Key representation X key view X key scale X imagery quality	57.0104	2	28.5052	.187	
Trial block	502.6875	3	167.5625	1.101	
Trial block X groups	1648.5625	15	109.9042	.722	
Square residual	155.1042	3	51.7014	.340	
Square residual X groups	3267.1458	15	217.8097	1.432	
Error 2	10954.5000	72	152.1458		
Total	41060.4792	191			

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

Table D-5
ANALYSIS OF VARIANCE SUMMARY -- TIME (PER IMAGE SET)
FOR EXPERIMENT TWO

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Key view	4151.406	1	4151.406	.587
Sequence	8658.819	3	2886.273	.408
Sequence X key view	7933.569	3	2644.523	.374
Error 1 (Subj. w/groups X sequence)	226322.400	32		
Within subjects				
Key representation	257.560	1	257.560	.179
Key view X key representation	2052.060	1	2052.060	1.425
Imagery set	51206.119	3	17068.706	11.853 **
Key view X imagery set	489.369	3	163.123	.113
Imagery quality	43329.306	1	43329.306	30.089 **
Key view X imagery quality	1410.156	1	1410.156	.979
Key representation X imagery quality	1696.000	1	1696.000	1.178
Key view X key representation X imagery quality	702.000	1	702.000	.614
Trial block	20639.169	3	6879.723	4.777 **
Trial block X key view	6304.619	3	2101.540	1.459
Residual	5164.080	6	860.680	.598
Error 2	138244.800	96		

**$p < .01$

Table D-6
ANALYSIS OF VARIANCE SUMMARY -- LOG TIME (PER IMAGE SET)
FOR EXPERIMENT TWO

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Key view	.524	1	.524	.891
Sequence	.431	3	.144	.244
Sequence X key view	.792	3	.264	.448
Error 1 (Subj. w/groups X sequence)	18.840	32	.589	
Within subjects				
Key representation	.052	1	.052	.674
Key view X key representation	.122	1	.122	1.592
Imagery set	4.466	3	1.489	19.442 **
Key view X imagery set	.033	3	.011	.144
Imagery quality	3.970	1	3.970	51.850 **
Key view X imagery quality	.143	1	.143	1.870
Key representation X imagery quality	.080	1	.080	1.040
Key view X key representation X imagery quality	.030	1	.030	.390
Trial block	1.645	3	.548	7.163 **
Trial block X key view	.312	3	.104	1.358
Residual	.493	6	.082	1.060
Error 2	7.351	96	.077	

**$p < .01$

Table D-7
ANALYSIS OF VARIANCE SUMMARY -- NUMBER CORRECT
(PER IMAGE SET) FOR EXPERIMENT TWO

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Key view	1.225	1	1.225	2.741
Sequence	4.200	3	1.440	3.133
Sequence X key view	3.275	3	1.092	2.443
Error 1 (Subj. w/groups X sequence)	14.300	32	.447	
Within subjects				
Key representation	.900	1	.900	1.172
Key view X key representation	.025	1	.025	.033
Imagery set	15.400	3	5.133	6.687 **
Key view X imagery set	3.875	3	1.292	1.682
Imagery quality	25.600	1	25.600	33.346 **
Key view X imagery quality	.625	1	.625	.814
Key representation X imagery quality	.400	1	.400	.521
Key view X key representation X imagery quality	.025	1	.025	.032
Trial block	1.000	3	.333	.434
Trial block X key view	.875	3	.292	.380
Residual	2.575	6	.429	.559
Error 2	73.700	96	.768	

**$p < .01$

Table D-8
ANALYSIS OF VARIANCE SUMMARY -- EFFICIENCY SCORE
(PER IMAGE SET) FOR EXPERIMENT TWO

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	
Between subjects					
Key view	2175.625	1	2175.625	2.891	
Sequence	283.550	3	94.517	.126	
Sequence X key view	454.425	3	151.475	.201	
Error 1 (Subj. w/groups X sequence)	24082.00	32	752.563		
Within subjects					
Key representation	1010.025	1	1010.025	2.828	
Key view X key representation	12.100	1	12.100	.034	
Imagery set	15934.750	3	5311.583	14.872	**
Key view X imagery set	942.625	3	314.208	.880	
Imagery quality	18147.600	1	18147.600	50.812	**
Key view X imagery quality	511.225	1	511.225	1.431	
Key representation X imagery quality	555.075	1	555.075	1.554	
Key view X key representation X imagery quality	159.950	1	159.950	.448	
Trial block	2602.100	3	867.367	2.429	
Trial block X key view	432.875	3	144.292	.404	
Residual	2464.775	6	410.796	1.150	
Error 2	34286.400	96	357.150		

**$P < .01$

Table D-9
ANALYSIS OF VARIANCE SUMMARY -- TIME (PER IMAGE SET)
FOR EXPERIMENT THREE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	
Between subjects					
Sequence	10227.937	3	3409.312	.812	
Error 1 (Subj. w/sequence)	67143.200	16	4196.450		
Within subjects					
Key representation	70.313	1	70.313	.047	
Imagery set	31066.537	3	10355.512	6.882	**
Imagery quality	27714.012	1	27714.012	18.418	**
Key representation X imagery quality	2657.000	1	2657.000	1.766	
Trial block	8128.637	3	2709.546	1.801	
Residual	2816.000	3	938.700	.624	
Error 2	72226.400	48	1504.717		

**$p < .01$

Table D-10
ANALYSIS OF VARIANCE SUMMARY -- LOG TIME (PER IMAGE SET)
FOR EXPERIMENT THREE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Sequence	1.815	3	.605	1.721
Error 1 (Subj. w/sequence)	5.624	16	.351	
Within subjects				
Key representation	.017	1	.017	.207
Imagery set	3.200	3	1.067	12.748 **
Imagery quality	2.390	1	2.390	28.570 **
Key representation X imagery quality	.304	1	.304	3.619
Trial block	.563	3	.188	2.244
Residual	.320	3	.107	1.274
Error 2	4.016	48	.084	

** $p < .01$

Table D-11
ANALYSIS OF VARIANCE SUMMARY -- NUMBER CORRECT
(PER IMAGE SET) FOR EXPERIMENT THREE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Between subjects				
Sequence	1.237	3	.412	.541
Error 1 (Subj. w/sequence)	12.200	16	.763	
Within subjects				
Key representation	.313	1	.313	.419
Imagery set	1.037	3	.346	.464
Imagery quality	12.013	1	12.013	16.106 **
Key representation X imagery quality	1.520	1	1.520	2.040
Trial block	2.537	3	.846	1.134
Residual	4.030	3	1.340	1.800
Error 2	35.800	48	.746	

** $p < .01$

Table D-12
ANALYSIS OF VARIANCE SUMMARY -- EFFICIENCY SCORE (PER IMAGE SET) FOR EXPERIMENT THREE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	
Between subjects					
Sequence	6077.637	3	2025.879	3.228	
Error 1 (Subj. w/sequence)	10042.300	16	627.644		
Within subjects					
Key representation	588.600	1	588.600	2.643	
Imagery set	7170.038	3	2390.013	10.731	**
Imagery quality	9052.512	1	9052.512	40.645	**
Key representation X imagery quality	122.500	1	122.500	.550	
Trial block	2810.538	3	936.846	4.206	*
Residual	2573.600	3	857.900	3.850	*
Error 2	10690.500	48	222.719		

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

APPENDIX E SUPPLEMENTARY PERFORMANCE DATA

Table E-1

MEAN TIME TO MAKE AN INDIVIDUAL IDENTIFICATION
IN EXPERIMENT ONE (Seconds)

Small Scale Key

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	42.94	38.80	39.92	40.55
Schematic	46.17	45.48	50.17	47.28
	44.55	42.14	45.05	43.91

Large Scale Key

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	33.89	32.08	35.06	33.68
Schematic	41.20	35.03	47.95	41.40
	37.55	33.55	41.51	37.54

Scale Data Combined

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	38.41	35.44	37.49	37.11
Schematic	43.69	40.26	49.06	44.34
	41.05	37.85	43.28	40.72

Table E-2

MEAN TIME TO MAKE AN IDENTIFICATION IN EXPERIMENT TWO
(Seconds)

Key View

Key Representation	Vertical	Oblique	
Photographic	26.86	27.61	27.23
Schematic	21.31	28.77	26.60
	25.64	28.19	26.92

Table E-3

MEAN TIME TO MAKE AN IDENTIFICATION IN EXPERIMENT THREE
(Seconds)

Key Representation

Photographic	Photographic and schematic	
28.38	28.85	28.62

Table E-4

MEAN PROPORTION (AND NUMBER) OF CORRECT IDENTIFICATIONS IN EXPERIMENT ONE

Small Scale Key

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	.62 (5.00)	.64 (5.12)	.69 (5.50)	.65 (5.21)
Schematic	.69 (5.50)	.61 (4.87)	.67 (5.37)	.66 (5.25)
	.66 (5.25)	.62 (5.00)	.68 (5.44)	.65 (5.23)

Large Scale Key

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	.69 (5.50)	.67 (5.37)	.64 (5.12)	.67 (5.33)
Schematic	.76 (6.12)	.75 (6.00)	.76 (6.12)	.76 (6.08)
	.73 (5.81)	.71 (5.69)	.70 (5.62)	.71 (5.71)

Scale Data Combined

Key Representation	Key View			
	Vertical	Oblique	Together	
Photographic	.66 (10.50)	.66 (10.50)	.66 (10.62)	.66 (10.54)
Schematic	.73 (11.62)	.68 (10.87)	.72 (11.50)	.71 (11.33)
	.69 (11.06)	.67 (10.69)	.69 (11.06)	.68 (10.94)

Table E-5

MEAN PROPORTION (AND NUMBER) OF CORRECT IDENTIFICATIONS IN EXPERIMENT TWO

Key Representation	Key View		
	Vertical	Oblique	
Photographic	.73 (5.85)	.68 (5.45)	.71 (5.65)
Schematic	.69 (5.50)	.65 (5.20)	.67 (5.35)
	.71 (11.35)	.67 (10.65)	.69 (11.00)

Table E-6

MEAN PROPORTION (AND NUMBER) OF CORRECT IDENTIFICATIONS IN EXPERIMENT THREE

Key Representation		
Photographic	Photographic and Schematic	
.75 (6.00)	.72 (5.75)	.73 (11.75)

APPENDIX F

SUMMARY OF ANALYSIS OF VIEW X QUALITY INTERACTION FOR LOG TIME (PER IMAGE SET) FOR EXPERIMENT ONE

Table F-1

MEAN LOG TIME (PER IMAGE SET) FOR EXPERIMENT ONE

Imagery Quality	Key View			
	Vertical	Oblique	Together	
Poor	5.19	4.98	5.06	5.07
Good	4.82	4.82	5.00	4.88
	5.01	4.90	5.03	4.97

Table F-2

ANALYSIS OF SIMPLE EFFECTS FOR KEY VIEW FOR LOG TIME (PER IMAGE SET) FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Key view at level of poor quality imagery	.776	2	.388	1.098
Error w/cell (poor quality)	8.481	24	.353	
Key view at level of Good quality imagery	.625	2	.312	1.151
Error w/cell (good quality)	6.513	24	.271	

Table F-3

ANALYSIS OF SIMPLE EFFECTS FOR IMAGERY QUALITY FOR LOG TIME (PER IMAGE SET) FOR EXPERIMENT ONE

Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Imagery quality at level of vertical key view	2.158	1	2.158	21.129**
Imagery quality at level of oblique key view	.364	1	.364	3.561
Imagery quality at level of key views together	.063	1	.063	.618
Error (within) (Table C-2)	7.354	72	.102	

$^{**}P < .01$

APPENDIX G

Table G-1

NUMBER OF SUBJECTS CORRECTLY IDENTIFYING EACH VEHICLE

Imagery Set		Experiment One (N=48)	Experiment Two (N=40)	Experiment Three (N=20)
1	M-48	33	25	13
	M-75	33	22	19
	M-37	39	34	14
	M-52	22	21	11
2	M-55	33	32	17
	M-151	37	30	15
	M-113	34	24	9
	M-41	47	38	20
3	M-74	41	32	18
	M-577	21	13	11
	M-60	21	23	14
	M-62	26	23	13
4	M-88	35	28	18
	M-35	25	25	11
	M-108	38	32	17
	M-114	40	35	15

APPENDIX H PERFORMANCE AS A FUNCTION OF IMAGERY QUALITY

Table H-1

MEAN TIME (PER IMAGE SET) FOR EXPERIMENT ONE
(Seconds)

	Representation		View			Scale	
	Photographic	Schematic	Vertical	Oblique	Both	Reduced	Large
Poor quality imagery	161.98	201.46	198.47	162.59	184.09	193.71	169.73
Good quality imagery	134.94	153.23	129.94	140.19	162.12	157.60	130.56
All imagery	148.46	177.34	164.20	151.39	173.11	175.66	150.15

Table H-2

MEAN NUMBER CORRECT (PER IMAGE SET) FOR EXPERIMENT ONE

	Representation		View			Scale	
	Photographic	Schematic	Vertical	Oblique	Both	Reduced	Large
Poor quality imagery	2.12	2.50	2.50	2.12	2.31	2.17	2.46
Good quality imagery	3.15	3.17	3.03	3.22	3.22	3.06	3.25
All imagery	2.63	2.83	2.77	2.67	2.77	2.61	2.85

Table H-3

MEAN EFFICIENCY SCORE (PER IMAGE SET) FOR EXPERIMENT ONE

	Representation		View			Scale	
	Photographic	Schematic	Vertical	Oblique	Both	Reduced	Large
Poor quality imagery	.019	.015	.015	.017	.018	.014	.020
Good quality imagery	.028	.025	.025	.030	.023	.024	.029
All imagery	.023	.020	.020	.024	.021	.019	.024

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Table H-4

MEAN TIME (PER IMAGE SET) FOR EXPERIMENT TWO
(Seconds)

	Representation		View	
	Photographic	Schematic	Vertical	Oblique
Poor quality imagery	128.65	119.60	122.00	126.25
Good quality imagery	89.22	93.20	83.15	99.27
All imagery	108.94	106.40	102.57	112.76

Table H-5

MEAN NUMBER CORRECT (PER IMAGE SET) FOR EXPERIMENT TWO

	Representation		View	
	Photographic	Schematic	Vertical	Oblique
Poor quality imagery	2.37	2.32	2.50	2.20
Good quality imagery	3.27	3.02	3.17	3.12
All imagery	2.82	2.67	2.84	2.66

Table H-6

MEAN EFFICIENCY SCORE (PER IMAGE SET) FOR EXPERIMENT TWO

	Representation		View	
	Photographic	Schematic	Vertical	Oblique
Poor quality imagery	.024	.023	.025	.021
Good quality imagery	.049	.040	.050	.039
All imagery	.037	.032	.038	.030

Table H-7

MEAN TIME (PER IMAGE SET) FOR EXPERIMENT THREE
(Seconds)

	Representation Photographic	Photographic/Schematic
Poor quality imagery	137.90	128.25
Good quality imagery	89.15	102.55
All imagery	113.52	115.40

Table H-8

MEAN NUMBER CORRECT (PER IMAGE SET) FOR EXPERIMENT THREE

	Representation Photographic	Photographic/Schematic
Poor quality imagery	2.75	2.35
Good quality imagery	3.25	3.40
All imagery	3.00	2.87

Table H-9

MEAN EFFICIENCY SCORE (PER IMAGE SET) FOR EXPERIMENT THREE

	Representation Photographic	Photographic/Schematic
Poor quality imagery	.024	.021
Good quality imagery	.047	.039
All imagery	.035	.030