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SENSOR-AIDED TARGET ACQUISITION SIMULATION STUDIES

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JANUARY 1980

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AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
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NOTICES

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AMRL-TR-79-118

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Air Force Aerospace Medical Research Laboratory

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A Target Acquisition Library was established to organize and facilitate accession of a large number of presented papers, journal articles, and technical reports dealing with all aspects of visual and mediated target acquisition. This report is the first in a planned series of special interest reviews of this literature. It is a survey of material describing sensor-aided target acquisition simulation (i.e., laboratory) studies (excluding radar, which will be treated separately). The introduction discusses the

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unique problems and applications of mediated target acquisition and its role in our military defense system. A brief description of the library itself and of the criteria for selecting the included studies is also provided as background.

SUMMARY

Recent and continuing technology advancements have resulted in a multiplicity of target acquisition systems and system concepts. The human factors practitioner is repeatedly confronted with problems related to the capabilities and limitations of the observer as an integral component of the target acquisition process. In order to assist the human factors specialist, the Visual Display Systems Branch, Human Engineering Division, of the Air Force Aerospace Medical Research Laboratory has established a Target Acquisition Library to provide a central bibliographic source. Further, the library holdings are exercised to produce special area literature surveys. This document is one such survey, dealing with sensor-aided target acquisition studies employing sensor simulations.

PREFACE

This report, which is a survey of a specialized group of studies, was compiled by the Visual Display Systems Branch, Human Engineering Division of the Air Force Aerospace Medical Research Laboratory, in support of Project 7184, Task Work Unit 1127. The Work Unit Manager for the Air Force was Mr. William Kama. The effort was supported, in part, by Systems Research Laboratories, Inc., Dayton, Ohio, under Air Force contract F33615-79-C-0503. Dr. John Courtright was the contract monitor.

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INTRODUCTION

TARGET ACQUISITION RESEARCH APPROACHES

The problem of performing air-to-surface target acquisition in the face of a highly developed air defense threat is of critical importance. The rapid expansion in sensor-related technology has, unfortunately, led to a proliferation of few-of-a-kind sensors, each with relatively unique characteristics. The target acquisition researcher, whether a systems analyst concerned with the satisfaction of stringent mission requirements or the human factors practitioner attempting to optimize the transfer of displayed information, rarely has the opportunity to work with the actual system of interest. First, he is often treating a planned or designed system rather than one that exists. Second, flight tests are extremely expensive and offer very limited degrees of freedom over which (experimental) control may be exercised. Two other approaches to evaluating target acquisition system capabilities and limitations exist: literature review and simulation. The several approaches to system simulation, together with strengths and weaknesses, have been treated elsewhere (e.g., Kuperman and Kama, 1978). The researcher must address the extant literature, either as a rational departure point on which he will base more specific studies or as a last and sole resort to gaining insight into his problem.

TACTICAL CONSIDERATIONS

United States tactical doctrine for conventional warfare is based on the combined and coordinated utilization of air and ground forces. In the attack, the Air Force mission emphasizes the destruction/suppression of enemy tanks, antitank guided missiles, artillery, and air defenses. Defensively, the air arm is charged with close air support and the destruction of uncommitted enemy forces. Field Manual 100-5, Operations, describes the priorities of the suppression function as "to first destroy enemy air defense command and control centers, then systematically reduce the surface-to-air-missiles (SAM) and antiaircraft artillery (AAA) sites in the vicinity of targets to be struck by the fleets of follow-on aircraft or in the corridors to be opened.

The significance of ground-to-air threats is not unduly emphasized. Since WW II, the capability of the air defense weapons within a forward division has increased in range by a factor of almost four and in altitude by a factor of about two. Technically, these weapons are typified by automatic guidance systems, advanced radar and optical sights, and high maneuverability. Further, the number of such weapons organic to a division has approximately doubled during the last 30 years.

Crawford (1977) suggests that "exposure to surface-to-air defenses could be significantly decreased by aircraft maintaining very low altitude and high speed under the weather and under defense radar coverage throughout the entire flight." She also notes that terrain masking, which can enhance aircraft survivability, also results in target masking and reduced time to acquire and initiate attack on the target.

SENSOR SYSTEMS

Target acquisition, at night, under adverse weather, or when battlefield smoke is present, must rely on infrared or visible wavelength sensors to provide the pilot with a mediated view of the target scene. New sensors are being combined with new operational concepts. For example, both the Quick Strike Reconnaissance (QSR) and Real Time/Near-Real Time Reconnaissance RPV systems exploit video bandwidth data links to provide imagery for a ground-based interpretation team to exploit in the rapid detection and identification of targets, determination of target coordinates, and reporting through a direct link to a command and control center. Petroski (1977) describes the QSR concept and also provides some of the evolutionary background of FLIR systems from the 1965 RED SEA I Project flights through the more recent Pave Tack pod development. The development of advanced sensors and target acquisition systems is continuing through programs such as the Air Force FLIR Technology Demonstration effort, while concept demonstrations are being performed through annual exercises such as BLUE FLAG and REFORGER.

Despite the activity in developing sensors and sensor system concepts, and perhaps to some extent spurred on by that activity, a large number of research issues have been raised in support of sensor-aided target acquisition systems. Among those being addressed currently within this Laboratory are:

- Assessing the jam resistance of several types of image compression hardware in terms of performance decrements for a television-guided munition.
- Determining the impact of a high-resolution, narrow field-of-view FLIR sensor on operator/display optimization.
- Developing, validating, and applying figures of merit for quantifying the performance capabilities within and across the several display technologies.

The target acquisition research area is drawing heavily on the human engineering discipline for support. Because understanding and applying the available literature are the human factors engineer's most powerful tools, a better appreciation of both that body of information and how to access it appears to be a beneficial goal for system developers, engineers, and managers to pursue.

OVERVIEW OF THE TARGET ACQUISITION LITERATURE

Traditionally, the human factors engineer, as most professionals, gradually acquired the bibliographic materials that form his research data base. Newcomers to the field and those working with the human engineer's support were (and still are) confronted with the problem of identifying, obtaining, and evaluating the relevance of reported research data. Since the area of target acquisition has been primarily of interest to the military, this task was further complicated by the fact that most publications in the area have been in the form of technical reports rather than open literature articles or papers. The Defense Technical Information Center (DTIC) provides the basic means of accession, although it is not available to all researchers. However, performing a DTIC search has often resulted in a prolonged "learning curve" period, during which keywords and search logic are iteratively refined.

One significant approach to reducing this "learning curve" has been through the preparation of annotated bibliographies and literature reviews. These materials provide the user with a consolidated set of abstracts covering the broader literature. Several excellent bibliographies exist in the area of target acquisition. Among them are: Levine and Youngling, 1977; Jones et al., 1974; Bliss, 1974; and Erickson, 1964. However, a limitation to the use of these sources is their attempt to cover the entire literature; their resultant broadness of scope may sometimes prove to be a burden to the researcher seeking answers to a specific problem. More specifically directed literature summaries, such as this document, will ease that burden by addressing a more limited research area within the existing data base.

A brief overview of the organization of the target acquisition literature may serve to point out the difficulties encountered in trying to apply it. Much of the research deals with visual (i.e., unaided) performance and includes a range of material spanning basic psychophysical research through high face validity programs such as SEEKVAL and JTF-2. Another major portion is devoted to radar systems rather than electro-optical sensors. Much of the early (and current) research was based on the extraction of information from photography, and the acquisition systems included cameras, downwardlooking infrared scanners and laser line scanners; this work falls most properly under imagery (or photographic) intrepretation rather than target acquisition research. A growing segment of the literature is devoted to imagery enhancement, recently emphasized in application to FLIR imagery; little of this research includes operator performance studies. The same situation obtains for work in image compression. Lastly, because of the transfer of technology from visual psychophysics to applied research, the "targets" of interest are often geometric shapes rather than military equipment and facilities.

SENSOR-AIDED TARGET ACQUISITION STUDIES

The traditional human factors approach to analyzing a sensor-display system has been based on two parameters: lines (resolution) across the target and the visual angle subtended by that target on the display. One of the most frequently cited sources (Johnson, 1958) developed a relationship "between the number of lines resolved at the target and the corresponding decisions of detection, recognition, and identification." These results were found by Johnson "to be independent of contrast and scene signal-to-noise ratio" for a resolution pattern (i.e., in a Military Standard 150A sense) at the same contrast as the military target of interest. For example, an average resolution of eight lines (four cycles) was found to be required for correct recognition (of the nine target types considered). At the display, the minimum visual angle required to be subtended by the target for correct recognition, and considering the exigencies of an operational task, "should probably be approximately 20 minutes," as reported by Steedman and Baker (1960) in their major study of speed and accuracy of form recognition. Application of these two behaviorally related parameters has allowed the researcher to perform trade-off analyses which include the following system parameters:

- Target size
- Slant range
- Sensor resolution
- Sensor field-of-view
- Display size
- Display resolution
- Viewing distance

Generally, these analyses were based on a sensor-display integration which would support the display of at least four TV lines across the nominal target at a subtended angle of at least 20 minutes. It is noteworthy that Johnson's work was basically a computational investigation while Steedman and Baker, with the exception of a small supplementary sample, used a laboratory paradigm in which the briefing target available to the subject exactly duplicated the probe target in shape, size, orientation and contrast. The research community has had almost two decades of experience in applying this trade-off approach (lines across target critical dimension versus subtended angle at the display). In fact, it forms the baseline for more recently developed, predictive models (see, for example, Mendez and Freitag, 1973, for a review paper) of target acquisition performance. The increased emphasis on aircraft survivability has, however, spurred the development of high-resolution (typically 875-line), narrow-field-of-view (much less than 25 degrees) sensors to be flown at high speed and low altitude. The sensor/display/operator interface problem is being revisited because of the new technology and tactics. As Crawford (1977) points out, there is a dearth of experience in performing target acquisition at low altitude. Because of these factors, increased emphasis is being placed on simulation studies as an effective means to understanding advanced sensor capabilities.

AMRL TARGET ACQUISITION LIBRARY

In view of the currency and importance of air-to-ground target acquisition research, and in order to support in-house study and analysis efforts, AFAMRL recently established a Target Acquisition Library within the Visual Display Systems Branch of the Human Engineering Division. As an active engineering services project, the Library is being developed by the addition of relevant technical documents, by the development and distribution of user-oriented accession tools, and by the preparation and publication of special interest applications studies/reviews. This report, covering Library holdings on the evaluation of sensor-aided operator performance through system simulation, rep:esents the first of these publications.

At present, the Library contains just over 300 technical reports, journal articles, and proceedings. It is arranged hierarchically according to the following table.

TABLE 1. ORGANIZATION OF LIBRARY

I. Sensor-aided
   A. Studies
      1. Laboratory
      2. Field
   B. Mathematical models
   C. Sensors
      1. FLIR
      2. Electro-optical
      3. Other
   D. Displays
      1. CRT (panel-mounted)
      2. Helmet-mounted
      3. Other

II. Unaided Visual
   A. Studies
      1. Laboratory
      2. Field
         a. SEEKVAL
         b. Other
   B. Mathematical models
   C. Basic visual research

III. Photographic integration
   A. Interpreter performance
   B. Film-recording systems
      1. Cameras
      2. Line scan infrared
      3. Laser line scan
   C. Enabling features
      1. Color
      2. Stereo

IV. Camouflage/Deception/Disruption

V. Image Processing
   A. Compression
   B. Cueing
   C. Enhancement

VI. Radar

VII. Bibliographies and Literature

LITERATURE SURVEY

SURVEY CRITERIA

The material reviewed for this survey has been sifted from more than 300 references in the AFAMRL Target Acquisition Library. The individual studies were chosen for inclusion according to several criteria. For the purposes of this review, only laboratory studies/experiments dealing with sensor-aided or mediated air-to-ground target acquisition were applicable. Of these, the studies which simulated the task through the use of 1) imaging a terrain model, 2) video generation by a flying spot scanner from photography, or 3) infrared or other electro-optical sensor recordings made of local terrain were considered appropriate. These restrictions made it possible to insure, to some extent, the face validity of each study included in this report. As mentioned in the Introduction, the cost of flight testing is prohibitive. Consequently, most investigators rely upon simulation, and these films, video output, and photographs contain several kinds of terrain and targets. Frequently, actual reconnaissance materials from previous war zones are available for use. However, the most common stimulus materials are those taken in or near the investigators' own facilities. Displays originating in this manner often contain a mix of target types, military and civilian, including geographical landmarks and rural countryside.

Another area of interest when considering a study was the role of contrast and its documentation. The author's definition of contrast, as applied in his experimentation, was noted, as was the range of contrast (when available). The definition of contrast varies among authors.

Nine of the studies were based on FLIR simulation, while the remainder dealt with television sensors. Only five exploited directly recorded imagery of the "real-world," while over 40 percent exploited terrain boards. One-fifth of the studies employed still, rather than dynamic, imagery. With these caveats in mind, it is hoped that this report will be of use to the research community.

DOCUMENT EXTRACTS

The last section of this review contains extracts from the thirty-five studies identified in performing the literature search. Each extract provides specific descriptive information about the reported study that we feel may complement the more commonly reported author's abstract. First, a bibliographic reference is provided; then the "System" used by the investigator to collect and display the stimuli and to present it to the subject in a controlled manner is briefly described. Next follows a concise description of the Experimental Design, including targets used, definition, and range of contrast, and also a listing and/or graphic presentation of the study variables (when available).

ABSTRACTS

The appendix is comprised of a collection of the author's abstracts or (if they are not available) a section from his summary or introduction to give the reader a concise overview of the intent and direction of the document. Where available, DTIC Accession Numbers have been provided.

STUDY 1

Reference:

Wagner, D. W., April 1975, Target Detection with Color Versus Black and White Television, NWC TP 5731, Naval Weapons Center, Aircraft Systems Dept., Weapons Systems Analysis Division, China Lake, CA.

System:

A closed circuit color television system and a terrain model were used to investigate the effects of color television, as compared to black-and-white television, on target detection performance. The subjects responded to a display on a television monitor.

Experimental Design:

1. Targets - Nine military tanks, 1000:1 scale, each tank painted a shade of green, brown, or gray.

2. Contrast - Three luminance contrast levels for each of the three colors: 0, -0.3, +0.3.
   Target/Background contrast was determined using formula

$$\frac{L_t - L_b}{L_b}$$

   L_t = target luminance in foot-lamberts

   L_b = background luminance in foot-lamberts

3. Range of contrast - -0.3, 0.0, +0.3

4. Design (See Figure 1)

   a. Independent Variables

      (1) Two colors of background

      (2) Three levels of resolution

      (3) Three target colors

b. Dependent Variables

(1) Percent correct target detection

(2) Target detection time

GREEN BACKGROUND										
PRESENTATION MODE	RESOLUTION, TV LINES	GREEN TARGETS			BROWN TARGETS			GRAY TARGETS		
		CONTRAST								
		+0.3	0.0	-0.3	+0.3	0.0	-0.3	+0.3	0.0	-0.3
COLOR	25									
	35									
	300									
BLACK AND WHITE	25									
	35									
	300									
BROWN BACKGROUND										
COLOR	25									
	35									
	300									
BLACK AND WHITE	25									
	35									
	300									

*Figure 1
2 × 2 × 3 × 3 × 3 treatments by subjects
factorial design for 10 subjects

*Authors' Text, p. 12.

STUDY 2

Reference:

Stinnett, T. A., K. C. Leonard, Jr., and D. B. Faubert, August 1969, Multisensor Weapon Delivery System, AFAL-TR-69-257, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

System:

A standard TV camera was modified to be electronically and optically compatible with an AGA Thermovision infrared camera. A three-color television monitor, which allowed the display of imagery in black and white or any combination of red, blue, and green, was modified to accept the experimental sensor data. Video recording locations were sites adjacent to Westinghouse Aerospace Division and Westinghouse Surface Division.

Experimental Design

1. Targets - three vehicles: light gray pickup truck, dark blue sedan, and white Volkswagen.

2. Definition of contrast

$$\text{Brightness contrast} = \frac{B_t - B_b}{B_b}$$

where

B_t = target brightness

B_b = background brightness

3. Range of contrast (Not available)

4. Design

   a. Independent Variables

      (1) Five display modes

      (2) Three time-of-day conditions

      (3) Target types

      (4) Background scenes

b. Dependent variables

(1) Detection time

(2) Number of detection responses

(3) Recognition time

(4) Number of recognition responses

(5) Number of incorrect and incorrect responses

STUDY 3

Reference:

Snyder, H. L., R. L. Keesee, W. S. Beamon, and J. R. Aschenbach, October 1974, Visual Search and Image Quality, AMRL-TR-73-114, Aerospace Medical Research Laboratory. Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio.

System:

Dynamic Target Recognition Experiments - 35mm movie film of targets on a terrain board was underscanned by the 3:4 aspect ratio television camera; the resulting field of view presented on the TV monitor was approximately 40 degrees vertical by 30 degrees horizontal, with a boresight depression angle of 45 degrees. Subjects were asked to identify prebriefed targets and indicate their location on the monitor which was marked off into quadrants.

Experimental Design:

1. Targets--Combination of military vehicles, planes, equipment, etc., filmed from terrain model

2. Definition of contrast

   L_o--Luminance of object

   L_b--Luminance of background

   $$\text{Target/Background Brightness Contrast} = \frac{L_b - L_o}{L_b}$$

   when

   $L_b > L_o$

   or

   $$\frac{L_o - L_b}{L_o}$$

   when

   $L_o > L_b$

3. Range of contrast -
0.122 - 0.662

4. Design

a. Independent variables

Five noise levels (signal-to-noise ratios)
video and decibels

b. Dependent variables

(1) Correct or incorrect response

(2) Slant range at time of response

STUDY 4

Reference:

Snyder, H. L., December 1976, Visual Search and Image Quality: Final Report, AMRL-TR-76-89, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

System:

A variable parameter video system was utilized to produce mixed signal and noise input from a wide bandwidth mixer. Terrain board imagery, processed in this manner, was displayed on a 17-inch TV monitor. The video signal is calibrated and altered in accordance with the experimental requirements of video bandwidth, line rate, aperture response, white peak clipping and gamma. Subjects sat in front of a monitor and responded when an appropriate target was identified.

Experimental Design:

1. Targets - Military vehicles and sites, 3000:1 scale, filmed from terrain model on 35mm movie film

2. Definition of contrast

   L_o--Luminence of object

   L_b--Background luminence

   Target/Background Brightness Contrast:

   $$\frac{L_b - L_o}{L_b}$$

   when

   $L_b > L_o$

   or

   $$\frac{L_o - L_b}{L_o},$$

   when

   $L_o > L_b$

3. Range of contrast
   0.122 - 0.662

4. Design (See Figure 2)

   a. Independent variables

      (1) Five video systems

      (2) Five noise levels

      (3) Three filmed missions

      (4) Targets

   b. Dependent variables

      (1) Percent correct target acquisition

      (2) Ground range to target at time of correct response

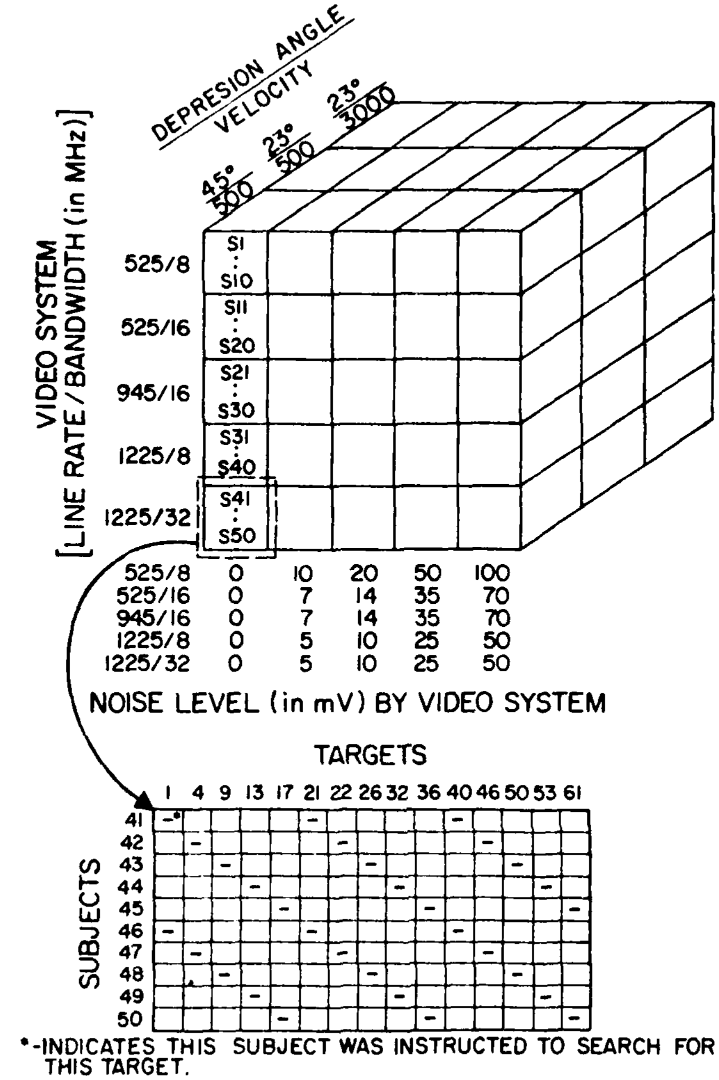


*Figure 2

*Authors' Text, p. 14.

STUDY 5

Reference:

Rusis, G., and H. L. Snyder, March 1965, Laboratory Studies in Air-to-Ground Target Recognition: II. The Effect of TV Camera Field of View, T5-133/3111, Autonetics, Human Factors Dept., Research Engineering and Reliability Division, Anaheim, CA.

System:

A closed circuit TV was used to view rear-projected 16mm motion pictures and diplay the video in a simulated cockpit. The subjects viewed the display on an 8-in. TV monitor inside the cockpit.

Experimental Design:

1. Targets -- 15 geographical sites in local terrain

2. Definition of contrast (None available)

3. Range of contrast (None available)

4. Design

   a. Independent variables

      (1) FOV (as determined by focal length of lens) 25° vertical × 34° horizontal, 7.5° vertical × 10° horizontal, 6.2° vertical × 8.2° horizontal

      (2) Size of targets

   b. Dependent variables

      (1) Incorrect target recognitions

      (2) No-response targets

STUDY 6

Reference:

Bergert, J. W., and F. D. Fowler, May 1970, Target Acquisition Studies, Visual Angle Requirements for TV Displayed Targets, OR 10,689, Martin Marietta Corp., Orlando, FL.

System:

A TV camera and zoom lens were housed in a gimbaled flight head, which was flown over a three-dimensional terrain model simulating natural and man-made features of military significance. The subject's task was to indicate detection of a target as he viewed a moving scene on a TV monitor.

Experimental Design:

1. Targets -- Terrain board, scale 600:1; simulating natural and man-made features of military significance, i.e., hydroelectric plant, village, airport, harbor area, etc.

2. Definition of contrast

$$C = \frac{B_b - B_o}{B_b}$$

where

B_o=brightness of the object

B_b=brightness of background

3. Range of contrast
10, 25, 35, -50% target/background contrast

4. Design

   a. Independent variables

      (1) 7.3° - 14.5° - Television field of view

      (2) 10, 25, 35, -50% target/background contrast

      (3) Open-cluttered fields - target/background area

      (4) Static and 350 knots flight speed

b. Dependent variables

(1) Slant range at detection and recognition

(2) Visual angle subtended at detection and recognition

(3) Decision time

STUDY 7

Reference:

Levine, S. H., and E. W. Youngling, February 1973, Real-time Target Acquisition with Moving and Stabilized Image Displays, Report MDC E0769. McDonnell-Douglas Corp., McDonnell Aircraft Reconnaissance Laboratory, St. Louis, MO.

System:

A stimulus film was converted to video with a flying spot scanner. Output was viewed by subject on a 9-in. TV monitor mounted in a simulated cockpit.

Experimental Design:

1. Targets

   a. "Difficult" - (Display size: 1/5 inch): revetments, trench fortifications, small trucks.

   b. "Easy" - (Display size: 3/4 inch): forts, fortified positions, large trucks

2. Definition of contrast (None available)

3. Range of contrast (None available)

4. Design:

   a. Independent variables

      (1) Aircraft speed (360, 560, 900, 1200 kt)

      (2) Target location in FOV

      (3) Type of target key

      (4) Closing rate (360, 560, 900 kts)

   b. Dependent variables

      (1) Percent correct identification of targets

      (2) Response time

STUDY 8

Reference:

Bruns, R. A. et al., November 1970, Dynamic Target Identification on Television as a Function of Display Size, Viewing, Distance, and Target Motion Rate, TP-70-60, Naval Missile Center, Systems Integration Branch, Point Mugu, CA.

System:

To simulate air-to-surface target identification, oblique high-resolution reconnaissance photos were converted to film by zooming a television camera, at a preselected speed, toward the target area. Subjects viewed the moving display on TV monitors.

Experimental Design:

1. Targets - 32 different sites, including trucks, bridges, oil storage tanks, radar, river barges, small buildings, revetted antiaircraft gun implacements, and surface-to-air missile sites.

2. Definition of contrast (None available)

3. Range of contrast (None available)

4. Design (See Figure 3)

   a. Independent variables

      (1) Display size

      (2) Display height subtended angle

      (3) Display degradation

      (4) Target motion rate

   b. Dependent variables

      (1) Target identification accuracy

      (2) Angle subtended by target at observer's eye at time of correct target identification

Experimental Design for Combining Displays, Viewing Distances, and Subjects

Subject	Monitor/Display Viewing Distance Sequence				Session
	Run No. 1-16	Run No. 17-32	Run No. 33-48	Run No. 49-64	
1	1A	2B	3C	4D	1
2	2B	4D	1A	3C	
3	3C	1A	4D	2B	
4	4D	3C	2B	1A	
5	2C	1B	3D	4A	2
6	1B	4A	2C	3D	
7	3D	2C	4A	1B	
8	4A	3D	1B	2C	
9	1C	2D	4B	3A	3
10	2D	3A	1C	4B	
11	4B	1C	3A	2D	
12	3A	4B	2D	1C	
13	3B	2A	1D	4C	4
14	2A	4C	3B	1D	
15	1D	3B	4C	2A	
16	4C	1D	2A	3B	

*Figure 3

*Author's text, p. 16.

STUDY 9

Reference:

Ozkaptan, H., J. G. Ohmart, J. W. Bergert, and R. A. McGee, October 1968, Target Acquisition Studies: Fixed Television Fields of View, OR 9656, Martin Marietta Corp., Orlando, FL.

System:

A TV system was used to view targets on a 600:1 scale terrain model. Dynamic movement was provided by rotating a TV camera which was mounted in a 3-degrees-of-freedom flight table. Subjects viewed the terrain model, in simulated flight, on an 8-in. TV monitor.

Experimental Design

1. Targets - three shapes resembling small hangars and quonset huts

2. Definition of contrast

$$C = \frac{B_o - B_b}{B_b}$$

where

B_o = brightness of object

B_b = brightness of background

3. Range of contrast (negative) 5, 10, 15, 20, 25, 35%

4. Design (See Figure 4)

   a. Independent variables

      (1) Target to background contrast

      (2) Background scene

      (3) TV camera field of view

      (4) Target shapes

      (5) Target offset from center of target area

      (6) Mission

b. Dependent variables

(1) Slant range

(2) Time to detection

(3) Visual angle at detection

Experimental Design

Field-of-view	4°																	
Contrast	5%			10%			15%			20%			25%			30%		
Offset	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shape	L	R	H	R	H	L	H	L	R	L	R	H	R	H	L	H	L	R
Treatment	34	53	27	59	36	31	21	8	25	6	62	55	69	65	40	44	51	16
Target area	1	9	17	13	21	6	22	14	5	18	10	3	23	15	2	11	19	7

Field-of-view	7°																	
Contrast	5%			10%			15%			20%			25%			30%		
Offset	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shape	L	R	H	R	H	L	H	L	R	L	R	H	R	H	L	H	L	R
Treatment	63	28	50	66	1	2	54	47	67	61	26	48	57	10	38	35	22	60
Target area	24	8	12	20	1	9	17	16	4	5	13	22	21	6	10	14	2	18

Field-of-view	10°																	
Contrast	5%			10%			15%			20%			25%			30%		
Offset	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shape	L	R	H	R	H	L	H	L	R	L	R	H	R	H	L	H	L	R
Treatment	9	37	17	46	15	20	5	18	58	71	24	52	43	3	14	32	7	12
Target area	19	3	15	7	24	11	12	20	1	16	23	8	4	17	13	9	5	21

Field-of-view	14°																	
Contrast	5%			10%			15%			20%			25%			30%		
Offset	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shape	L	R	H	R	H	L	H	L	R	L	R	H	R	H	L	H	L	R
Treatment	49	72	56	13	39	23	11	70	45	64	29	30	4	68	33	41	19	42
Target area	6	22	14	3	18	16	10	7	23	2	12	19	8	11	20	15	4	24

*Figure 4

*Author's Text, p. 42.

STUDY 10

Reference:

Fowler, F. D., and D. B. Jones, January 1972, Target Acquisition Studies: 1) Transition from Direct to Mediated Viewing, 2) Target Acquisition Performance: Color vs. Monochrome TV Displays, OR 11,768, Martin Marietta Corp., Orlando, FL.

STUDY 1

System:

A 600:1 scale, three-dimensional terrain model was used to simulate flight toward target area with subjects seated on an observer platform overlooking the model. After visually acquiring the target, subject would shift his gaze to a cockpit-mounted TV monitor and attempt acquisition on the display.

Experimental Design:

1. Targets - two-dimensional building silhouettes

2. Definition of contrast (Not available)

3. Range of contrast
   6-57%

4. Design (See Figure 5)

   a. Independent variables

      (1) Field of view

      (2) Target areas (8)

   b. Dependent variables

      (1) Slant range to target (each response)

      (2) Elapsed time from direct detection to mediated detection.

Target/Area Characteristics for Study I

Area	Brightness Contrast (Percent)		Target/Area Color	Target
	DV	TV		
17/2	57	52	Dark Green/Tan	RS
14	41	31	Tan	H
18	54	32	Light Green	RS
20	52	27	Light Green	LS
34	34	20	Green	H
13	50	25	Brown	LS
14/17	10	6	Tan/Green	H
4	37	22	Light Brown	LS

*Figure 5

*Author's Text, p.7.

STUDY II

System:

Color and monochrome TV video recordings of simulated flights were made using the terrain model. Several target/surround color combinations and contrast levels were selected. Subjects were seated in front of a color TV monitor to view the display.

Experimental Design:

1. Targets -- 14 target areas were selected to present a wide range of colors and target/background combinations

2. Definition of contrast (Not defined)

3. Range of contrast
   22-84% (See 4, Design)

4. Design (See Figure 6)

a. Independent variables

1. Mode: Color and monochrome
2. Response: Detection and recognition
3. Target area

b. Dependent variables

1. Slant range to target at response
2. Elapsed time from detection to recognition

Study II: Color versus Monochrome Test. Target/Background Characteristics

Target Area	Basic Color	Brightness Contrast - Displayed (percent)		
		Color	B&W	Average
11	Lt. Grn	65	65	65
2	Tan	42	40	41
18	Lt. Grn	49	42	46
20	Lt. Brn	53	55	54
4	Grn	40	39	40
14	Grey	36	38	37
15	Grn	42	33	37
13	Lt. Grn	43	43	43
17	Dk Grn	45	46	46
34	Grn	37	39	38
20/11	Lt. Brn/Lt. Grn	69	68	68
17/2	Dk Grn/Tan	86	83	84
18/14	Lt. Grn/Grey	28	33	30
14/17	Grey/Dk Grn	23	20	22

*Figure 6

*Author's Text, p. 10.

STUDY 11

Reference:

Freitag, M., and D. MacLeod, March 1974, The Effect of Scene Rotation on Target Acquisition and Tracking, AMRL-TR-74-19, (AD A008202), Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

STUDY I
DETECTION

System:

Video taped sequences of simulated approaches to surface targets were made using a 600:1 scale terrain model and a gimbal-mounted TV camera. Subjects viewed the tapes on a TV monitor under controlled conditions and indicated when a target was detected.

Experimental Design:

1. Targets - three types of vehicles: a tank, a truck, and a semi trailer-tractor

2. Definition of contrast

$$\%C = \frac{B_t - B_b}{B_t}$$

where

B_t = target luminance and

B_b = background luminance

3. Range of contrast 6-17%

4. Design (See Figure 7)

   a. Independent variable
      Gimbal order

   b. Dependent variable
      Detection time

EXPERIMENTAL TAPE CONDITIONS
FOR DETECTION AND RECOGNITION TESTS

Scene Number	Scene Identification	Gimbal	Area	Target
Tape Number 1				
1	26A	R-P	Fo	Ta
2	26C	R-P	Fo	S
3	18A	R-P	Fa	Ta
4	4C	Y-P	Fa	S
5	131B	R-P	HC	Tr
6	4A	Y-P	Fa	Ta
7	107C	Y-P	HC	S
8	131C	R-P	HC	S
9	6A	Y-P	Fo	Ta
10	6B	Y-P	Fo	Tr
11	18B	R-P	Fa	Tr
12	18C	R-P	Fa	S
13	6C	Y-P	Fo	S
14	107A	Y-P	HC	Ta
15	107B	Y-P	HC	Tr
16	4B	Y-P	Fa	Tr
17	131A	R-P	HC	Ta
18	26B	R-P	Fo	Tr
Tape Number 2				
1	4C	Y-P	Fa	S
2	6C	Y-P	Fo	S
3	107A	Y-P	HC	Ta
4	6A	Y-P	Fo	Ta
5	26C	R-P	Fo	S
6	4B	Y-P	Fa	Tr
7	107B	Y-P	HC	Tr
8	131B	R-P	HC	Tr
9	131A	R-P	HC	Ta
10	18B	R-P	Fa	Tr
11	18C	R-P	Fa	S
12	6B	Y-P	Fo	Tr
13	131C	R-P	HC	S
14	107C	Y-P	HC	S
15	4A	Y-P	Fa	Ta
16	18A	R-P	Fa	Ta
17	26A	R-P	Fo	Ta
18	26B	R-P	Fo	Tr

All experimental scenes were at 5,000 foot simulated offset, 2,000 foot simulated altitude.

*Figure 7

*Author's Text, p. 14.

STUDY II
RECOGNITION

System:

Same as described for Study I, Detection

Experimental Design:

1. Targets

2. Definition of contrast

3. Range of contrast

(ALL CONDITIONS SAME AS STUDY I)

4. Design

   a. Independent variable
      Scene rotation

   b. Dependent variable
      Recognition time

SEE FIGURE 7, STUDY I FOR EXPERIMENTAL TAPE CONDITIONS

STUDY III
TRACKING

System:

The same terrain model and TV system as used in Studies I and II were utilized in the tracking study, with the addition of a "controller" stick, used by the subject to maintain the target position in center screen. This simulated a compensatory tracking task.

Experimental Design:

1. Targets

2. Definition of contrast

3. Range of contrast

(ALL CONDITIONS AS SAME AS STUDY I)

4. Design

a. Independent variables

(1) Yaw/pitch control

(2) Roll/pitch control

b. Dependent variable

Mean tracking error (∿ degree/seconds)

STUDY 12

Reference:

Fowler, F. D., M. Freitag, D. B. Jones, and B. King, January 1971, Target Acquisition Studies: 1) Two Dimensional compared with Three Dimensional Targets, 2) Changes in Gamma for TV Displayed Targets. (AD 718382), OR 11,091, Martin Marietta Corp., Orlando, FL.

STUDY I
2-D vs 3-D

System:

A terrain board and gimbal-mounted TV camera were used to simulate flight over target area. The subject was seated in front of a TV monitor, observing the moving image of the terrain board.

Experimental Design:

1. Targets - three vehicles (gun, tank, and truck) and one building

2. Definition of contrast (Not available)

3. Range of contrast
   7-43%

4. Design (See Figure 8)

   a. Independent variables

      (1) Contrast

      (2) Targets

      (3) Target areas

   b. Dependent variables

      (1) Detection time

      (2) Recognition time

Area/Target/Contrast Combinations for the
TV Mediated Three-Dimensional Test

Area	7	11	18	33	19	15
Target	Truck	Tank	R. Shed	R. Shed	R. Shed	Gun
Contrast	20%	15%	7%	43%	33%	41%

Only one target orientation was used since this variable was not a significant factor in the Direct Visual experiment. Therefore only the Right Shed Plain target was used along with the vehicle targets.

*Figure 8

*Author's Text, p. 12

STUDY II
CHANGE IN GAMMA

System:

The same terrain board and TV set-up were used, except that a zoom lens was used to simulate closure. Subject observed moving target area on TV monitor and responded at moment of detection and/or recognition.

Experimental Design:

1. Targets - two-dimensional building type targets

2. Definition of contrast

$$C = \frac{B_b - B_t}{B_b}$$

where

B_b = background brightness

B_t = target brightness

3. Range of Contrast
   4-64% (See Figure 9)

4. Design

   a. Independent variables

      (1) Three gamma levels

      (2) Contrast levels

   b. Dependent variables

      (1) Detection time

      (2) Recognition time

Displayed Contrast for all Gamma Conditions
2D Target Enhancement Study Test Conditions

Target Area	Target Type	TV System Gamma	B_B (avg.) ft. Lamberts	B_T (avg.) ft. Lamberts	B_B-B_T	Contrast (avg.) Percent
5	L. Shed	0.55	36.0	34.0	2.0	5.6
	L. Shed	1.0	28.7	25.95	2.75	9.6
	L. Shed	2.2	13.05	10.75	2.3	17.6
11	House	0.55	38.05	32.05	6.0	15.7
	House	1.0	33.3	24.1	9.2	27.6
	House	2.2	17.3	8.53	8.77	50.6
17	L. Shed	0.55	28.4	27.0	1.4	4.9
	L. Shed	1.0	18.6	16.9	1.7	9.1
	L. Shed	2.2	5.88	4.75	1.13	19.2
33	House	0.55	36.1	33.1	3.0	8.3
	House	1.0	29.3	25.6	3.7	12.6
	House	2.2	15.7	10.05	5.65	36.0
19	R. Shed	0.55	38.05	35.9	2.15	5.6
	R. Shed	1.0	32.35	29.25	3.1	9.6
	R. Shed	2.2	16.05	12.15	3.9	24.3
6	L. Shed	0.55	28.75	21.8	6.95	24.2
	L. Shed	1.0	19.0	11.75	7.25	38.2
	L. Shed	2.2	4.95	1.78	3.17	64.0

*Figure 9

*Author's Text, p. 19.

STUDY 13

Reference:

Bruns, R. A., A. C. Bittner, Jr., and R. C. Stevenson, August 1972, Effects of Target Size, Target Contrast, Viewing Distance, and Scan Line Orientation on Dynamic Televisual Target Detection and Identification, TP-72-24, Naval Missile Center, Systems Integration Division, Point Mugu, CA.

System:

A 2000:1 scale, three-dimensional terrain model and a television camera were used to video tape record the attack sequences. Subject observed the simulated attack run on an 8-in. TV monitor and responded at detection and identification by pressing a button.

Experimental Design:

1. Targets - five different shapes resembling buildings

2. Definition of contrast

$$\text{Percent contrast} = \frac{\text{Brightness target-brightness background}}{\text{brightness background}} \times 100$$

3. Range of contrast
   3-76%

4. Design

   a. Independent variables

      (1) Viewing distance

      (2) TV raster scan line orientation

      (3) Target background contrast

      (4) Target size

   b. Dependent variables

      (1) Target detection time

      (2) Target identification time

STUDY 14

Reference:

Krebs, M. J., and C. P. Graf, September 1973 Real-Time Display Parameters Study, RADC-TR-73-300, (AD773850), Rome Air Development Center, Griffiss Air Force Base, NY.

System:

An infrared sensor mounted on a 50-foot tower was used to generate target thermal images which were then photographed. Background scenes were also photographed and retouched to simulate FLIR imagery. After digital processing of target photos to more closely resemble IR imagery, a composite picture of background with embedded target was produced by computer then converted to a transparency.

Experimental Design:

1. Targets - a jeep, a tank, a trailer truck, and a group of three men

2. Definition of contrast

$$\text{Percent contrast} = \frac{T-B}{\text{Max (TB)}} \times 100$$

T = target brightness

B = background brightness

3. Range of contrast
6, 12, 24, and 48%

4. Design

a. Independent variables

(1) Display size

(2) Display luminance

(3) Target background contrast

(4) Image quality

(5) Target type

(6) Number of targets

b. Dependent variables

(1) Detection time

(2) Detection accuracy

(3) Recognition time

STUDY 15

Reference:

Fowler, F. D., and D. B. Jones, April 1972, Target Acquisition Studies Final Report (OR 11,901), Martin Marietta Corp., Orlando, FL.

System:

A 600:1 scale terrain model and a three-axis, gimbal-mounted television camera were used to simulate flight. The subjects were seated before a TV monitor in a simulated cockpit separate from the terrain model.

Experimental Design

1. Targets
   a. Two-dimensional buildings
   b. Three-dimensional buildings and vehicles
2. Definition of contrast (Not available)
3. Range of contrast

   Nominal range 10-40%

   Extreme range 5-50%

   Positive contrast in all conditions

4. Design
   a. Independent variables
      (1) Viewing mode: black and white
      (2) Background
      (3) TV field of view
      (4) Briefed or unbriefed targets
      (5) Target dimensionality
      (6) TV aim point target offset

STUDY 16

Reference:

Evans, L. A., G. W. Levy, and G. W. Ornstein, Validation Study of A Target Identification Model, NA65H-766, North American Aviation, Inc., Columbus, OH.

System:

The stimulus materials were motion pictures of a TV monitor on which was presented the scene being viewed by a TV camera as it was translated over a 3000:1 scale terrain model. Subjects viewed the directly projected movies from assigned distances.

Experimental Design:

1. Targets - Buildings, aircraft, and oil tanks

2. Definition of contrast

$$C = \frac{B_t - B_b}{B_b} \times 100$$

where

B_t = average brightness luminance of the target

B_b = average brightness of the background

3. Range of contrast
5-85%

4. Design

   a. Independent variables

      (1) Contrast

      (2) Resolution ratio

      (3) Target angular subtense

      (4) Viewing mode

      (5) Display mode

      (6) Target size

b. Dependent variable
Probability of correct target identification as predicted by a mathematical model

The following equations define the output of the model:*

$$(1) \quad P_i = \begin{cases} P_i' \left\{1 - e^{-.038 \, P_i' \left(|C_i| - 2 \right)}\right\} & \text{for } |C_i| \geq 2 \\ 0 & \text{for } |C_i| < 2 \end{cases}$$

$$(2) \quad P_i' = e^{-\left[6.6188 \times 10^{-4} \{.003 \cos (\alpha_i/2) - 1\}^4 + .0208\right] \left[(N_i^2 - 64)/N_i t_i\right]^{.8684}}$$

$$(3) \quad N_i = 860 \left(\ln \frac{1}{P_R}\right)^{1.15} + \sqrt{739{,}600 \left(\ln \frac{1}{P_R}\right)^{2.3} + 64}$$

$$(4) \quad P_R = e^{-(r_i/\bar{r}_T)^2}$$

where

C_i = target-background brightness contrast during i,

α_i = angular subtense of the displayed target during i,

t_i = time over which the target could be viewed during i,

r_i = the linear resolution of the sensor system during interval i,

$\bar{r}_T$ = the empirically determined resolution required for an observer to recognize a given target, T, with probability 1/e = 0.367.

*Author's Text, p. 1.

STUDY 17

Reference:

Martin, W., H. L. Task, K. R. Woodruff, and A. Pinkus, February 1976, A Study of Element Density and Active-to-Total Area Ratio Requirements for Matrix Displays, AFAL-TR-75-235, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

System:

A 16mm movie projector was used to project stimulus imagery onto the rear surface of a rear-projection screen. Photographically produced grids were introduced between the projection screen and the subject. The imagery film strips were composed of continuous zoom sequences of still photographs of target vehicle models.

Experimental Design:

1. Targets - five models: tank, mobile gun, halftrack, uncovered truck, covered truck.

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Viewing distance

      (2) Percent active area

      (3) Element density

   b. Dependent variable

      Subtended angle of target at time of recognition

STUDY 18

Reference:

Kuperman, G., W. N. Kama, J. Fraggiotti, and J. Kettlewell, June 1977, Research and Simulation in Support of Near Real Time/Real Time Reconnaissance RPV Systems, AMRL-TR-77-73, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

System:

A special-purpose flying spot scanner was used to generate imagery simulating each of three sensor types from medium-altitude strip photography. Imagery was recorded on video tape. Subjects viewed the simulated imagery on a TV monitor.

Experimental Design:

1. Targets - Civilian complexes (industrial and transportation)

2. Definition of contrast

$$C = \frac{B_t - B_o}{B_o}$$

where

B_t = luminance of target

where

B_o = luminance of background

3. Range of contrast (Not available)

4. Design (See Figure 10)

a. Independent variables

(1) Sensor type

(a) Laser line scan sensor

(b) Slewable TV sensor

(c) Overflight TV sensor

(2) Altitude

(a) 500 ft.

(b) 1000 ft.

b. Dependent variables

(1) Percent of targets detected

(2) Time on display to detection

(3) Ground range at detection

(4) Slant range to target detection

(5) Image scale at detection

(6) Accuracy of interpretation

(7) Interpreter confidence

		Altitude	
		500	1000
SENSOR	Laser Line Scan		
	Slewable TV		
	Overflight TV		

*Figure 10. Experimental Design

*Author's Text.

STUDY 19

Reference:

Scanlan, L. A., December 1976, Target Acquisition Model Development: Effect of Realistic Terrain, Technical Report P76-484, Hughes Aircraft Co., Culver City, CA.

System:

The image scenes used were low-altitude oblique photographs of rural countryside with target vehicles optically embedded into the background scene. This was accomplished by superimposing a transparency of the target (obtained by photographing scale models on a featureless background) on a transparency of the background and optically processing the composite. The composite pictures were presented to the subjects via a rear projection display apparatus.

Experimental Design:

1. Targets - Armored personnel carrier, tank, and truck

2. Definition of contrast

$$C = \frac{B_{max} - B_{min}}{B_{min}}$$

or

$$C = \frac{B_{Background} - B_{Target}}{B_{Target}}$$

3. Range of contrast
   0.7 - 2.0

4. Design

   a. Independent variables

      (1) High and low background complexity

      (2) Display resolution

      (3) Angular subtense of target

4. Target type

5. Target to background contrast

b. Dependent variable

Time to detection

STUDY 20

Reference:

Levine, S. H., R. A. Jauer, and D. R. Kozlowski, May 1970, Human Factors Requirements for Electronic Displays: Effects of S/N Ratio and TV Lines over Target, McDonnell Douglas Corp., St. Louis, MO.

System:

KS-87 reconnaissance camera imagery was converted to a TV signal by a flying spot scanner. Subjects viewed the displayed image on a TV monitor, whose face was marked off into a 3 × 3 array of 3-inch squares, labeled by columns and rows. The labeling arrangement provided the subject with a means of identifying target location.

Experimental Design:

1. Targets - 18 test items: trailers, a boat, and construction equipment.

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) S/N ratio

      (2) TV lines over target

      (3) Number of incorrect responses; false alarms

   b. Dependent variables

      (1) Number of correct responses; hits

      (2) Response time

      (3) Number of incorrect responses; false alarms

STUDY 21

Reference:

Krebs, M. J., and L. Lorence, February 1975, Real Display Parameters Study II, RADC-TR-75-43 (AD A007990), Honeywell, Inc., Honeywell Systems and Research Center, Minneapolis, MN.

System:

Video-taped FLIR imagery was collected during several local flights and then edited to produce the desired target sequence. Imagery was presented to the subject on a television monitor, and subject's eye movements were measured and recorded using a viewinghood oculometer.

Experimental Design:

1. Targets

   a. Large: bridges and industrial facilities

   b. Small: military vehicles

2. Definition of contrast

$$\%C = \frac{\text{Target Luminance-Background Luminance}}{\text{Maximum Luminance}_{\text{Target, Background}}} \times 100$$

3. Range of contrast
   05% - 99%

4. Design

   a. Independent variables

      (1) Minimum target dimension

      (2) Maximum target dimension

      (3) Average target-to-background contrast

      (4) Maximum target-to-background contrast

      (5) Target type

      (6) Prior, task-related experience

b. Dependent variables

(1) Time to detection response

(2) Time to classification

(3) Time to identification

(4) Accuracy of detection

(5) Accuracy of classification

(6) Accuracy of identification

STUDY 22

Honeywell, Inc., December 1977, Final Report on Automated Image Enhancement Techniques for Second Generation FLIR, 77SRC93, Honeywell Inc., Systems and Research Center, Minneapolis, MN.

Experiment I - (Part II; Bloomfield, J. R., L. J. Levitan, C. D. Bremer, and J. Wald.

System:

Slides were prepared from thermal sensor imagery (FLIR or thermoscope) and presented to subjects on a direct-projection screen. Test images were treated by means of contrast enhancement, minimum resolvable temperature enhancement, and resolution restoration algorithms, or a combination of processes.

Experimental Design:

1. Targets
   a. Military vehicles: tanks, jeeps, trucks, APCs.
   b. Cattle grazing
2. Definition of contrast (Not available)
3. Range of contrast (Not available)
4. Design (Figure 11)
   a. Independent variables
      (1) Contrast enhancement
      (2) Resolution restoration
      (3) Minimum resolvable temperature
   b. Dependent variables
      (1) Time to respond
      (2) Accuracy of response

Treatment	Original Scene	Treatment	Noise Added to Original Scene
1.	Original Scene	12.	Noise Added to Original Scene
	A(a) Contrast Enhancement		B(a) Contrast Enhancement
2.	High Frequency Emphasis Recursive		
3.	Local Area Gain Brightness Control Recursive	13.	Local Area Gain Brightness Control Recursive
4.	Local Area Gain Brightness Control Nonrecursive		
	A(b) Minimum Resolvable Temperature		B(b) Minimum Resolvable Temperature
5.	Recursive Adaptive Smoothing Filter	14.	Recursive Adaptive Smoothing Filter
		15.	Nonrecursive Adaptive Smoothing Filter
6.	5 x 5 Median Adaptive Smoothing Filter	16.	5 x 5 Median Adaptive Smoothing Filter
	A(c) Resolution Restoration		B(c) Resolution Restoration
7.	2 x 2 Digital Magnification		---
8.	Stochastic Approximation Resolution Restoration		
	A(d) Cascade Process		B(d) Cascade Process
9.	Combination of Treatments 3 and 5	17.	Combination of Treatments 13 and 14
10.	Combination of Treatments 3, 5 and 7	18.	2 x 2 Digital Magnification of Condition 17
11.	Combination of Treatments 3, 5 and 8	19.	Combination of Condition 17 and Stochastic Approximation Resolution Restoration

*Figure 11

*Author's Text, p. 235.

Experiment II (Part III; Williams, L. G., and W. G. Chaplin).

System:

Search scenes were created from direct photographs of targets or from photographs of a monitor displaying infrared sensor imagery and embedded by computer at a specified location in a background scene transparency. The composite slides were presented to subjects by direct projection.

Experimental Design:

1. Targets: Military and civilian vehicles

2. Definition of contrast

$$\frac{MIT-IMB}{MAX\ (MIT,\ IMB)} = C_L$$

$$\frac{PIT-IMB}{MAX\ (PIT,\ IMB)}$$

$$\frac{VIT-IMB}{MAX\ (VIT,\ IMB)}$$

(MIT - Mean Target Intensity
PIT - Peak Target Intensity
VIT - Valley Target Intensity
IMB - Immediate Background Intensity)

3. Range of Contrast (Not available)

4. Design (See Figure 12)

   a. Independent variables

      1. Degree of task difficulty

      2. Level of display resolution

   b. Dependent variables

      1. Time to target detection

      2. Accuracy of target identification

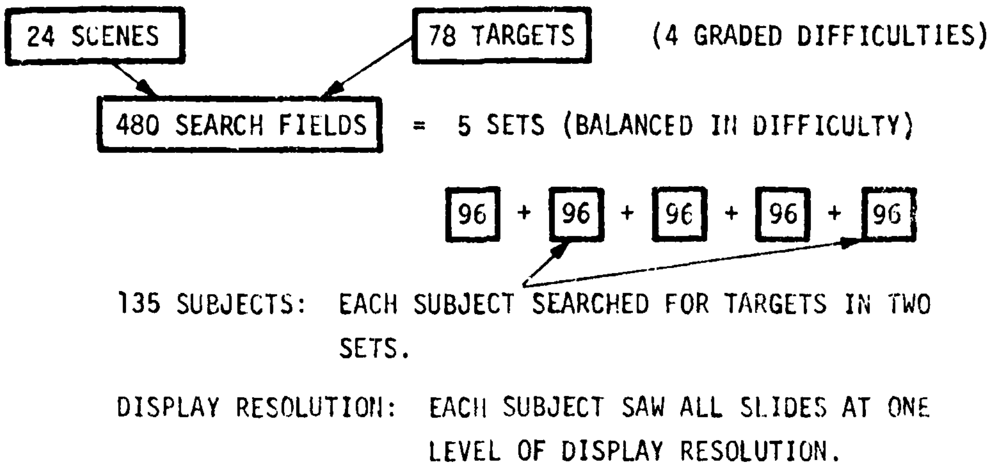


Figure 94. Main Features of the Experimental Design

***Figure 12**

***Author's Text, p. 268.**

STUDY 23

Whitehurst, H. O., August 1977, Ship Acquisition on Television: Three Laboratory Experiments, NWC TP 5978 (AD A050200), Naval Weapons Center, Systems Development Department, China Lake, CA.

EXPERIMENT I

System:

Targets were video taped with zoom lens calibrated for fast changes in simulated slant ranges. Subjects viewed the video taped sequences on a TV monitor and indicated their responses by marking a scoresheet or pushing a response button.

Experimental Design:

1. Targets - 1:1250 scale model waterline ships
2. Definition of contrast (Not available)
3. Range of contrast (Not available)
4. Design
   a. Independent variables
      (1) Targets
      (2) Subjects
      (3) Light position
      (4) Wake
      (5) Aspect angle
      (6) Range
      (7) Camera depression angle
   b. Dependent variable
      Accuracy of identification

EXPERIMENT II

System:

The same method of video taping with a zoom lens as was employed in Experiment I was utilized to provide the imagery for the second experiment.

Experimental Design:

1. Targets - 1:1250 scale model waterline ships: combat and merchant types

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Light azimuth

      (2) Light elevation

      (3) Ship aspect angle

      (4) Wake size

   b. Dependent variable

      Range at recognition

EXPERIMENT III

System:

The method of video taping targets with a zoom lens was the same as that used in Experiments I and II. Subjects responded by pressing one button to indicate type of ship and another for ship orientation.

Experimental Design

1. Targets - four 1:1250 scale model ships: combat and merchant

2. Definition of contrast

$$C = \frac{L_t - L_b}{L_b} \times 100$$

3. Range of contrast
Close range: 07.7% - 100%
Far range: 06.8% - 90%

4. Design (Figure 13)

   a. Independent variables

      (1) Target-background contrast

      (2) Contrast sign

      (3) Ship aspect angle off low

      (4) Targets

      (5) Subjects

   b. Dependent variables

      1. Range at orientation determination

      2. Range at target recognition

The simulated ranges in km at which each ship was videotaped are given in each cell.

Contrast sign	T/B contrast	Aspect angle, deg											
		20				45				70			
		Ship targets											
		1	2	3	4	1	2	3	4	1	2	3	4
Positive	Low	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4	16 12 8 4
	Medium	32 24 16 8	28 20 12 4	28 20 12 4	28 20 12 4	32 24 16 8	28 20 12 4	28 20 12 4	28 20 12 4	36 28 20 12	36 28 20 12	36 28 20 12	36 28 20 12
	High	32 24 16 8	32 24 16 8	28 20 12 4	28 20 12 4	44 36 28 20	36 28 20 12	36 28 20 12	36 28 20 12	44 36 28 20	44 36 28 20	44 36 28 20	44 36 28 20
Negative	Low	32 24 16 8	32 24 16 8	28 20 12 4	28 20 12 4	36 28 20 12	32 24 16 8	32 24 16 8	32 24 16 8	36 28 20 12	36 28 20 12	36 28 20 12	36 28 20 12
	Medium	32 24 16 8	32 24 16 8	32 24 16 8	32 24 16 8	44 36 28 20	44 36 28 20	36 28 20 12	44 36 28 20	44 36 28 20	44 36 28 20	44 36 28 20	44 36 28 20
	High	44 36 28 20	36 28 20 12	36 28 20 12	36 28 20 12	52 44 36 28	52 44 36 28	52 44 36 28	52 44 36 28	52 44 36 28	52 44 36 28	52 44 36 28	52 44 36 28

***Figure 13**

*Author's Text, P. 50.

STUDY 24

Reference:

Rogers, J. C., and W. L. Carel, December 1973, Development of Design Criteria for Sensor Displays, NR 213-107, Hughes Aircraft Co., Display Systems and Human Factors Dept., Culver City, CA.

ELECTRO-OPTICAL STUDY

A television scanner was used to convert low-altitude oblique aerial photography to digitized video data which was displayed directly on a TV monitor.

Experimental Design:

1. Targets - Military vehicles
2. Definition of contrast (Not available)
3. Range of contrast (Not available)
4. Design
   - a. Independent variables
     - (1) Spatial quantization
     - (2) Gray scale quantization
   - b. Dependent variables
     - (1) Size of target at correct recognition
     - (2) Definition of target at recognition

STUDY 25

Reference:

Beamon, W. S., and H. L. Snyder, November 1975, An Experimental Evaluation of the Spot Wobble Method of Suppressing Raster Structure Visibility, AMRL-TR-75-63, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

System:

35mm movie films of a terrain model were converted to television video and displayed on a TV monitor. Spot wobble was implemented by using the electrostatic deflection method.

Experimental Design:

1. Targets - Military vehicles and facilities

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Four levels of spot wobble

      (2) Viewing distance

   b. Dependent variable

      Correct/incorrect response

STUDY 26

Reference:

Task, H. L., and J. P. Hornseth, January 1974, An Evaluation of the Honeywell 7A Helmet-Mounted Display in Comparison with a Panel Display: Target Detection Performance, AMRL-TR-74-3, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

System:

16mm motion pictures were projected from a terrain board onto the vidicon of a TV camera. Video signals from the camera were then sent into a multiplexing system that superimposed in-raster video crosshairs on the picture video. This output signal was fed into a video distribution amplifier, then to the display.

Experimental Design:

1. Targets - Two POL dumps and two bridges

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Altitude

      (2) Type of display

   b. Dependent variables

      (1) Slant range at target identification

      (2) Number of correct identifications

STUDY 27

Reference:

Task, H. L., and R. W. Verona, August 1976, A New Measure of Television Display Quality Relatable to Observer Performance, AMRL-TR-76-73, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

System:

16mm movie film, made by slowly zooming in on photographs of targets, was converted to TV video and displayed on a miniature CRT display. Targets were viewed monocularly through a high-quality magnifying eyepiece.

Experimental Design:

1. Targets - Five vehicles

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variable
      CRT spot size

   b. Dependent variable
      Angular size of target at recognition

STUDY 28

Reference:

Williams, L. G., and J. M. Erickson, April 1976, FLIR Operator Requirements Study, AFAL-TR-76-9, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, OH.

EXPERIMENT I

System:

Transparencies of photographed FLIR imagery were digitized and then degraded by computer processing to create a given level of each variable. Positive transparencies were obtained from a digital film writer and were displayed on a rear-projection screen.

Experimental Design:

1. Targets - Military vehicles, horses, men, barrels, and landscapes (i.e., a no-target-present condition)

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Number of scan lines

      (2) Modulation transfer function

      (3) Noise

      (4) Magnification

      (5) Target category

   b. Dependent variable
      Correct target recognition

EXPERIMENT II

System:

Transparencies were produced and displayed in the same manner as in Experiment I.

Experimental Design:

1. Targets - Military vehicles and equipment

2. Definition of contrast (Not available)

3. Range of contrast: 0.75 (average)

4. Design

   a. Independent variables

      (1) Number of scan lines

      (2) Scan aperture size

      (3) Noise

      (4) Magnification

      (5) Target category

   b. Dependent variable
      Correct target recognition

EXPERIMENT III

System:

Film strips of photographed FLIR imagery were produced by digital image processing and animation techniques. The stimulus film was projected on a rear-projection screen.

Experimental Design:

1. Targets - Military vehicles

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

a. Independent variables

(1) Noise

(2) Number of scan lines

(3) Scan aperture size

(4) Magnification

(5) Target category

b. Dependent variable
Recognition accuracy

STUDY 29

Reference:

Hershberger, M. L., and D. F. Guerin, June 1975, Binocular Rivalry in Helmet-Mounted Display Applications, AMRL-TR-75-48, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

System:

Two slide projectors were used to simulate binocular rivalry in two visual scenes (HMD and Ambient) by projection onto separate, rear-projection screens, placed at right angles to each other. Imagery was obtained by photographing an F-14 cockpit and a ground scene at a landing strip for the ambient scene, and a helicopter located adjacent to a runway as a target image for the HMD scene. Both scenes were viewed from a distance of 15 inches.

Experimental Design:

1. Targets - Helicopter near runway
2. Definition of contrast

$$\frac{B_{max}}{B_{min}}$$

3. Range of contrast
   4.6 and 21.9

4. Design

   a. Independent variables

      (1) HMD resolution

      (2) HMD field of view

      (3) HMD transparency

      (4) HMD framing

      (5) HMD color

      (6) HMD eye presentation

      (7) HMD accommodation

      (8) HMD luminance

      (9) HMD contrast

      (10) Ambient scene luminance

(11) Ambient scene accommodation

(12) Ambient scene complexity

b. Dependent variables

(1) Percent of HMD visibility

(2) HMD image predominance

(3) Ambient scene image predominance

STUDY 30

Reference:

Grossman, J. D., January 1977, Feasibility Study of an FLIR/Imaging Seeker System, NWC-TP-5909 (AD B016387), Naval Weapons Center, China Lake, CA.

System:

Two video cameras were used simultaneously to simulate FLIR and an imaging IR seeker. Two configurations were considered: fixed line of sight FLIR and a slewable FLIR, operating in a "series-of stills" mode. They were mounted together on a pan-and-tilt platform which was suspended over a movable 1000:1 scale terrain board. Imagery was displayed on a single TV monitor mounted in a simulated cockpit. A four-function stick grip was provided for the subject, which controlled the position of the platform and engaged or disengaged the two sensor systems.

Experimental Design:

1. Targets - White, 2-1/2 ton truck

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Background clutter density

      (2) FLIR/seeker misalignment

      (3) Change in resolution between sensors

   b. Dependent variables

      (1) Search time with FLIR

      (2) Time to relocate target with seeker

STUDY 31

Reference:

deGroot, Sybil, January 1978, Human Factors Aspects of Low Level Television and Forward Looking Infrared Sensor Display: I. Feasibility Study of Scaled Subjective Complexity of Still Scenes Applied to Computer Image Generation, AFOSR-77-3242, Florida International University, School of Technology, Miami, FL.

System:

Subjects were asked to evaluate sets of photographs of displays of two E/O sensor systems: LLLTV and FLIR. These displays had been previously recorded onto video tape.

Experimental Design:

1. Targets - 16 local "target-scenes" from each sensor

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variable
      Scene complexity

   b. Dependent variable
      Time to match sets of photographs

STUDY 32

Reference:

Williams, L. G., and J. M. Erickson, FLIR Image Quality and Target Recognition: The Effects of Number of Scan Lines, Scan Aperture, Size, Noise, and Magnification, Honeywell, Inc., Systems and Research Center, Minneapolis, MN.

System:

Photos were produced by photographing the displayed output of an infrared sensor. The photos were then degraded using an image processing technique. Resultant transparencies were projected on a rear-projection screen.

Experimental Design:

1. Targets - Military vehicles

2. Definition of contrast (Not available)

3. Range of contrast (Not available)

4. Design

   a. Independent variables

      (1) Number of scan lines

      (2) Scan aperture size

      (3) Noise

      (4) Magnification

   b. Dependent variable
      Accuracy of target recognition

STUDY 33

Reference:

Levine, S. H., L. R. Beideman, and E. W. Youngling, August 1978, Dynamic FLIR Target Acquisition Phase 1, MDC E1920, McDonnell Douglas Astronautics Co., St. Louis, MO.

System:

Simulation system using psuedo-colored scale models photographed on a terrain board was developed. The output of a computer-controlled, zoom optical imagery target generator, using photographic transparencies of a terrain board, was picked up by a TV camera and the scene was reproduced on a CRT, as simulated infrared imagery.

Experimental Design: (Planned Study)

1. Targets - Military vehicle models: tank, truck, and halftrack; scale 1:250
2. Definition of contrast

$$\text{Contrast ratio (CR)} = \frac{B_{max} - B_{min}}{B_{min} + I}$$

where

I = screen luminance addition due to ambient light.

$$\text{Differential Contrast (CD)} = \frac{B_{max} - B_{min}}{B_{min}}$$

$$\text{Modulation (M)} = \frac{B_{max} - B_{min}}{B_{max} + B_{min}}$$

3. Range of contrast (Not available)

4. Design (See Figure 14)

   a. Independent variables

      (1) Starting slant range

      (2) Closing rate to target

(3) Target type and signature

(4) Background complexity

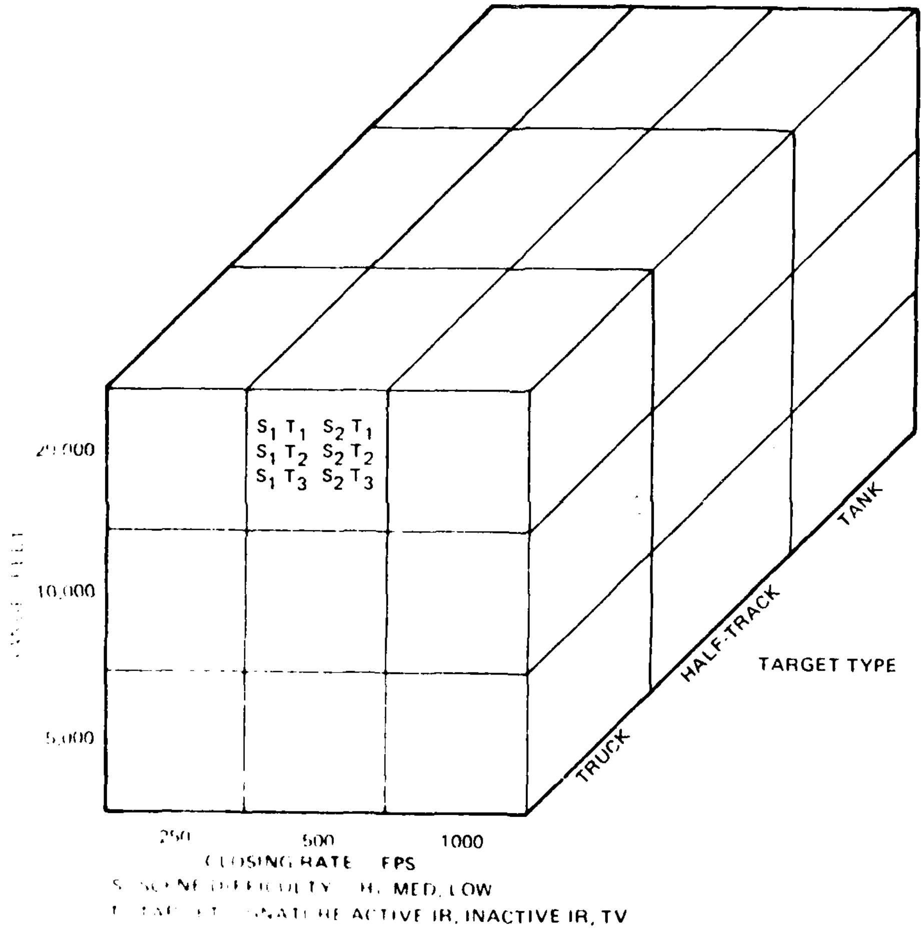
(5) Speed

b. Dependent variables

(1) Response time

(2) Accuracy of target identification

(3) Range at acquisition



EXPERIMENTAL DESIGN

*Figure 14

*Author's Text, p. 97.

STUDY 34

Reference:

Humes, J. M., and D. K. Bauerschmidt, November 1968, Low Light Level TV View Finder Simulation Program. Phase B-The Effects of Television System Characteristics Upon Operator Target Recognition Performance, AFAL-TR-68-271, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

System:

35mm motion picture films of targets, terrain, etc., were obtained by viewing a 3000:1 scale terrain model. These stimulus films were then transformed into a video signal and displayed to subjects on a TV monitor in a simulated aircraft cockpit.

Experimental Design:

1. Targets - A variety of military vehicles, buildings, industrial and transportation facilities

2. Definition of contrast

$$\text{Target/background brightness contrast} = \frac{L_b - L_o}{L_b}$$

when

$$L_b > L_o,$$

or

$$= \frac{L_o - L_b}{L_o}$$

when

$$L_o > L_b,$$

where

L_o = luminance of the object

L_b = background luminance

3. Range of contrast
   0.048 - 0.750

4. Design

   a. Independent variables

      (1) Video bandwidth

      (2) Scan line frequency

      (3) Display aspect ratio

      (4) Signal-to-noise ratio

      (5) Image enhancement

      (6) Display contrast ratio

      (7) Frame integration time

      (8) Lens focal length

      (9) Camera painting angle

      (10) Aircraft velocity and altitude

   b. Dependent variable
      Response time to target

STUDY 35

Reference:

Barnes, M. J., January 1978, Display Size and Target Acquisition Performance, NWC-TP-6006 (AD A054624), Naval Weapons Center, Systems Effectiveness Division, China Lake, CA.

EXPERIMENT I

System:

The display was generated by video taping the imagery from a terrain model and displaying that imagery on a TV monitor.

Experimental Design:

1. Targets - Tanks, missiles, houses, and trucks
2. Definition of contrast

$$\text{Contrast} = \frac{T_L - B_L}{B_L}$$

3. Range of contrast
   -27 to -48

4. Design

   a. Independent variables

      (1) Display size

      (2) Visual angle of target

      (3) Simulated airspeed

      (4) Mode of image presentation

      (5) Operator uncertainty

      (6) Target/background contrast

      (7) Signal/noise ratio

      (8) TV resolution

      (9) Task load

      (10) Number of targets

   b. Dependent variable
      Number of correct decisions

EXPERIMENT II

System:

Same as used in experiment I.

Experimental Design:

1. Targets - Tank, truck

2. Definition of contrast (Same as Experiment I)

3. Range of contrast
   -27 to -48

4. Design

   a. Independent variables

      (1) Visual angle of target

      (2) Number of targets

      (3) Signal-to-noise ratio

      (4) Contrast

      (5) Configuration

   b. Dependent variable
      Number of correct decisions

APPENDIX

Wagner, D. W., April 1975, Target Detection With Color Versus Black and White Television, NWC TP 5731, Naval Weapons Center, Aircraft Systems Department, China Lake, CA.

Abstract

An experiment was conducted to investigate target detection performance on color and black-and-white TV. Green, brown, and gray model tank targets were viewed under 25, 35, and 300 TV lines resolution against a green and a brown background on a terrain model. Target-to-background luminance contrasts studied were positive (targets lighter than the surround), negative (targets darker than the surround), and zero. Color provided a slightly higher percentage of target detection than did black-and-white TV (74% versus 69%). Background color did not significantly affect performance, although it figured prominently in several interaction effects. Gray targets were more detectable than either brown or green targets. Higher resolution improved performance about equally for both color and black-and-white TV, and targets lighter than the background were detected more easily than either negative or zero contrast targets.

Stinnett, T. A., K. C. Leonard, Jr., and D. B. Faubert, August 1969, Multisensor Weapon Delivery System, AFAL-TR-69-257, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

The concept of integrating multisensor data for presentation on a composite display is a logical choice to improve human performance and thereby extend the capabilities of tactical weapon delivery systems. The rapid improvement of sensor data acquisition capabilities has outstripped the ability to display the available data in a manner compatible with human performance requirements. The time sensitivity involved in target detection, recognition, and attack makes it mandatory that sensor data be acquired, processed, and displayed in the most meaningful way. To evaluate the validity of the multisensor concept, an extensive experimental program was conducted to compare human performance in viewing a composite multisensor display with individual sensor displays. Because of schedule constraints, it was decided to concentrate only on combining TV and infrared sensors. Other sensors such as radar, laser illuminators, etc., have been considered out of the scope of this study. It is strongly recommended that they be considered in future studies. To provide combined TV and infrared imagery for display, a standard TV camera was modified to be electronically and optically compatible with an AGA Thermovision infrared camera (2.0 - 5.4μ). Both cameras were electronically

synchronized and shared an identical 5 × 5 degree field-of-view. Registered imagery of various scenes was recorded on video tape for experimental playback on a three-color experimental display monitor. A display processor unit was designed and constructed to provide for the control and display of various single-sensor and multisensor mode combinations. A controlled experiment using 15 flight experienced and 15 non-flight experienced observers was conducted to compare composite multisensor imagery against TV alone and infrared alone. The effects of imagery color coding were also evaluated and factored into the experiment. The basic experimental results indicate that a definite improvement in human performance in terms of target recognition occurs for the display in color of composite TV and infrared imagery. A reduction in reaction time on the order of 7 seconds occurred for target recognition and 2 seconds for target detection. It was also apparent that along with higher accuracies, significantly smaller variability in operator responses occurred for the composite display. This improvement in human performance has obvious ramifications in terms of systems effectiveness.

Snyder, H. L., R. J. Keesee, W. S. Beamon, and J. R. Aschenbach, October 1974, Visual Search and Image Quality, (AMRL-TR-73-114),. Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

Abstract

Several experiments were conducted to evaluate alternative unitary measures of video line-scan system image quality. A metric based upon the Modulation Transfer Function of the imaging system was derived, with emphasis placed upon the photometric properties of the system. This metric was shown to predict well the average effects of several imaging system parameters upon the ability of observers to extract information from both dynamic and static images. In attempting to predict the ability of observers to acquire specific targets in an air-to-ground search task, however, other target and background parameters become very important, and such image quality measures must therefore be refined. Relationships among alternate measures of line-scan image quality were discussed, and a conceptual model was presented for combining system noise, raster interference, scene content, and the visual requirements of the observer.

Snyder, H. L. December 1976, Visual Search and Image Quality: Final Report, AMRL-TR-76-89, Aerospace Medical Research Laboratory, Aerospace Medical Division, Wright-Patterson Air Force Base, OH.

Abstract

This report presents the results of an air-to-ground television target acquisition experiment which investigated the effects of mission profile, video system line rate and bandwidth, and video noise level. The target acquisition performance data are related to these variables and to a measure of display image quality, the Modulation Transfer Function Area (MTFA), which is measured microphotometrically at the display surface.

The target acquisition performance results are largely as expected. For a camera field of view of 18.8° × 14.2°, the mean ground ranges of correctly acquired targets are 28,661, 24,376, and 12,171 ft., respectively, for mission profiles of 23° depression angle, 500 ft/sec velocity; 23°, 3000 ft/sec; and 45°, 500 ft/sec. As depression angle decreased, there was a large decrease in acquisition range; as velocity increased, there was a smaller decrease in acquisition range. Altitude was 10,000 ft.

Corresponding percentages of targets correctly acquired for these three missions were 75, 55, and 97 percent. As velocity increased, there was a significant decrease in the number of targets acquired.

The target acquisition data are consistent with other related studies.

Image quality measures were moderately correlated with target acquisition performance; linear correlations ranged from 0.22 to 0.70. Correlations were generally higher for two-dimensional MTFA values than for one-dimensional measures.

Also discussed are problems and concepts related to photometric noise measurement, eye movements during visual search, and display photometry.

Rusis, G., and H. L. Snyder, March 1965, Laboratory Studies in Air-to-Ground Target Recognition: II. The Effect of TV Camera Field of View, T5-133/3111, Autonetics, Human Factors Department, Anaheim, CA.

Abstract

A laboratory simulation experiment was performed to determine the effect of the TV camera lens field of view upon air-to-ground target recognition by closed-circuit television. Measures of performance were probability of correct target recognition, range of correct

recognition, and number of errors committed. It was found that, as the field of view decreased, (1) probability of correct recognition decreased, (2) range of correct recognition increased, (3) incorrect target recognitions did not vary, and (4) number of no-response targets increased. The results were discussed in terms of their applicability to tactical airborne situations.

Bergert, J. W., and F. D. Fowler, May 1970, Target Acquisition Studies: Visual Angle Requirements for TV Displayed Targets, OR 10,689, Martin Marietta Corporation Orlando, FL.

Abstract

The objective of this study was to determine the smallest angle that an object viewed on a television display could subtend at the observer's eye and be detected or recognized as a target. Tests were conducted using both static and dynamic modes to provide a data baseline for the dynamic conditions simulating aircraft flight. Television field of view, target-to-background contrast and target background areas were varied for the detection and recognition tasks at briefed target positions.

A significant finding of this study was that performance appeared to be degraded by introduction of the dynamic factor. On the previous study of target acquisition with direct vision, no differences in subject performance were obtained between the static and dynamic tests for either detection or recognition. However, in that study the differences between the obtained visual angles for detection and recognition were statistically significant. For this TV mediated study, the performance differences between the static detection and static recognition tests were not statistically different. No differences were obtained between dynamic detection and dynamic recognition for the narrow field of view. However, for the wide viewing angle dynamic recognition was the most difficult task. An increase in target contrast on the television mediated test produced a greater change in performance than was evidenced in the direct vision test. The narrow field of view required larger visual angles but resulted in a lower percentage of incorrect responses than did the wide field of view.

Levine, S. H., and E. W. Youngling, February 1973, Real-Time Target Acquisition With Moving and Stabilized Image Displays, MDC E0769, McDonnell Douglas Corporation, St. Louis, MO.

Abstract

Current high-performance aircraft achieve speeds which exceed man's ability to visually acquire a target before it is overflown. We are faced with the problem of extending man's capability to match that of the aircraft. Electronic sensors such as radar and TV systems offer potential solutions; however, considerable research into the best utilization of these systems is still required. McDonnell Aircraft's approach to this research has been to design and build a variable configuration display mockup (VCDM) in which actual flight images can be electro-optically manipulated to measure performance and evaluate system improvements. To maintain our operational orientation, stimulus imagery was generated using aerial imagery from the McDonnell Douglas Reconnaissance Laboratory data base, containing strategic and tactical targets.

Moving Window Displays

In these systems, an area on the ground is imaged and moves down the display at a rate proportional to the speed of the aircraft. A series of studies was performed to evaluate the effects of image motion generated by various aircraft speeds. Imagery was viewed on the 5.5-in. CRT display in the cockpit station of the VCDM, at image motion rates yielding from 1 to 6 seconds on the display and simulated aircraft speeds of from 675 to 114 knots. Overall, the data indicate that a moving display can be used for the acquisition of "easy" targets (large truck parts, fortifications, storage area) at speeds resulting in as little as one second on the display. For all practical purposes, the relationship between image-motion and time-on-display limits the use of moving window displays to missions against large targets or those allowing slow aircraft speeds.

Stabilized Image Displays

In these systems, the sensor tracks an area on the ground so that a stationary image is displayed to the operator. As the aircraft closes with the target, the image scale increases, producing a zoom effect. Since the system depends on tracking a fixed point, it can be used only for targets of known location, or where a specific ground area needs to be searched. The variables manipulated were: closing rate (360 to 1200 knots), starting field of view (100% vs. 66% of original image), target offset from the center of the display (center, middle, edge), and type of briefing aid (photo or sketch of target). This series of studies indicated that targets can be sucessfully acquired

on a stabilized image display at closing rates as high as 1200 knots, provided the navigation system is adequate to place the target in the center two-thirds of the field of view, and appropriate briefing aids are available.

In summary, at moderate speeds, moving window displays are effective against large targets, while stabilized image displays are effective against targets of known location at much higher speeds. These data contribute to the definition of the aircraft envelope and the mission types within which man can effectively utilize these sensor/display systems.

Bruns, R. A., et al., November 1970, Dynamic Target Identification on Television as a Function of Display Size, Viewing Distance, and Target Motion Rate, TP-70-60, Naval Missile Center, Systems Integration Division, Point Mugu, CA.

Abstract

This report describes the results of a research study whose goal was evaluation of the effects of (1) television display size, (2) display degradation, (3) observer viewing distance, and (4) target motion rate on target identification performance. Appendixes to the report describe (1) a reconnaissance transparency projection system to simulate the televisual air-to-surface tactical target attacks used as test material in this study, and (2) a rating procedure to compare target briefing photographs in terms of qualities important for target identification. The target ratings are then used to predict target identification performance in the simulated target attacks.

Ozkaptan, H., J. G. Ohmart, J. W. Bergert, and R. A. McGee, October 1968, Target Acquisition Studies: Fixed Television Fields of View, OR 9656, Martin Marietta Corporation, Orlando, FL.

Abstract

A study was conducted to investigate an operator's target acquisition capability while viewing a television monitor. The study was conducted under realistically simulated flight conditions in the Guidance Development Center of the Orlando Division of Martin Marietta Corporation. Pilot performance, in terms of search, detection, and recognition, was assessed for both briefed and unbriefed missions. It was found that:

1. Performance as a function of contrast is strongly dependent upon field of view and type of briefing;

2. Probability of detection is influenced by field of view only in the unbriefed mode;

3. Extensive target search requirements exist in briefed as well as unbriefed modes and strongly affect target acquisition performance in both modes.

Fowler, F. D., and D. B. Jones, January 1972, Target Acquisition Studies: (1) Transition From Direct to TV Mediated Viewing, (2) Target Acquisition Performance: Color Versus Monochrome TV Displays, OR 11,768, Martin Marietta Corporation, Orlando, FL.

Abstract

Two aspects of air-to-ground daylight target acquisition were investigated. Study I examined the task of finding a target displayed on a cockpit-mounted CRT after the pilot had acquired it visually through the cockpit canopy. The effect of three different TV camera fields of view on the subject's ability to transition from outside to inside conditions was studied. The second experiment evaluated the differences in acquisition performance elicited by color and monochrome TV display presentations of ground targets. Both tests used 2-D building type target silhouettes which provided a range of contrasts relative to their backgrounds, in terms of brightness and color differences. As in previous study phases, these tests utilized the Martin Marietta Guidance Development Center Simulation facility, including the 40 ft × 40 ft 600:1 scale terrain model, for basic stimulus generation. Results of Study I showed that the experienced pilot-subjects detected and then recognized the targets by direct vision before detecting them on the TV monitor. The primary target characteristic influencing detection within each FOV condition appeared to be brightness contrast. The major conclusion was that substantial improvements in integrated TV display subsystem design are required to provide effective direct-view-to-on-board display transitioning. Study II results showed that color contrast did not affect displayed target acquisition performance for this type of mission over the range of target/background conditions used. Again, brightness contrast appeared to determine acquisition distance more than any other factor. It is concluded, therefore, that color contrast normally plays a secondary role in airborne target acquisition.

Freitag, M., and S. MacLeod, March 1974, The Effect of Scene Rotation on Target Acquisition and Tracking, AMRL-TR-74-19, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH.

Abstract

Three studies were performed to determine the effects of scene rotation on target acquisition and tracking performance. Video tapes of simulated straight-in approaches to surface vehicular targets were made at constant offset, altitude, and speed, using a terrain table (600:1) and a gimbal-mounted TV camera. Detection and (separate) recognition tests were then made under load (button-pushing) and no-load conditions. No difference in detection slant range and erroneous detections was found between the rotated (roll-pitch) and non-rotated (yaw-pitch gimbal order) conditions or between the load/no-load conditions. Statistically significant differences were found between the recognition ranges and error scores for gimbal order but, again, not between load/no-load conditions. When 30 subjects were asked to track rotated and nonrotated targets resulting from gimbal order, significant differences were found in tracking error scores using a rate controller and the same flight conditions as the previous two studies on target acquisition. It was concluded that every attempt should be made to stabilize or deroll the sensor LOS if maximum recognition and tracking performance are to be realized in airborne electro-optical systems in ground target acquisition and tracking.

Fowler, F. D., M. Freitag, D. B. Jones and B. King, January 1971, Target Acquisition Studies: (1) Two-Dimensional Compared With Three-Dimensional Targets; (2) Changes in Gamma for TV Displayed Targets, OR 11,091 (AD 718 382), Martin Marietta Corporation, Orlando, FL.

Abstract

This study had two major objectives. The first was to determine whether the detection and recognition of two-dimensional targets are significantly different from the detection and recognition of three-dimensional targets when target acquisition is performed using direct unaided vision and when utilizing a TV display. The second objective was to determine how differences in TV-system transfer characteristics (gamma or dynamic gray scale) affect target detection and recognition capability.

To fulfill the first objective, tests were run in the Martin Marietta Guidance Development Center (GDC). Trained pilots detected and recognized targets under simulated flight conditions utilizing both two-dimensional and three-dimensional targets with both the unaided eye and with the aid of a closed-circuit TV system. Slant ranges and visual angle requirements were determined for the conditions tested.

No evidence for the superiority of three-dimensional targets over two-dimensional targets was found, either with direct unaided vision or with TV-mediated detection or recognition.

A second series of tests was run in the GDC to determine the effect of changes in gamma (the gray scale transfer characteristic) on target detection and recognition capability with a television sensor. Six trained pilots performed simulated target detection and recognition tasks under three gamma levels. Slant ranges and visual angle requirements were determined for the conditions. Changes to the gamma of the TV transfer characteristics did indicate a trend to earlier detection and recognition of targets. This was partly attributed to interaction of gamma with the contrast level of the displayed TV picture. For positive contrast targets, higher gamma levels tended to increase the contrast inherent in the target/background relationship, thereby enhancing target acquisition.

Bruns, R. A., A. C. Bittner, Jr., and R. C. Stevenson, August 1972, *Effects of Target Size, Target Contrast, Viewing Distance and Scan Line Orientation on Dynamic Televisual Target Detection and Identification*, TP-72-24, Naval Missile Center, Systems Integration Division, Point Mugu, CA.

Abstract

This report describes a simulation research study which measured the effects of (1) target size, (2) target-to-background contrast, (3) television raster scan line orientation, and (4) display viewing angle on both target detection and target identification using television. One hundred twenty different simulated air-to-surface target "attacks" against buildings on a three-dimensional terrain model were videotape-recorded using a 525-line television system. These attacks were then shown to 16 subjects whose tasks were to detect the target from it[illegible]ground and to identify it from a number of alternatives shown [illegible]fing photographs. Performance measures were (1) slant range at correct detection (SRD), (2) slant range at identification (SRI), and (3) probability of correct identification (PCI).

Major conclusions reached were as follows:

1. Target effects were of major importance across all three criteria but were comparatively the most important for PCI. Target effects were found to be primarily related to target size, expressed either as target area or target diagonal.

2. Target contrast was by far the most important variable investigated for SRD. It was also of major importance for SRI and was of moderate importance for PCI. Increased target contrast resulted in increased subject performance across all three criteria.

3. Vertical raster scan line orientation was statistically superior (11 percent greater slant range) to horizontal raster scan line orientation for the SRD criterion only, but the differences were in the same direction for all three criteria.

4. The different display viewing angles used in the study had no significant effect on any of the three criteria, although the outcome for the detection task may have been dependent upon the task structure employed.

5. Subjects' differences were of substantial importance for all three criteria but were comparatively the most important for SRI.

6. None of the independent variables interacted significantly for any of the three criteria.

Based on the results of this study, it is recommended that further research focus on (1) techniques for contrast image enhancement, (2) verification of the superiority of vertical versus horizontal scan line orientation, and (3) delineation of the effects of display viewing angle upon a target detection task requiring search across the entire television display.

Krebs, M. J., and C. P. Graf, September 1973, <u>Real-Time Display Parameters Study</u>, RADC-TR-73-300 (AD 773 850), Rome Air Development Center, Griffiss Air Force Base, NY.

Abstract

The objective of this effort was to study the effect that certain critical real-time display parameters had on operator target acquisition performance. Detection and recognition performances were investigated as a function of changes in display size, display luminance, target-to-background contrast, image quality, target type, and number of targets. The results demonstrated that display size and luminance had the largest effect on detection time and probability of detection, whereas target-to-background contrast had the most important influence on recognition performance. Records of eye movements during the search task were used to investigate scanning patterns.

Fowler, F. D., and D. B. Jones, April 1972, Target Acquisition Studies (Final Report), OR 11,901, Martin Marietta Corporation, Orlando, FL.

Abstract

This report presents the final results of studies to obtain baseline data about human target acquisition performance. The five major areas of investigation included Visual and TV Search, Detection and Recognition; Visual and TV Detection and Recognition Threshold; 2-D versus 3-D Targets; TV Gamma Effects; Visual to TV Transition; and Color versus Monochrome TV. All the studies were accomplished using the three-dimensional 600:1 scale terrain model, flight platform, and cockpit simulation at the Martin Marietta Guidance Development Center.

Evans, L. A., G. W. Levy, and G. W. Ornstein, July 1965, Validation Study of a Target Identification Model, NA65H-766, North American Aviation, Inc., Columbus, OH.

Abstract

A research program was undertaken to assess the validity of a previously developed mathematical model for predicting target identification probabilities. A major validation study and three auxiliary studies were conducted. The purpose of the validation study was to compare predictions of the model with empirically obtained probabilities. Stimulus materials were generated by filming a TV monitor screen upon which was presented the scene being viewed by a TV camera as it swept over a terrain model containing various targets of differing surround and contrast. These materials were subsequently projected at three different projection speeds and viewed from each of three different distances by three groups of twenty subjects. Empirical probabilities for each of 54 "flight" conditions (involving variations in contrast, resolution ratio, target angular subtense, and viewing time) were experimentally obtained and were compared with probabilities estimated from these factors by a mathematical model of target identification performance.

The three auxiliary studies were designed to investigate specific assumptions or aspects of the target identification model. Specifically, they were to determine (1) whether the predicted probability of target identification is a function of display mode (static or dynamic); (2) whether performance is a function of target size independent of the relative proportion of the field of view occupied by the target; and (3) whether the target identification model predicts equally well for two different levels of system resolution.

Martin, W., H. L. Task, K. R. Woodruff, and A. Pinkus, February 1976, A Study of Element Density and Active-to-Total-Area Ratio Requirements for Matrix Displays, AFAL-TR-235, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, OH.

Abstract

A study was performed to determine the impact of two important matrix display design variables on tactical target recognition performance. Element density (i.e., the visual angle subtended by individual display resolution elements) and the percent active area on the display surface were experimentally manipulated by adjusting viewing distance from a rear projection screen on which a grid mask was placed. The targets were presented to subjects using zoom imagery at a simulated slant range, which initially precluded recognition.

As the target size increased, subjects were asked to press a remote projector control button when they were "virtually certain" of their responses. The results indicate little effect of percent active area (i.e., down to 55%) on target recognition performance for element angular subtense values between 0.75 and 3.0 minutes of arc (corresponding to element densities of from approximately 165 to 40 elements per inch at a 28-inch viewing distance). The effects of element density, however, were large and conformed to expectations derived from the limiting resolution of the visual system. Both geometric and mathematical deviations are provided for the relationships between element density, viewing distance, target size, sensor field of view, total number of display elements, and slant range at time of target recognition.

Kuperman, G., W. N. Kama, J. Fraggiotti, and J. Kettlewell, June 1977, Research and Simulation in Support of Near Real Time/Real Time Reconnaissance and RPV Systems, AMRL-TR-77-33, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

A facility was developed for assessing operator performance in target recognition and interpretation tasks using real time and near real time electro-optical sensor imagery. A programmable image scanner was upgraded to generate simulated sensor imagery under operational flight profiles. A study was performed to compare operator performance against three candidate sensors. The study utilized two V/H levels, the operationally preferred and the minimum commensurate with RPV survivability. Significant findings were developed for the dependent measures of: percent of targets detected, time on display until detection, ground range at detection, slant range at detection, and displayed image scale at detection. Accuracy of interpretation and interpreter confidence did not yield significant results. These results were combined with analytically based performance measures to produce a sensor comparison table in which twelve criteria, weighted by their respective operational impact, were used. A slewable television camera, equipped with zoom optics, and supported by a near real time playback capability, achieved the highest performance score. Additionally, seventeen areas were identified in which future investigations could provide operationally important findings to the RPV Special Project Office.

Scanlan, L. A., December 1976, Target Acquisition Model Development: Effect of Realistic Terrain, Technical Report P76-484, Hughes Aircraft Company, Culver City, CA.

Abstract

The research obtained data on the effect of realistic background scene complexity on tactical vehicle target detection and the interaction of scene complexity with electro-optical sensor and display variables. Data were obtained which verified that performance prediction could be accomplished using selected metrics describing the characteristics of the background scene. The obtained data were used to investigate potential forms of a detection model which includes the influence of the scene. Finally, the influence of field of view and method of sensor search on detection performance was assessed.

Levine, S. H., R. A. Jauer, and D. R. Kozlowski, May 1970, Human Factors Requirements for Electronic Displays: Effects of S/N Ratio and TV Lines-Over-Target (Presented at 1970 National Aerospace and Electronics Conference of IEEE, Dayton, OH, 18-20 May 1970). McDonnell-Douglas Corporation, St. Louis, MO.

Abstract

This study was performed as part of a McDonnell Aircraft Company Reconnaissance Laboratory program to determine the observer requirements for effective utilization of electronic reconnaissance displays. Twelve subjects viewed a high-fidelity reconnaissance TV display which simulated real-time operations. Images having an average of 6, 9 and 11 TV lines-over-target successively appeared at S/N ratios of 4, 8, 16, 32, 64 and 100 to 1. The observer located discrete targets with one of three levels of response certainty: detection, recognition, or identification. Performance was measured in terms of correct responses and false alarms. Overall, as the S/N ratio and the TV lines-over-target increase and response certainty decreases, the number of correct responses goes up. False alarms remain constant for S/N ratios greater

than 8:1 and TV lines-over-target, and go down with increases in response certainty. These data show that the most effective way to improve performance, increasing the number of correct responses while reducing or maintaining false alarms, is to increase the number of correct responses while reducing or maintaining false alarms, is to increase the number of TV lines-over-target or the S/N ratio.

An analysis of the display characteristics showed that resolvable lines-over-target, a compound variable derived from the number of TV lines-over-target and display resolution as a function of the S/N ratio, had a high correlation with correct responses, accounting for 66 percent of the variance. Design criteria including display specification, performance prediction, and tradeoffs between display resolution and scale can be derived from these data.

Krebs, M. J., and L. Lorence, February 1975, Real-Time Display Parameters Study II, RADC-TR-75-43 (AD A007790), Honeywell, Inc., Honeywell Systems and Research Center, Minneaspolis, MN.

Abstract

The purposes of the study were: (1) to explore the effects of prior task-related experience on FLIR target acquisition; and (2) to determine the effects of several real-time imagery-related variables on target acquisition. Three groups of subjects were tested including trained FLIR operators, photo interpreters, and untrained college students. The 30 subjects were presented with airborne videotapes of FLIR imagery which had been edited into 15-second segments. Eleven different targets were included in the stimulus set, ranging from large industrial facilities to small military vehicles. Detection, classification and identification time, and accuracy were recorded. Scanning patterns were also recorded using the viewing hood oculometer.

As expected, the FLIR operators were superior to the other groups in detection time and accuracy. Unexpectedly, however, the FLIR group was no better than the untrained group in classification and identification accuracy. Scan pattern analysis indicated some interesting differences between the FLIR and untrained groups. The differing effects of imagery characteristics on the various response categories were presented.

The results were discussed in terms of their implications for operator training and sensor/display requirements.

Honeywell, Inc., Systems and Research Center, December 1977, Final Report on Automated Image Enhancement Techniques for Second Generation FLIR, 775RC93, Honeywell, Inc., Minneapolis, MN.

Abstract

The objective of this experimental evaluation was to discover whether observer performance was affected by changes in image quality caused by various enhancement techniques. A number of thermal images, views of the ground containing one or more military vehicles, were transformed using various enhancement algorithms. Observers were asked whether particular hot spots on the resultant images were tanks, armored personnel carriers, trucks, or jeeps. A total of 109 observers took part in the experiment. Using the Mann-Whitney, two-sample, two-tailed U test, the proportion of correct responses (accuracy) and the response times for images transformed by the enhancement algorithms were compared with the data obtained with the untransformed, original images.

Most of the enhancement algorithms had little effect on response time, although there were some significant changes: (1) there was a small improvement when noise-free images were treated with a combination of contrast and minimum resolvable temperature algorithms; (2) there was a decrement (i.e., longer response time) when a combination of contrast, minimum resolvable temperature, and resolution restoration algorithms was used on noisy images; and (3) there were also decrements when two different minimum resolvable temperature algorithms were used on images with very large targets. With the accuracy comparisons, there were no significant differences between the transformed and the original images.

Whithurst, H. O., August 1977, Ship Acquisition on Television: Three Laboratory Experiments, NWC-TP-5978 (AD A050200), Naval Weapons Center, China Lake, CA.

Abstract

This report consists of a summary of three laboratory experiments on ship acquisition on television, plus information on how to apply the prediction equations that are included. Examples are given, along with limitations on the conditions under which the equations can be used. Some comparisons of the results of these experiments with the results of similar studies are also included.

Experiment I was conducted to determine the relative importance of seven factors to ship identification on television. Targets had the strongest effect, followed by subjects, light position, ship wake,

ship aspect angle, slant range, and camera depression angle. Ranges at which a ship could be recognized as a merchant ship or combatant under varying light azimuth, light elevation, ship aspect angle, and ship wake size conditions were determined in Experiment II. Multiple regression analysis yielded an equation to estimate recognition ranges. Experiment III was conducted to determine the ranges at which ships can be recognized and their orientation (direction of movement) determined. The factors of primary interest were target-to-background contrast, contrast sign, and ship aspect angle. Multiple regression analyses were performed and four predicted equations are included.

Rogers, J. C., and W. L. Carel, December 1973, Development of Design Criteria for Sensor Displays, (AD 744 725), Hughes Aircraft Co., Display Systems and Human Factors Department, Culver City, CA.

Abstract

This is the annual report of research conducted under ONR Contract Number N00014-72-C-0451, NR 213-07, entitled Development of Design Criteria for Sensor Display Systems. This report summarizes the work accomplished since the interim report dated June 1973. The following topics are treated in this annual report:

- Psychophysical studies, modulation sensitivity function
- Cognitive demand studies
- Analysis of display mechanization performance criteria.

Beamon, W. S., and H. L. Snyder, November 1975, An Experimental Evaluation of the Spot Wobble Method of Suppressing Raster Structure Visibility, AMRL-TR-75-63, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

Television displays generate an image composed of a number of parallel raster lines. These lines, when visible, act as an interfering pattern and detract from operator performance in obtaining information from the video system. One way to reduce line visibility is to deflect the scanning spot vertically as it scans; this technique is commonly termed spot wobble. An experiment was conducted which evaluated changes in operator performance as indicated by the ranges at which targets were acquired and the number of correct responses to target presentation in a simulated air-to-ground search task. These performance parameters were evaluated at four spot wobble amplitudes and three viewing distances. The main findings were that spot wobble had

no significant effect on the number of correct responses, but that large-amplitude spot wobble significantly increased the ranges at which targets were acquired.

Additionally, several subjective indicators of preferred image quality were evaluated, and they show that there is wide variance among subjects as to what image characteristics they prefer.

Task, H. L., and J. P. Hornseth, January 1974, An Evaluation of The Honeywell 7A Helmet-Mounted Display in Comparison With a Panel Display; Target Detection Performance, AMRL-TR-74-3, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

Target detection performance of two groups of eight subjects was compared. Subjects of one group wore the Honeywell Model 7A helmet-mounted display (HMD). A Hewlett-Packard Model panel display was used to present the imagery to the subjects of the other group. A 16mm movie projector and a TV camera were used to present the twenty-two target runs to terrain board imagery simulating inflight target search and detection. Performance scores obtained were average slant range to detection and number of correct identifications. Although performance (slant range and hits) with the panel display was slightly better than performance with the HMD, the difference in performance was not statistically significant. Implications for HMD design and evaluation are discussed.

Task, H. L., and R. W. Verona, August 1976, A New Measure of Television Display Quality Relatable to Observer Performance, AMRL-TR-76-73, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

This report describes a new, direct-measurement method of determining the imaging quality of cathode-ray tube (CRT) line scan displays. This measurement was specifically developed as a more critical and realistic indicator of display quality. The measurement consists of recording the modulation contrast available on the display as a function of spatial frequency. An electronic sine-wave generator produces a sine-wave intensity pattern on the face of a CRT display. The display luminance distribution is scanned using a telephotometer or microphotometer, depending on the size of the display.

The modulation contrast of the display is obtained from the photometer scan for several spatial frequencies. The resulting graph showing modulation versus frequency is defined as the Sine Wave Response (SWR) Curve of the display.

Since human vision is not linearly related to modulation, it is desirable to transform the modulation axis to another parameter which is linearly related to vision.

Theoretically, this can be accomplished by transforming the modulation contrast to two incremented Gray Shades. The resulting Gray Shade Response (GSR) indicates how many gray shades are visible as a function of spatial frequency.

A new single display quality metric is defined using the GSR curve as a display. The measure is derived from the Modulation Transfer Function Area (MTFA) concept and is defined as the area between the visual threshold curve and the GSR. This area is referred to as the Gray-Shade Frequency Product or GFP.

A brief study was performed to determine the correlation of GFP with performance in a target recognition task. The results for three display conditions indicate that the GFP is at least as good a measure of display quality as MTFA.

Williams, L. G., and J. M. Erickson, April 1976, FLIR Operator Requirements Study, AFAL-TR-76-9, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

Three experiments were carried out to determine the quantitative relationships between FLIR image quality parameter and target recognition. Simulated FLIR imagery was used in each experiment to measure recognition performance as a function of specific image quality variables. The original target imagery was produced by photographing the displayed output of an infrared sensor. A variety of target types and examples was used. In each experiment the original target images were degraded by digital image processing techniques according to specific levels of the image quality variables. Experimentation was then carried out in a laboratory situation to measure recognition performance. Data from a total of 43,764 experimental trials were collected and analyzed. The implications of the results of the three experiments to system design are discussed.

The image quality variables investigated in Experiment I were: number of scan lines, modulation transfer function, noise, and magnification. Increasing the number of scan lines improved resolution and, therefore, resulted in improved recognition performance. Raster sampling was found to dominate performance to such a degree that noise and modulation transfer function had minor roles. Target characteristics, such as size and contrast, were also highly correlated with recognition.

Experiment II investigated the following image quality variables: number of scan lines, scan aperture size, noise, and magnification. Methods of measuring resolution and the effects of target size and contrast were also studied. The optimum scan aperture was found to depend on the scene noise level, with overscanning improving performance in a noisy environment. Magnifying the target image had little effect on performance, unless the image was noiseless or of high resolution. The best predictor of recognition performance was found to be the displayed maximum dimension divided by the system resolution.

In Experiment III, the effects of dynamic noise on the recognition of degraded FLIR targets were investigated. The targets were degraded according to the image quality variables of Experiment II. Dynamic noise was simulated by producing and then projecting film strips of the degraded targets. The noise on each 35mm frame was independent of the noise on the preceding frame. The effects of the image quality variables were highly consistent with those found in Experiment II. Overall, there was an average of 8 percent improvement in recognition at each noise level when the noise was dynamic. Data from this experiment suggest experimental results using static imagery may be extended to dynamic imagery.

Hershberger, M. L., and D. F. Guerin, June 1975, Binocular Rivalry in Helmet-Mounted Display Applications, AMRL-TR-75-48, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

A research program was conducted to determine the relationships between helmet-mounted display (HMD) design parameters and binocular rivalry. Four laboratory studies and a modulation transfer function image quality analysis were conducted during the course of the study program. A qualitative laboratory evaluation was conducted preparatory to formal laboratory research to get a "feel" for the binocular rivalry phenomenon with HMDs before construction of laboratory equipment for formal research. A screening study which investigated 12 parameters was then conducted to determine which parameters affected binocular rivalry with HMDs. A parametric study was next conducted to

establish functional relationships between HMD parameters and binocular rivalry for the parameters identified in the screening study to have a major impact on binocular rivalry. The final laboratory study was a validation study which compared selected HMD system configurations in realistic HMD and non-HMD tasks for binocular rivalry effects. The image quality analysis evaluated the effects of ambient illumination, display luminance, combiner transparency, and angular display subtense on HMD video quality using modulation transfer function analysis techniques.

Grossman, J. D., January 1977, Feasibility Study of FLIR/Imaging Seeker System, NWC-TP-5909 (AD B016387), Naval Weapons Center, China Lake, CA.

Abstract

A three-part study was performed to determine the conditions under which an aircrewman can use a FLIR search set and an imaging seeker. The flight geometry and system characteristics that result in these conditions were also delineated. The three parts of the study included: (1) an analysis of the time available to perform the tasks required of an operator, (2) a review of research on the time required to perform these tasks with a fixed-position FLIR; and (3) an experimental evaluation of the time required using a ground-stabilized, slewable FLIR.

deGroot, S., January 1978, Human Factors Aspects of Low Light Level Television and Forward Looking Infrared Sensor Displays: I. A Feasibility Study of Scaled Subjective Complexity of Still Scenes Applied to Computer Image Generation, AFOSR-TR-78-1237 (AD A058938), Florida International University, School of Technology, Miami, FL.

Abstract

Initial research was conducted to investigate human responses to still E-O sensor displays so effects of simulated realism could be evaluated. Research objectives included identifying scenes at different levels of scene-complexity and relating major perceptual with physical factors amenable to computer image generation.

Nine subjects psychometrically scaled for scene-complexity photographic sets of Low Light Level Television (LLLTV) and Forward Looking Infrared (FLIR) displays of 16 target-areas. After debriefing, subjects matched sensor displays with color photographs. Analysis included tests for significant complexity differences, correlation between scales, and content anayses. Results included synthesized physical measures to quantify sensor displays and contrasting subject responses. Scaling FLIR scense was reported a different and more difficult task than scaling LLLTV displays; however, matching FLIR displays with color photographs was faster with fewer errors, implying FLIR perceptual cues are comparable with the graphic detail displayed by LLLTV. Findings support a simulation using an optical array of surfaces, edges, and lines with trade-off parameters in the design of a Sensor Simulator determined empirically. Additional evidence indicated that visual parameters of FLIR displays may be more modified by mission assignment and atmospheric variables.

Williams, L. G., and J. M. Erickson, FLIR Image Quality and Target Recognition: The Effects of Number of Scan Lines, Scan Aperture Size, Noise and Magnification, (undated paper). Honeywell, Inc., Systems and Research Center, Minneapolis, MN.

Abstract

The objective of this study was to determine how four image quality variables--number of scan lines, scan aperture size, noise, and magnification--affect target recognition. Using simulated FLIR imagery, recognition accuracy was measured under combinations of the four image quality variables. The original set of target pictures was produced by photographing the displayed output of an infrared sensor. These pictures were then degraded by computer processing designed to simulate FLIR systems. The digital image processing included the following steps: (1) converting the original picture to binary form on magnetic tape using a scanning microdensitometer; (2) scanning this input information within the computer using a square aperture, (3) adding gaussian noise; (4) applying a square writing aperture, (5) writing this processed information on magnetic tape; and (6) converting the information on tape to a film transparency. Accuracy of target recognition for each of the degraded targets was then measured experimentally.

Levine, S. H., L. R. Beideman, and E. W. Youngling, August 1978, Dynamic FLIR Target Acquisition, Phase I, MDC E1920, McDonnell Douglas Astronautics Co., St. Louis, MO.

(Experiment in Progress: This reference included in study because of Infrared Terrain Board Facility).

To aid in the selection of our study variables, a literature review was conducted. Scene, target, environmental, and aircraft flight parameters were evaluated to determine their potential for affecting target acquisition performance, and a list of those factors making significant contributions to performance was generated. This list was then integrated with the mission scenario and the sensor capability to identify the major factors influencing target acquisition performance in an operational context. A study was configured to investigate these variables within the boundary conditions set by the mission scenario. In this study, a 3^5 factorial design will be used to obtain performance measures on the effects of starting range, rate of closure with the target, target type and signature, and background scene complexity. These data will serve as a baseline against which to evaluate additional variables affecting the target acquisition process. Further studies utilizing these variables will be identified as part of the Phase II effort.

Humes, J. M., and D. K. Bauerschmidt, November 1968, Low Light Level TV View Finder Simulation Program, Phase B--The Effects of Television System Characteristics Upon Operator Target Recognition Performance, AFAL-TR-68-271, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Abstract

A series of four experimental studies was conducted to determine the effects of airborne low light level television (LLLTV) viewfinder system parameters and mission considerations upon operator target recognition performance. The LLLTV system parameters (studied as independent experimental variables) included video bandwidth, scan line frequency, display aspect ratio, signal-to-noise ratio, image enhancement, display contrast ratio, frame integration time, lens focal length, and camera pointing angle. These parameters were studied at various levels of simulated aircraft velocity and altitude.

Experimental equipment included the following: (1) a simulated stationary aircraft cockpit with a panel-mounted TV display, (2) a TV system with adjustable parameters, and (3) an optical projection system to present the stimulus imagery (simulating the real-time image) to the TV system. The stimulus imagery used during the studies was obtained by photographing a terrain model (containing a variety of targets) under the desired conditions aircraft speed and altitude. Engineering personnel and college students were used as subjects; they were briefed as to the appearance of the target to be acquired but not as to its immediate surroundings. They were required to respond as soon as the target was positively identified. Performance measures included percent correct recognition, slant range at recognition and time to recognize.

Statistical analyses of these data were performed; the significant results are detailed herein. Additional analyses provided estimates of recognition performance for groups of targets classified by size and target/background contrast.

Implications of the results of this effort for LLLTV viewfinder system design are also discussed.

Barnes, M. J., January 1978, Display Size and Target Acquisition Performance, NWC TP 6006, AD A054624, Naval Weapons Center, Systems Effectiveness Division, China Lake, CA.

Abstract

Two experiments were conducted to find factors that have an important effect on display size criteria in a cockpit-display system. Subjects in both experiments detected military targets simulating images from a TV camera looking obliquely forward as it is flown over the terrain.

The results of the two experiments indicated that the physical size of a television monitor is not an important factor if MTF and visual angle are held constant. Of the factors studied, the four most important were: number of targets, visual angle of targets, target contrast, and target configuration.

The data from the second experiment were used to generate a multiple regression model. The relationship between target visual angle and display size allowed the regression model to be used to predict performance as a function of display size.

REFERENCES

Kuperman, Gilbert G., and William N. Kama, August 28-31, 1978, "Real-Time Reconnaissance Systems Simulator," Proceedings of the Society of Photo-Optical Instrumentation Engineers, 22nd International Technical Symposium: Visual Simulation and Image Realism, San Diego, CA.

FM 100-5, Operations, 1 July 1976, Headquarters, Department of the Army, Washington, D.C.

Crawford, Natalie W., August 1977, "Low Level Attack of Armored Targets," The Rand Corporation, Paper P-5982.

Petroski, Richard R., December 1977, Quick Strike Reconnaissance/ Reconnaissance Reporting Facility (QSR/RRF) Rapid Exploitation Orientation, Final Technical Report RADC-TR-77-375, Rome Air Development Center; Griffiss Air Force Base, N.Y.

Levine, S. H., and E. W. Youngling, December 1977, Research in Advanced Sensor Systems: Target Acquisition Bibliography, MDC E1603, McDonnell Douglas Corporation, St. Louis, MO.

Jones, D.B., M. Freitag, and S. C. Collyer, September 1974, Air-to-Ground Target Acquisition Source Book: A Review of the Literature, OR 12,470 Martin Marietta Corporation, Orlando, FL.

Bliss, W. D., May 1974, A Review of the Literature on Briefing and Target Acquisition Performance, NWC TP 5650, Naval Weapons Center, China Lake, CA.

Erickson, R. A., September 1964, "Target Acquisition Studies at the Naval Weapons Center: A Bibliography, NWC TP 5708, Naval Weapons Center, China Lake, CA.

Johnson, John, "Analysis of Image Forming Systems", Proceedings of Image Intensifier Symposium, 6, 7 October 1958, Ft. Belvoir, VA.

U.S. Government Printing Office, 12 May 1969, MIL-STD-150A, Military Standard: Photographic Lenses. Washington, D. C.

Steedman, W. C., and C. A. Baker, 1960, "Target Size and Visual Recognition, Human Factors, Volume II, No. 3.

Mendez, Antonio J., and Melvin Freitag, March 1973, "The State of the art in FLIR Target Acquisition Modelling,", A Collection of Unclassified Technical Papers on Target Acquisition, Martin Marietta Aerospace: Orlando, FL.

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