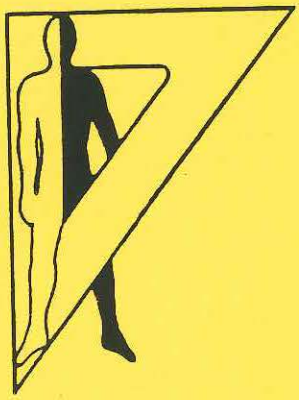

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BASIC RESEARCH 6.1
PUBLICATIONS AND PAPERS
1964-1990

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U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005-5001

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APPROVED: John D. Weisz

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CONTENTS

OFFICE OF THE CHIEF, BEHAVIORAL RESEARCH DIVISION

Major James M. King, Ph.D. (Psychology)
University of Texas at Arlington, 1976

Sandra Y. Price, Secretary
Bessie Yancone, Clerk Typist

Projects and Staff

1. Auditory Performance

G. Richard Price, Ph.D. (Physiological Psychology)
Princeton University, 1963

Georgès R. Garinther, B.S. (Electrical Engineering)
Gannon College, 1957

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California State University at Long Beach, 1981

Joel T. Kalb, Ph.D. (Physics)
Georgia Tech, 1976

Major Leslie J. Peters, Ph.D. (Audiology)
Pennsylvania State University, 1986

Kim M. Smith, M.S. (Communication Disorders)
Pennsylvania State University, 1988

Pamela A. Mundis, Mechanical Engineering Technician

Christopher L. Moody, Animal Caretaker

SP4 Ronald D. Sneed, Veterinary Technician

2. Remote Operations and Information Processing Team

Lynn C. Oatman, Ph.D. (Physiological Psychology)
University of Delaware, 1968

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University of Delaware, 1975

V. Grayson Cuqlock-Knopp, Ph.D. (Engineering Psychology)
University of Illinois, 1983

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Michigan State University, 1973

Linda L. F. Mullins, B.S. (Psychology)
University of Maryland, 1978

Dale R. Shires, B.A. (Computer Science)
University of Delaware, 1988

Danette G. Holland, Research Assistant

3. **Stress and Performance**

Gerald A. Hudgens, Ph.D. (Experimental Psychology)
Purdue University, 1965

Linda L. Fatkin, M.A. (Experimental Psychology)
Towson State University, 1984

James P. Torre, Jr., B.S. (Psychology)
Adelphi University, 1954

Samuel Wansack, M.S. (Biochemistry)
Pennsylvania State University, 1975

Joseph Mazurczak, B.S. (Electrical Engineering)
City University of New York, 1963

Jean Breitenbach, Psychology Technician

4. **Variance Component Estimation and Associated Diagnostics**

Jock O. Grynovicki, Ph.D. (Mathmematical Statistics; Experimental Design--Linear Models)
University of Delaware, 1989

5. **Visual Performance**

Deborah P. Birkmire, Ph.D. (Cognition)
University of Delaware, 1982

Robert Karsh, B.A. (Experimental Psychology)
Brooklyn College, 1957

Robert H. Lambert, B.A. (Aeronautical Engineering)
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B. Diane Barnette, B.S. (Computer Studies)
University of Maryland, 1988

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Johns Hopkins University, Baltimore, Maryland

Leslie A. Whitaker, Ph.D.
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Contracts

Adaptive Decision Aids
Leslie A. Whitaker, Ph.D.
Klein Associates, Yellow Springs, Ohio

Stereovision in Remote Navigation
John Merritt, M.A.
Interactive Technologies, Williamsburg, Massachusetts

Remote Navigation
Warren Torgerson, Ph.D.
Johns Hopkins University, Baltimore, Maryland

Factors Affecting Signal Detectability
Jerome Siegel, Ph.D.
University of Delaware, Newark, Delaware

Human Control of Nonllinear, Nonstationary Systems
John W. Senders, Ph.D.
University of Maine, Orono, Maine

Procedural Text: Structure and Use
Carol B. Mills, Ph.D.
American Institutes for Research in the Behavioral Sciences, Washington, DC

Hormonal, Psychological, and Endogenous Opioid Peptide Correlates of the Stress Response
Robert T. Chatterton, Ph.D.
Northwestern University, Chicago, Illinois

The Effects of Speech Intelligibility, Operator Expertise, and Task Difficulty on Operator Performance
David Payne, Ph.D.
State University of New York (SUNY), Binghamton, New York

Active Noise Systems
Dan Gauger
Bose Corporation, Framingham, Massachusetts

Model Development: Task Performance as a Function of Speech Intelligibility
Leslie A. Whitaker, Ph.D.
Klein Associates, Yellow Springs, Ohio/University of Dayton, Dayton, Ohio

Development of a Speech Efficiency Index
Donna Mayo
American Institutes of Research, Washington, DC

AUDITORY PERFORMANCE

TECHNICAL ISSUE: The ability to hear is essential to soldier performance in present and conceptual Army systems; high noise levels produce reduced crew efficiency and limitations in weapon design. Research is essential to determine how mission accomplishment is affected by acoustic/auditory factors.

OBJECTIVE: To generate soldier performance data via laboratory and field evaluations that are aimed at finding the mechanisms by which noise affects man, quantifying its role as a factor in system performance, and countering these effects to maximize both crew and weapon performance.

Two major thrusts support this effort:

1. Identification, quantification, and modeling of the mechanisms affecting ears exposed to intense impulses; and

2. Identification and quantification of human performance changes for Army-relevant tasks associated with various auditory capacities.

SYNOPSIS:

1. Weapons design is presently limited because the physiological mechanisms responsible for hearing loss from intense impulses were essentially unknown and the noise standards for impulse noises thus penalized large caliber weapons unnecessarily. This program is providing data and a theoretical base for a major reassessment of impulse noise hazard as well as suggestions for new forms of hearing protection and muzzle brakes or compensators for weapons.

A mathematical model will be developed to predict auditory hazards for all types of impulse and muzzle device designs that will reduce hazard (and detectability and localizability as well). These will be tested with animal ears for verification. Future research will include broadening the model to allow for additional variables known to be critical, such as number of rounds, spacing between rounds, and interactions with other sounds.

The long term challenge of this research will be to assess and model the interactions between variables known to have an influence on auditory hazards.

2. The ability to hear is essential for performance in the Army; yet the effect of auditory impairment on performance of Army-relevant tasks cannot presently be quantified. Therefore, data and a theory of auditory performance need to be developed in order to relate system performance to auditory variables in the soldier-machine interface.

A model has been developed that incorporates the latest information about sound propagation and human psychophysical detection standards. This model has been proposed for inclusion in MIL-STD 1474B and is currently being used by the Army Materiel Systems Analysis Agency (AMSAA) and the Project Manager for Mobile Electric Power. A design handbook that will identify methods to minimize noise is also in progress.

Research is focusing on finding ways to relate task demands (auditory and extra-auditory) and auditory capacities to performance. For example, studies have been conducted of the effects of varying levels of speech intelligibility on the ability of armored vehicle crews to identify targets, navigate, complete missions, and so forth.

COLLABORATIVE AND COOPERATIVE RESEARCH:

Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) of the National Academy of Sciences/National Research Council.

Design of muzzle devices for safer, higher performance weapons in conjunction with the U.S. Army Ballistic Research Laboratory.

PAYOFF: The fundamental knowledge gained from this research will result in new design standards for weapons with no increase in hazard, improved operational effectiveness when auditory tasks are involved, and improved tactical information about acoustic detection and identification of enemy targets.

REMOTE OPERATIONS AND INFORMATION PROCESSING

TECHNICAL ISSUE: Survival on the modern battlefield depends on the Army's ability to acquire targets from distant, concealed positions; drive and navigate vehicles remotely; and conduct operations under the cover of night. Knowledge of soldiers' performance with displayed presentations of indirect visual information is absolutely essential to determine that indirect viewing systems incorporate image display and system interface characteristics that enhance soldiers' capacities and capabilities.

OBJECTIVE: To generate soldiers' performance data employing laboratory and field evaluations concerning the quality and quantity of visual information required to enable soldiers to effectively employ systems that rely on indirect, processed, degraded, or altered presentations of visual information.

SYNOPSIS:

Four tasks support this objective:

1. Remote Navigation: In an effort to lessen the hazards associated with exposing humans to the battlefield, teleoperated vehicles are replacing

the soldier in the vehicle. This project seeks to lessen the difficulty of navigating a vehicle remotely by determining how (a) knowledge of the environment is obtained and used by navigators, (b) knowledge differs with both individual differences and changes in the quality of input information, and (c) how and why psychophysical judgments are different when made indirectly by teleoperation than when made directly by line of sight.

A study is being conducted to determine if soldiers who are high in visual and spatial ability are better suited for remote navigation than soldiers high in verbal and analytical ability, both in general and under degraded resolution conditions. Also, interviews are being conducted with expert land navigators to determine what are the critical cues they use for finding their way in off-road environments. A third study of direct and indirect psychophysical judgment making is planned.

Follow-on research efforts will incorporate previous research findings and will focus on establishing guidelines for navigational decision aids that are adaptive to the abilities of the users.

2. Image Processing: This research project is directed toward discovering those characteristics of visual displays required to maximize soldiers' operator performance with teleoperated systems at the lowest possible bandwidth. The characteristics of visual displays studied include resolution, gray levels, and the most effective combinations thereof to enhance operator performance.

A sophisticated image-processing capability for low data rate remote driving and other types of low data rate teleoperations is being developed, which will present the operators with dynamic (simulated real time) driving imagery having various combinations of gray levels and resolution. Also, both aliased and anti-aliased versions of these gray level resolution combinations will be presented, since this variable seems to have an important effect upon identification and recognition.

The remote driving simulation research will determine the necessary operating ranges for such things as pixel counts, gray levels, and graded resolution parameters to achieve acceptable performance with minimum bandwidth. A model will be developed to describe how gray levels and resolution interact in obtaining acceptable driving performance.

Future research will focus on more sophisticated bandwidth reduction techniques for images in a simulation environment, and the performance levels achieved with these techniques will be incorporated with previous research findings for constructing better predictive models.

3. Target Acquisition: The ability of soldiers to extract visual information from displays is essential to the operation of a variety of military systems using displayed information from indirect viewing devices. However, providing systems with the optimal field of view and resolution to enable soldiers to successfully perform target acquisition tasks is not possible, since a performance data base for target acquisition does not presently exist.

This research is directed toward assessing how soldiers' target detection, recognition, and identification performance is related to the resolution of displayed information from indirect viewing systems. A set of real world scenes and targets will be constructed and systematically altered using image processing technology. The alterations include enhancing or degrading basic scenes by pixel averaging, altering shades of gray, spatial frequency analyses, and other contrast filtering. Electro-optical raster imaging systems capable of varying equipment parameters such as resolution (horizontal and vertical), shades of gray, and signal-to-noise ratios are also used to degrade real world scenes and targets for presentation on cathode ray tube (CRT) displays.

Target acquisition performance data are used to assess the displayed visual information required to enable soldiers to use military systems that rely on indirect, processed, degraded, or otherwise altered visual stimuli to detect, classify, recognize, and identify targets.

The long term challenge is to develop a performance data base for target detection, recognition, and identification required for field of view and resolution tradeoffs using indirect viewing systems.

4. Target Acquisition Performance Correlates: The objectives of this program are

1. to conduct basic research on visual parameters such as field of view and resolution that affect soldiers' ability to acquire targets using CRT systems;

2. to examine the psychophysiological correlates of target acquisition performance in order to select soldiers to operate these systems; and

3. to develop on-line procedures for assessing the operator's mental state in order to optimize information flow and enhance performance.

This program will generate target acquisition performance data for various field of view and resolution combinations as well as developing techniques for selecting the best operators for CRT-based systems and enhancing their performance under field conditions. Results from this research will impact on a wide variety of indirect vision systems and aided target recognition systems.

COLLABORATIVE AND COOPERATIVE RESEARCH:

Visual factors that affect signal detectability with the University of Delaware

Brainstem indicators of operators' mental state with the University of Ottawa

Studies of line of sight and remote, psychophysical judgments with Johns Hopkins University

Adaptive decision aiding in off-road environments with Klein Associates

Image processing with Morgan State University

Stereovision and remote navigation with Interactive Technologies

PAYOFF: Results from this research program will generate basic human performance data which is essential to the development of soldier-operated systems that use indirect vision devices for presenting information, visual displays for military systems, artifical intelligence (AI) systems, and aided target recognition systems.

STRESS AND PERFORMANCE

TECHNICAL ISSUE: Knowledge of combat stress and how it affects soldiers' performance is extremely important to field commanders as well as developers of Army materiel. Field commanders need to know what they can expect from soldiers, and materiel developers need to design equipment that mitigates the adverse impacts that stress can impose on soldier performance.

OBJECTIVE: To generate soldier performance data via laboratory and field evaluations that quantify stress and its effects on performance.

SYNOPSIS:

Five tasks support this objective:

1. An Investigation of Human Control of Nonlinear, Nonstationary Systems: This research will result in a heuristic model that will be incorporated into an interactive program permitting the system designer or evaluator to receive a prediction of the quality of human performance and the effects of mitigating design features. It will be capable of (a) predicting the tracking accuracy of proposed power control systems when its nonlinearities are known; (b) specifying the design characteristics and parameter values; and (c) troubleshooting existing control systems.

Literature has been reviewed and a successful model constructed which accounts for performance in the presence of certain nonlinearities. A simulation of human operator and control of a nonlinear device has been programmed and shown to be operable.

2. Hostile Environment Simulator: The objective of this effort is to minimize the suppressive effects of enemy fire. Efforts focus on developing an extensive library of weapons effects signatures with an accurate and meaningful method of signature presentation. These will be used to simulate systematic integrated training using battlefield conditions to dictate the course of action and to study the effects of system design parameters on soldier performance under simulated fire.

3. The Acoustic Startle Response and the Disruption of Motor and Cognitive Performance: This research is directed toward improving the assessment of notional weapon systems concepts, their design, and the design of their coordinate training systems by developing a body of knowledge describing the relationship between cognitive and motor functions disrupted by the startle reflex.

Several experiments studying the effects of habituation, simulation intensity, stimulus repetition, transfer, warning, and intratympanic reflex have been completed. Data are currently being analyzed.

4. Combat Stress Mechanisms and Effects on Performance: The objective is to establish standard operating procedures (SOPs) and measurement techniques for assessing the effects of combat stress on the performance of soldier-operated weapons systems and on the tactical performance capabilities of individual soldiers. The intent is to demonstrate their applicability to operations research modeling suppression effects and performance.

Research will initially focus on determining which physiological (endocrine and peripheral) and psychological measures are most useful in identifying severe, combat-like stress responses. Efforts will then be directed toward field and laboratory studies to determine, through manipulation of several promising psychosocial variables, SOPs for eliciting combat-like stress responses without actually exposing test participants to life threats. The degree of stress elicited will be validated against physiological and psychological profiles from subjects experiencing a variety of stressors at moderate and severe intensities in naturally occurring situations.

Investigations are currently under way to determine stress response profiles to high and moderate intensities of film stress, surgical procedures, and competitive examinations. Data from these investigations have been integrated into a stress metric to be used to validate procedures for use in subsequent evaluations when soldiers are exposed to combat-simulated stresses in various weapons systems tests. In response to a request from the Soldier Support Center, stress metric is incorporated in the Human Technologies Data Base Library.

In an initial attempt to assess competition as a potential stressor for testing new weapon systems under stress conditions, a Human Engineering Laboratory (HEL) Salvo Stress field study was conducted using soldiers from the 101st and 82nd Airborne Divisions. Their marksmanship performance in competition was compared in a preliminary evaluation of alternate designs for the Advanced Combat Rifle Program. The test situation proved to be moderately stressful as verified by both physiological and psychological indices. Thus, competition will be further evaluated as a component in the continuing development of standardized procedures for testing soldier-weapon systems under stress.

Future efforts will focus on broadening the combat stress model from acute stress to include the dimensions of multiple and chronic stress. Evaluations of new psychological and physiological measures will be conducted.

5. HEL-PROJECT MANAGER TRADE AI Direct Fire Weapons Test Bed: This effort is to determine how to design expert systems to perform teaching roles now performed by humans and to acquire, through a program of experimental studies, the basic knowledge needed to design cost-efficient training systems for future line of sight direct fire weapons. Specific HEL focus is on quantifying the effects of practice, feedback, target characteristics, weapon characteristics, and physiological responses on tasks performed in the operation of direct fire weapons.

Experiments were conducted to determine if the test bed rifle simulation could support marksmanship training and to determine the value of weapon realism and performance feedback in training. Findings were (a) test bed marksmanship skills transferred to the field; (b) level of performance was comparable to the Army trained shooters; and (c) shooters who trained without noise, recoil, and feedback performed at the same level as the shooters who trained with these characteristics.

COLLABORATIVE AND COOPERATIVE RESEARCH:

Studies of psychophysiological responses to stress with Northwestern University.

PAYOFF: The fundamental knowledge gained from this research and improved soldier-weapon performance under stress conditions will enhance the design of all soldier-operated systems designed for combat use. Specific system applications include the Advanced Combat Rifle, Enhanced M16A2, and the Advanced Antiarmor Weapon System-Medium.

VARIANCE COMPONENT ESTIMATION AND ASSOCIATED DIAGNOSTICS

TECHNICAL ISSUE: Experimental variability and complex interactions such as soldiers' performance using various test items may hinder and complicate evaluation and interpretation of results from experimental field trials and human factors evaluations. Consequently, the ability to correctly evaluate weapon systems, Army procedures and techniques is hindered. To effectively evaluate factors of interest as well as to prevent the possibility of inflated error estimates that could cause the evaluators to make type II errors, researchers and evaluators need to be able to estimate and identify sources of variability.

OBJECTIVE: To develop variance components estimates, diagnostics and associated distribution theory for all random and mixed experimental designs that are essential in the evaluation of weapon systems and Army procedures. Through this effort, a formalized methodology will be developed to explain, control, and reduce inflated error variances that could lead researchers to make type II errors in their research efforts. Consequently, this new methodology will enhance the chance that the correct inferences and conclusions are made.

Two major thrusts support this effort:

1. Theoretical development and validation of the distributions of unbiased efficient variance component estimates and associated diagnostics.

2. Formalized methodological implementation of the variance components diagnostics to all random and mixed experimental designs including repeated measures, crossover, imbalanced, hierachical, and fractionated factorials.

SYNOPSIS:

1. An important consideration in weapon system design, equipment design, and selection is variability and its influence in regard to the soldiers' systems performance. Experiments are conducted to estimate variability and to determine sources of the varability in regard to performance measures. Unfortunately, distribution theory associated with unbiased and efficient variance component estimates is unknown and therefore, the ability of researchers to identify significant sources and differences in performance variability across different weapon systems is hindered. This program provides a theoretical basis for estimating and detecting sources of variability that may mask true performance differences between systems of interest.

The literature has revealed that estimates of variance components in a given experimental model can be realized as averages of sample covariances which may be dependent or independent. The distribution theory will be developed in both cases, and simulation of hierachical design will be performed for verification.

Critical values for estimates of the variance components for a range of correlations, sample sizes, and variances will be generated so that significant variance components associated with different weapon systems of interest can be identified and compared using confidence intervals.

Follow-on research efforts will incorporate research finds in complex and imbalanced experimental situations that experimenters frequently encounter during field testing.

2. A general methodology for checking outliers, model differences, and unexplained sources of varability that deflate F ratio estimates and cause type II errors is essential. At present, researchers have no formal methodology to investigate significant variance components and model assumption in mixed or random experimental designs that are essential in research development, testing, and evaluation of Army systems and procedures. These diagnostics and distribution theory need to be developed to identify sources of system variability relating to performance.

In addition, if the variability is not system-specific, the researcher can control, eliminate, or account for this variability in the experimental model. Thus, the evaluator obtains an unbiased estimate of the error term and therefore reduces the possibility of making a type I or type II error.

Components (covariances) comprising the significant variance components estimate provide a diagnostic basis to identify which experimental combination of factor levels is contributing to the significant estimate.

Developing the distribution of these diagnostics thereby gives the formal basis that can be used to identify causes of large or small variance estimates and model deficiences.

This mixed or random analog of residual analysis, complete with diagnostic tools, will be presented. This involves, in part, a reexamination of the model for mixed or random effects. The distribution applies to any random or mixed experimental design model, and will be illustrated on actual repeated measures experiments conducted by the Army and validated by simulation.

PAYOFF: New distribution theory associated with unbiased and efficient estimates of variance will be made available. This will result in a formalized diagnostic methodology for all random and mixed experimental designs that provide researchers with the tools to estimate weapon systems' variability and determine which system performance is best.

VISUAL PERFORMANCE

TECHNICAL ISSUE: The eyes of the soldier still represent the most critical information sensor on the battlefield. Performance with many technologically complex Army systems depends heavily on information obtained by the soldier or operator through the visual modality. Basic research is needed to ascertain the visual factors that influence soldier performance.

OBJECTIVE: To optimize the use of visual information by soldiers through enhancing our knowledge of how visual stimuli are processed and how this processing relates to human performance by conducting investigations of eye movement behavior and peripheral vision detection.

SYNOPSIS:

Four tasks support this objective:

1. Target Discrimination: Of current interest to designers of tracked vehicles are those features of current or projected vehicles that increase or decrease their vulnerability to detection and recognition when viewed through threat sensor systems. To that end, a program of research was conducted to assess several human performance measures (including eye movements) of the perceptibility of four current and concept tracked vehicle designs.

2. Search and Target Acquisition: The search and target acquisition times used in the current Army Battlefield Model are inaccurate for a number of reasons, including the current use of technologically sophisticated display

systems such as forward looking infrared radar (FLIR) and automatic target recognition (ATR). These systems require soldiers to interpret and act upon the data presented in these displays. There is a serious lack of empirical data about the use of these systems by soldiers to perform search and target acquisition functions. It follows that the usefulness of these display systems, and ultimately the Army Battlefield Model, depends on acquiring a thorough understanding of the basic human performance issues in visual search and target acquisition.

Current efforts are using eye movement behavior to determine the influence of global and local clutter on search times and probability of detection. Future research will explore the role of local and global clutter in search and target acquisition tasks in multi-target environments.

3. Information Processing from Text and Graphic Displays: To perform their assigned duties, soldiers are often expected to operate and maintain technologically complex systems. Frequently, the knowledge soldiers need to do this is presented in the form of written text. This may be problematic because the soldier may not be able to read, comprehend, and encode into memory the information that is needed. This research program is directed toward discovering those factors that lead to the fastest, most accurate transfer of information from text and graphic displays to the soldier or operator.

Previous research identified factors both within a text (e.g., content, organization, and presentation format) and within a person (e.g., background expertise and purpose for reading) that influenced how a text was read and what was remembered from a text. Recent efforts have focused on extending these results to procedural text, that is, written material that gives instructions for the performance of some task. Future research will continue to investigate factors affecting the processing of procedural text. In addition, eye movement data, specifically eye fixations and fixation durations, will be used to assess the influence of presentation format on the processing of procedural text and on task performance.

4. Visual Detection Response with Complex Targets and Backgrounds: Typical detection models describe targets with single values for size and contrast. Predictions for probability of detection and detection times from these models are unreliable, especially at low contrast values of the target and immediate background. The use of the single value to describe targets may explain this unreliability for two reasons. First, target size in these models is generally measured by angular subtense which does not reflect perceived target area and shape. Second, they use an average luminance value which does not measure the multiple luminance values on any three-dimensional target.

The goal of this program of research is to investigate the complex variables known to influence the probability of detection and detection times and to incorporate these more accurate variables into a detection model. Specifically, empirical performance data are being collected to measure the peripheral sensitivity of the retina.

COLLABORATIVE AND COOPERATIVE RESEARCH:

Studies of the perceptibility of military vehicle silhouettes with the U.S. Army Tank-Automotive Command

Studies of search and target acquisition with the U. S. Army Communications-Electronics Command (CECOM) Center for Night Vision and Electro-Optics and the Institute for Defense Analyses

Studies of the structure and function of procedural text with the American Institutes for Research, Goucher College, Western Illinois University, and the University of Maryland

Studies of the visual detection response with complex targets and backgrounds with AMSAA and the CECOM Center for Night Vision and Electro-Optics

PAYOFF: The knowledge gained from these programs of research will impact the design of armored vehicles, the development of the Army Battlefield Model, the formulation of writing guidelines for technical manuals, and the improvement of visual detection models, thereby augmenting soldier performance.

BASIC RESEARCH 6.1
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