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SOME RESEARCH FINDINGS ON FIDELITY OF TRAINING DEVICES FOR FIXE--ETC(U)
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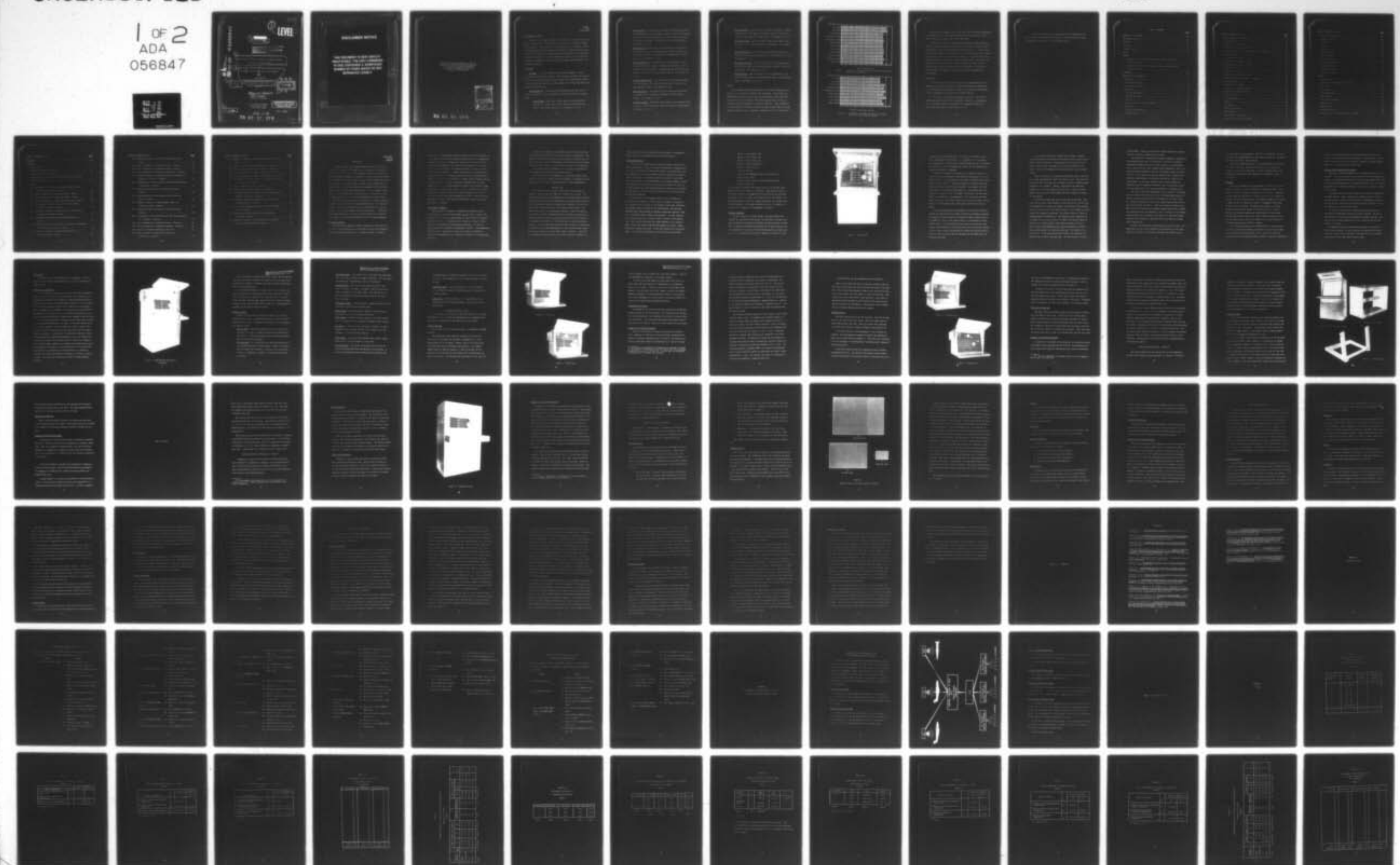

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RESEARCH REPORT

Some Research Findings on Fidelity of Training Devices For Fixed Procedures Tasks

by

John A. Cox, Robert O. Wood, Jr., Lynn M. Boren

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H. Walter Thorne

113 p.

DA-44-188-ARO-2

Approved:

ROBERT D. BALDWIN
Director of Research

U. S. Army Air Defense
Human Research Unit
Fort Bliss, Texas

21 July 1964

Task: RINGER

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This draft has been prepared for review by appropriate research and military agencies. It is considered tentative and may be modified or withdrawn at any time during the review process.

THE RESEARCH PROBLEM

Research was performed to determine the effects on proficiency development of using devices of less-than-perfect fidelity for training a lengthy fixed procedure. The fidelity of a training device was the degree to which it resembled that tactical equipment for which the training device was substituted. The fidelity of training devices was lowered in either appearance or functional quality. A fixed procedure was a part of a job in which all signals to the incumbent and actions by the incumbent were specified in an invariable sequence.

PROCEDURE

The Task. A 92-step procedure was used as an example of a fixed-procedure task during this research. This procedure concerned the operation of the Section Control Indicator (SCI) console of the Nike Hercules guided missile system when missiles are being prepared for firing (Blue Status) and being fired (Red Status).

Training Devices. Twelve different training devices were used in a series of studies. A brief description of each device has been presented below.

> The Hot Panel. This device was the same size and shape as the tactical SCI. Every light, switch, meter, intercom, and telephone on this device functioned. (See Figure 2, p. 13.)

The Cold Panel. On this device, every part was identical with the corresponding part on the hot panel. However, there was no electrical power to the device. Therefore, no lights, meters, intercom, or telephone functioned. All switches still could be operated. (See Figure 3, p. 17.)

The Frozen Panel. Every part on the frozen panel was identical in appearance with the corresponding part on the hot panel, but no part was operable. All switches were immovably fixed in OFF position. (See Figure 4, p. 17.)

The Cardboard Panel. The entire device was fabricated of cardboard, including the housing. The panel was painted in color to resemble the hot panel above. The remainder was painted the same gray color as that of the other device housings. (See Figure 11, p. 30.)

The Photographic Panel. This device was a full-sized black-and-white photographic print of the hot panel above, installed in a high fidelity housing. (See Figure 5, p. 21.)

The Drawing Panel. This device was a full-sized black-and-white line drawing of the hot panel, installed in a high fidelity housing. (See Figure 6, p. 21.)

The Hi-Fi Housing. This device was a replica of the housing of the hot panel. The cold panel was installed during the housing study. (See Figure 7, p. 25.)

The Box Housing. This device was a box made of plywood. It was of appropriate size and shape to hold the cold panel, which was installed for the study of housing effects. (See Figure 8, p. 25.)

The Frame Housing. This device was a simple wooden frame of appropriate size to hold and support the cold panel. (See Figure 9, p. 25.)

The Full-Sized Panel. This device was another line drawing on which the lettering was increased in size. The panel was 22" x 30". (See Figure 12, p. 34.)

The Half-Sized Panel. This device was a 15" x 22" reproduction of the full-sized panel above and was one-half the area of the full-sized panel. (See Figure 12, p. 34.)

The Small Panel. This device was a 5" x 7" reproduction of the full-sized panel and was one-nineteenth the area of the full-sized panel. (See Figure 12, p. 34.)

RESULTS

Five-man groups were trained with each of the above training devices until 15 or 20 men had been trained with each device. Each trainee was administered a proficiency test and a record was kept of the total training time used for each trainee. The resulting proficiency scores and training times were submitted to statistical analysis. Small differences in average (mean) proficiency scores and average training times were found among the several devices. These are illustrated in the two charts below.

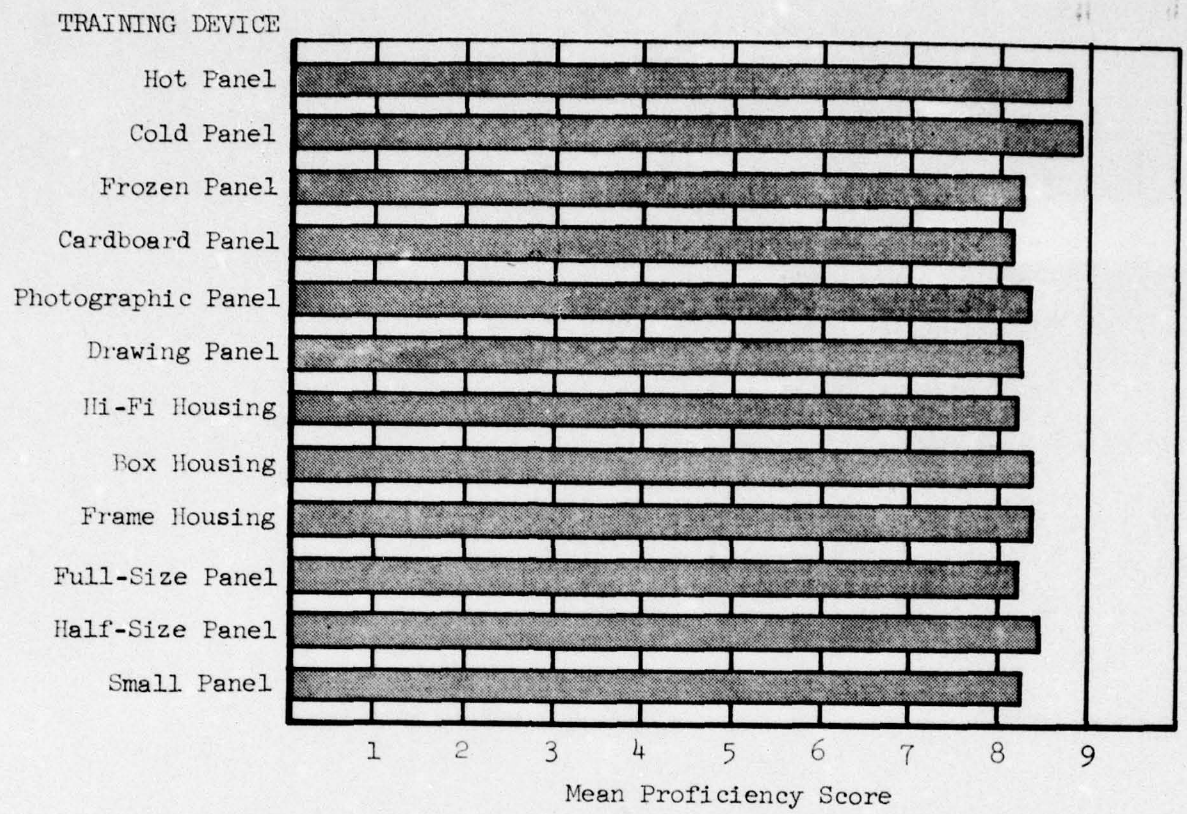

Figure A. Comparison of Average Proficiency Level Produced with Twelve Training Devices .

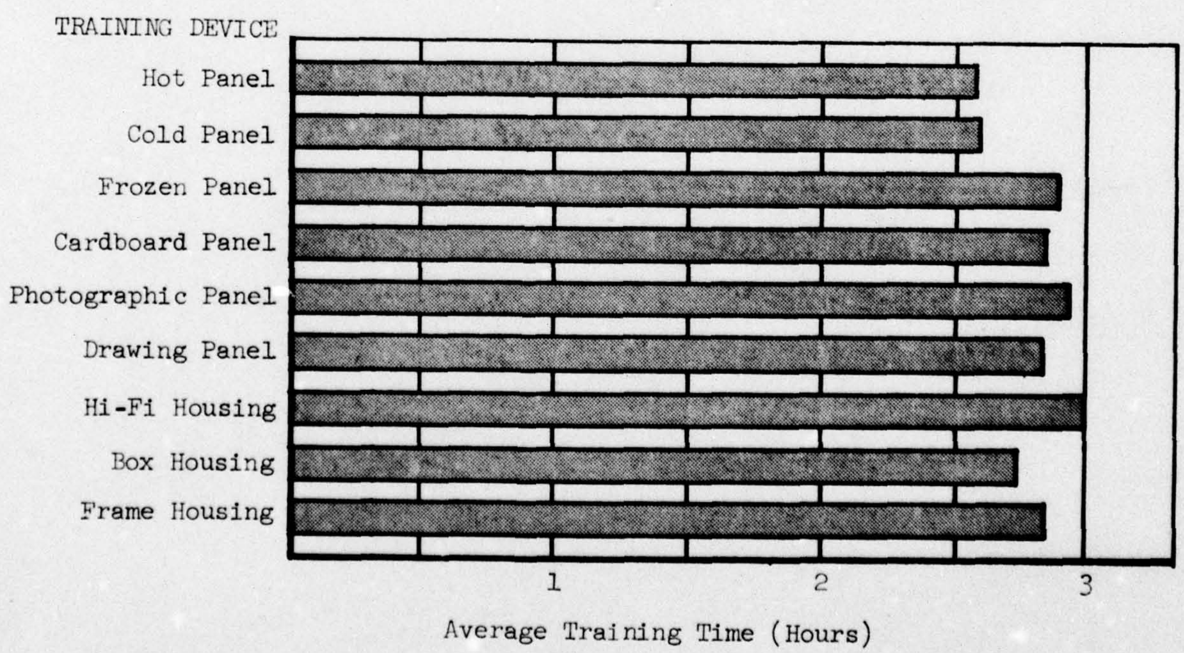

Figure B. Comparison of Average Time Required to Train with Each of Nine Training Devices

The statistical analyses showed that, while there were small differences in average proficiency and average training time for each device, none of these differences is larger than chance would allow.

A Field test of the above findings was performed in which military instructors trained soldiers to perform this task as part of Advanced Individual Training for Military Occupational Specialty (MOS 177). Some instructors used the actual live equipment during this training while other instructors used the full-size line drawing of the panel. Proficiency scores and training times were collected and analyzed statistically. Only chance differences were found between the terminal average proficiency scores or training times of the men trained under both conditions. The results of other research were compared to the above findings and largely tend to confirm them.

CONCLUSIONS

1. When men are being trained to perform a fixed procedure, the requirements for functional fidelity in the training device are quite low. A line drawing of the man-machine interface will train men as effectively in this circumstance as will a device of higher fidelity.

2. No effect on proficiency development is likely to occur due to reducing housing fidelity of the man-machine interface on a training device. The least expensive housing which will adequately support and protect the man-machine interface should be used.

3. Lowering the fidelity of a training device by reducing its size has no effect on proficiency development, so long as the parts of the device remain clearly visible to the individual trainee.

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Introduction

A training program uses various methods of training so that men will meet the training objectives. Use of a training device is one method of training men, and it is especially useful when trainees must learn and practice actions. The designer of training programs is faced with a question of whether to use a training device or some other method of training. Some guidance toward an answer to this question can be obtained from Gagne (1954), Miller (1954), Demaree (1961), Parker and Downs (1961), and Willis and Peterson (1961). When a training program designer has decided to use a training device, he is faced with other questions concerning the technical characteristics of such devices.

Task RINGER has the objective of determining the fidelity requirements of training devices for fixed procedures tasks. The fidelity of a training device is the degree to which it resembles that tactical equipment for which the training device is substituted. A fixed procedure task is a part of a job in which all signals to the incumbent and actions by the incumbent are specified in an invariable sequence.

Concerning fidelity.

For many years, transfer of training studies have shown that the more alike two situations are, the more that training in one situation will produce proper performance in the second situation. Bugelski notes that, "...experimental findings indicate that positive transfer is a function of the degree of similarity between stimuli (if responses are the same), and negative transfer is a function of the degree of difference between responses if the stimuli are the same" (1956, p. 403). The obvious conclusion is, "for maximum transfer of training, use devices of perfect fidelity." However, more recently, the older research findings have come to be suspected and devices having less-than-perfect fidelity have been found to produce the maximum transfer (Muckler, et al. 1959, pp. 129-132). Concern has also been expressed over the costs associated with high fidelity simulation (Miller, 1954; Muckler, et al., 1959; Parker & Downs, 1961). Thus, if it can be determined that lower-than-perfect fidelity devices can be used for training with no more than minor loss in proficiency development, and with no more than minor increases in training time, practical reductions in costs of training devices may be realized.

Dimensions of fidelity.

The definition of fidelity of simulation has eluded the human factors scientist for some time (Muckler, et al., 1959, p. 103). Thus a definition of fidelity is needed along with some scheme for measuring degrees of fidelity. The present work is based on a concept in which fidelity is recognized as having several dimensions. One group of these dimensions is referred to as appearance fidelity. Under appearance fidelity are such dimensions as color, size, shape, arrangement of parts, and the appearance of the container or housing of the man-machine interface.

However, when appearance is constant, training devices can still be differentiated from one another on the basis of functionality. That is, a knob or meter on one device may look exactly the same as that on another device, but on the first device the knob will move when turned, while on the other device the knob is fixed or frozen in one position.

The present report is concerned with functional characteristics and the appearance categories of size and housing.

Only gross categorical measurement of functional fidelity, size fidelity, and housing fidelity have been attained. No attempt has been made to determine the psychological degrees of these measurements.

Research Plan

The basic plan of each study in this report has six steps or factors. First, a task was chosen as a vehicle for the study. The task was considered to be representative of procedural tasks in general. Second, training devices were constructed which varied from one another on the particular dimension of fidelity being studied. The third step was to train groups of men with the several training devices. The fourth factor dealt with experimental controls. Control was applied to instructor effects, intelligence level of trainees, methods used in training (other than training device), and level of trainee experience with respect to the task. The fifth step was to measure trainee proficiency. The sixth and final step was to test the data for differences in proficiency which were associated with the training devices located at different points on the particular fidelity dimension. Since each of the separate studies had much of the above material in common, the common factors have been described below and should be understood to apply to each of the studies without further description.

<u>The procedural task.</u>

As defined for these studies, a procedural task is work in which every action taken by the job incumbent is specified, in sequence, and in which the actions to be taken are so simple, or so well known, that any trainee for the job will either know how to perform the action before he is trained or can learn to perform the action in one trial. Note that according to this definition, the pertinent demands for learning placed on the trainee are that he learn the sequence in which the actions are taken and names and/or locations of events in the sequence. He must learn to take each action in its turn and to avoid taking any action out of sequence.

The task used for this research was one which fulfilled the definition of a procedure, was long enough to present a challenge to any trainee, yet short enough to be economical during data collection, and geographically convenient to the investigators. The task was selected from those performed by Military Occupational Specialty (MOS) 177, Air Defense Missile Crewman, Nike Hercules. The task consisted of the actions taken by the Section Control Indicator (SCI) operator during Blue and Red Status when the system operates in the automatic mode. During Blue Status, missiles are prepared for firing. During Red Status, missiles are fired. During this procedure 106 actions are taken. The category and frequency of the actions are given below:

Operate a button switch (10)

Operate a toggle switch (36)

Operate a rotary switch (2)

Operate a rheostat control (2)

Operate a banana plug (1)

Write the time (3)

Give a verbal response on phone or intercom (11)

Monitor a light (22)

Monitor a sound, oral, or machine originated (19)

Monitor a meter (2)

In each step the operator has a signal given to him and must take a specific action as a result of the signal. Sometimes the signal for an action is simply the completion of the previous action, and sometimes the action to be taken is to monitor for the next signal. But psychologically each such unit, signal and action, is a complete step in this procedure. The complete procedure is given in Appendix A. A picture of the tactical SCI is presented in Figure 1.

Training procedure.

Men were trained in five-man groups. The group reported for training at approximately 0730 hours. The instructor introduced himself, directed the trainees to be seated, and identified each trainee. Then the instructor informed the trainees that he would instruct them in the operation of a piece of Nike Hercules equipment and identified the SCI. At this point the instructor displayed a diagram of a Nike

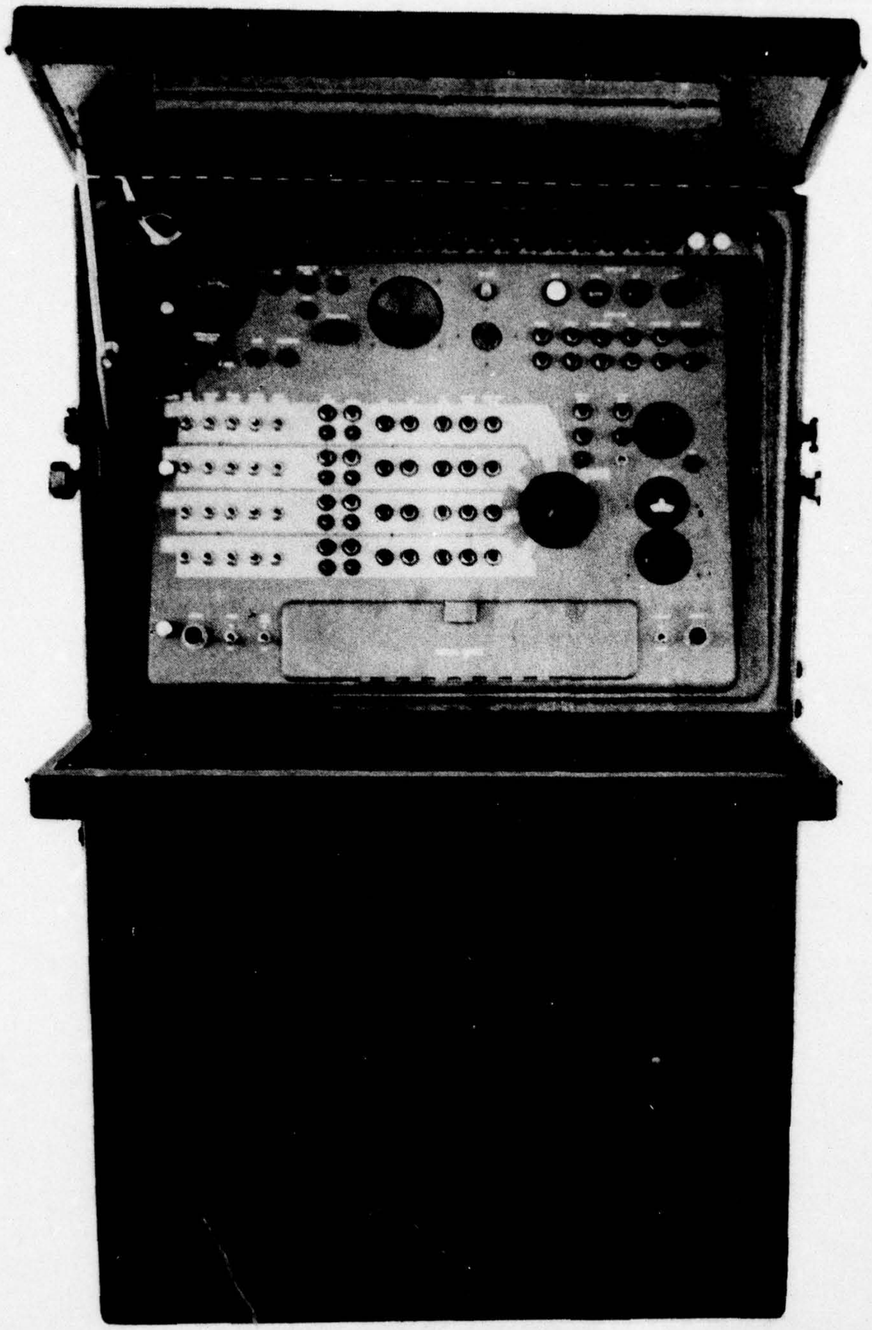

Figure 1. Tactical SCI

Hercules site and identified each major piece of equipment, giving a brief description of its function. (See Appendix B for the diagram and orientation.) The instructor requested questions from the trainees at this point. Very few questions were asked, and all questions were answered as directly as possible.

Following any questions and answers, the instructor moved to the training device and presented a demonstration talk-through of the 92-step procedure. He demonstrated and described the signal for an action and the action itself. He gave an explanation of why the action was taken. These explanations were very simple. For example, the first signal was the simultaneous illumination of a Blue Status light and sounding of an alarm buzzer. The proper action was to turn the Power switch to ON position. The explanation of why this action was taken was, "You turn the Power switch ON so that you will have power to this panel." The demonstration and talk-through included all of the 92 steps.

When this demonstration was completed, the instructor selected a trainee and required that he attempt to perform the complete procedure. The instructor told the other four trainees to watch carefully and to be prepared to identify the correct action if the performing trainee made an error. For the majority of the errors, the instructor would request identification of the correct action from an observing trainee. When the correct action was specified the instructor required the performer to make this action and the procedure was continued until the 92nd step was taken.

When the first trainee had finished the procedure, a second trainee was selected to perform on the training device, and the first trainee became an observer. This process was continued until each trainee had served as a performer twice and as an observer eight times. Training was completed at approximately 1030 hours the same morning.

During this training the instructor reinforced correct actions by such verbal expressions as "Good," and "That's right." Not every correct action was reinforced, and no attempt was made to follow an exact schedule of reinforcement. However, reinforcement was used more frequently in the early stages of training than it was in the later stages. Many times this reinforcement was also knowledge of results for the trainee.

The instructors also used cueing as a training technique. When a performing trainee would hesitate to take some specific action after he had apparently recognized the signal, the instructor would attempt to give a cue (or clue) to the correct action. As an example of a cue, consider the following conditions. The seventh action is, "Plug the Headset-Handset into Station 2." The seventh action's completion is the signal for the eighth action to be taken; the operator should announce on the Headset-Handset, "Blue Status received, Section A." When a trainee had completed action seven and hesitated too long to make his announcement the instructor might say, "You plugged it in, now use it." Cueing was used much more often in the early part of training than it was in the later part. No exact schedule of cueing was attempted. Rather, each instructor tried to estimate the proper time for a cue and an appropriate cue to use.

The tactical SCI automatically furnishes knowledge of results (KR) to an operator after many of his actions. Thus, when the operator presses the Prepared button for launcher number 1, the red Prepared light goes out, and the green Prepared light illuminates. One of the training devices produces the same KR for trainees as does the tactical SCI. But the other devices do not always do so. Therefore, the instructor would present the performing trainee with these KR on a verbal basis. In the above instance, when a trainee pressed the Prepared button the instructor would say, "Now this red light is off, and this green light is on," while he pointed to the proper lights.

Just as the instructor was required to give verbal KR to trainees when the training device did not do so, the trainees were required to produce a verbal action in place of a physical one at times. Thus, the trainee was required to monitor for a green Missile Ready-to-Fire-light as the action for step 62. During the training process, when a device would not illuminate the Missile Ready-to-Fire-lights, trainees were required to tell the instructor, "Now I am waiting for the Missile Ready-to-Fire-light for launcher 1 to come on," or make some similar statement that informed the instructor that he was taking the proper action (monitoring).

Training time varied from training group to training group. The experiences that each group underwent were controlled, but the total amount of time spent in the training situation was allowed to vary.

At no time was the trainee made to feel that he was rushed. One rest break was given approximately half way through the training time period. Otherwise the training was continuous.

All training was conducted in a room approximately ten feet wide and fifteen feet long. Other activities were going on inside the building, but not in the same room. The room was heated with a gas heater during cool weather and cooled with an evaporative cooler in hot weather.

Trainees.

Since the task selected for this research was from MOS 177, men receiving training in this MOS could not be used as trainees. They would have varying amounts of information about the task. Therefore, men were used who were receiving training in MOS 192, Air Defense Artillery Automatic Weapons Crewman. This decision presented the problem of selecting MOS 192 trainees who were of a comparable talent level to men in MOS 177 training. To resolve this problem, the General Technical (GT) scores of all men in training for MOS 177 were obtained from personnel records, and a distribution of these scores was made (see Appendix Table C-1). Then, groups of trainees for MOS 192 were selected such that the GT scores of each group matched the GT score distribution of the MOS 177 sample.

The GT score was chosen for the above selection factor because, of the Army aptitude area scores, this score is the most like a measure of general intelligence (Helme, 1960). Selection on only one aptitude variable was considered useful because the positive correlations among the several aptitude scores produces diminishing returns as control with additional variables is applied. Since only one variable was to be used for the matching process, a measure of general intellect seemed to be the most meaningful one to use.

Experimental and statistical controls.

Statistical control was applied to the intellectual level of the trainees. First, each group of men trained with any device was selected to match a particular distribution of GT scores (see Appendix Table C-1). This procedure was described in the preceding section. Then the variance associated with GT scores was removed from proficiency scores by statistical methods.

Differences among proficiency scores due to different instructors were also removed. Again, a statistical process was used. This control was applied in spite of the fact that the instructors, to reduce differences among themselves, practiced the training procedure at length and observed the practice of each other.

The method of training was controlled by specifying exactly the orientation, demonstration, and use of training devices. The use of reinforcement, cueing and verbal knowledge of results, along with the training methods, were practiced until each instructor was very proficient in their use.

The experience level of trainees with respect to the task to be learned was controlled. By using only men from another MOS who were naive with respect to Nike Hercules, no trainee used in this research knew anything of the task before training began.

Instructors.

Four persons served as instructors for this research. Each of these men was a research employee of the U. S. Army Air Defense Human Research Unit.

Proficiency measurement.

A high fidelity simulator of the SCI (the hot panel) was prepared (see Figure 2). The panel of this device was fully functional since all switches, meters and lights operated, appropriate sounds were provided, and the intercom and Handset-Headset operated. Even time delays of the tactical equipment occurred during operation of the simulator. For the purposes of this research, the hot panel device was considered equivalent to the tactical SCI and the relative effectiveness of other training devices was evaluated by testing the trainees on this hot panel.

For the proficiency test, a trainee was told that he was to perform the 92-step procedure using the hot panel. He was told that all parts of the device operated. Then the instructor operated a switch which turned on the Blue Status light and the alarm buzzer, and the trainee began the procedure he had learned. The instructor continued to operate the instructor's console and recorded each error the trainee made. An error was recorded for each step omitted or taken out of sequence. If the trainee asked a question, the question was answered and an error was recorded for that step. If the trainee made an error which would have prevented the procedure from being continued, the instructor corrected that error and recorded it, allowing the trainee to continue the test. The proficiency score was the number of steps performed correctly.

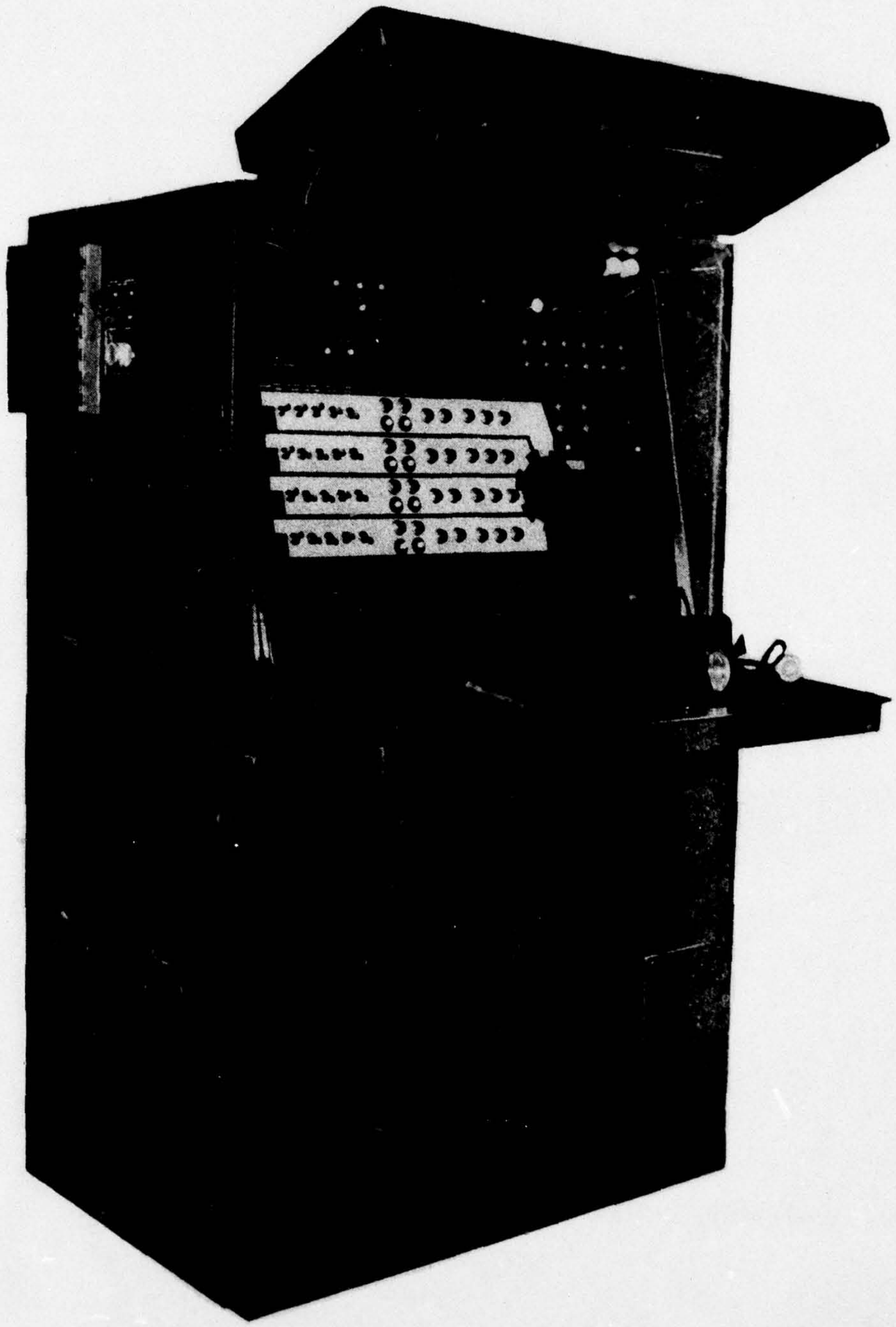

Figure 2. High Fidelity SCI Simulator
(Hot Panel)

At no time was the trainee made to feel rushed. The trainee was told that time was not a score on this test and that accurate performance was to be scored. Actually, total test time was recorded along with the proficiency score.

Each trainee was tested in the same room in which training had been conducted and in the same order as he performed during training. Only the trainee being tested and the instructor were in the room during the test. Training was completed about 1030 hours and testing was done between 1300 and 1400 hours the same day. Approximately ten minutes were required to test one trainee.

Training Devices

Twelve different training devices were used in the series of studies reported here. A brief description of each device has been presented below to give the reader an orientation to the discussion of each separate study.

The Hot Panel. This device was described on page 12 and illustrated in Figure 2. It was the same size and shape as the tactical SCI. Every light, switch, meter, intercom, and telephone on this device functioned.

The Cold Panel. On this device, every part was identical with the corresponding part on the hot panel. However, there was no electrical power to the device. Therefore no lights, meters, intercom, or telephone functioned. All switches still could be operated.

The Frozen Panel. Every part on the frozen panel was nonoperable. No light, meter, intercom, or telephone operated. No switch operated because each was immovably fixed in OFF position.

Cardboard Panel. The entire device was fabricated of cardboard, including the housing. The panel itself was painted in color to resemble the hot panel above. The remainder of the device was painted the same gray color as that of the other device housings.

Photographic Panel. This device was a full-sized black and white photographic print of the hot panel above.

Drawing Panel. This device was a full-sized black and white line drawing of the hot panel described above.

Hi-Fi Housing. This device was a replica of the wooden housing of the hot panel, with the cold panel installed during training.

Box Housing. This device was a box made of plywood. It was of appropriate size and shape to hold the cold panel, which was installed in this device during training.

Frame Housing. This device was a simple wooden frame of appropriate size to hold and support the cold panel.

Full-Sized Panel. This device was almost identical with the drawing panel described above and was also a line drawing. It has been differentiated from the drawing above because on the full-sized panel the lettering was larger than that on the drawing panel. The full-sized, 22" x 30", panel was used in a study of size.

Half-Sized Panel. This device was a 15" x 22" reproduction of the full-sized panel above and was one-half the area of the full-sized panel.

Small Panel. This device was a 5" x 7" reproduction of the full-sized panel and was one-nineteenth the area of the full-sized device.

Functional Fidelity - Study I

In this study, three levels of functional fidelity were defined. Measurement of the dimension was categorical, and no assumption was made that the categories were equidistant from one another.

Training devices.

The hot panel has been described above. It represents very high fidelity.

The second device was called the cold panel (see Figure 3). Every part of this panel was identical in appearance to a corresponding part on the hot panel. However, none of the lights would illuminate, and none of the meters would register. The Handset-Headset would not operate, although it could be plugged into the panel face. The intercom did not function, and no sounds were produced by the device. All switches were functional in that, when the

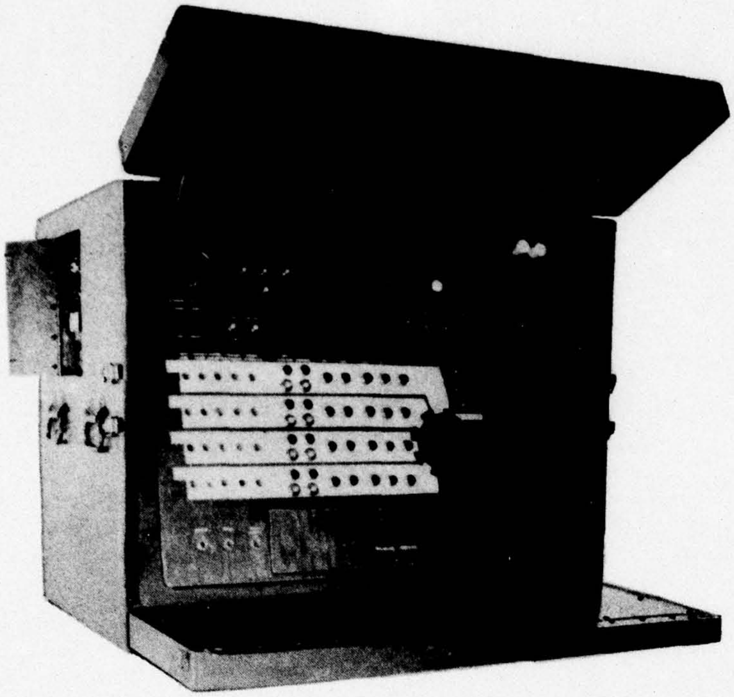

Figure 3. Cold Panel

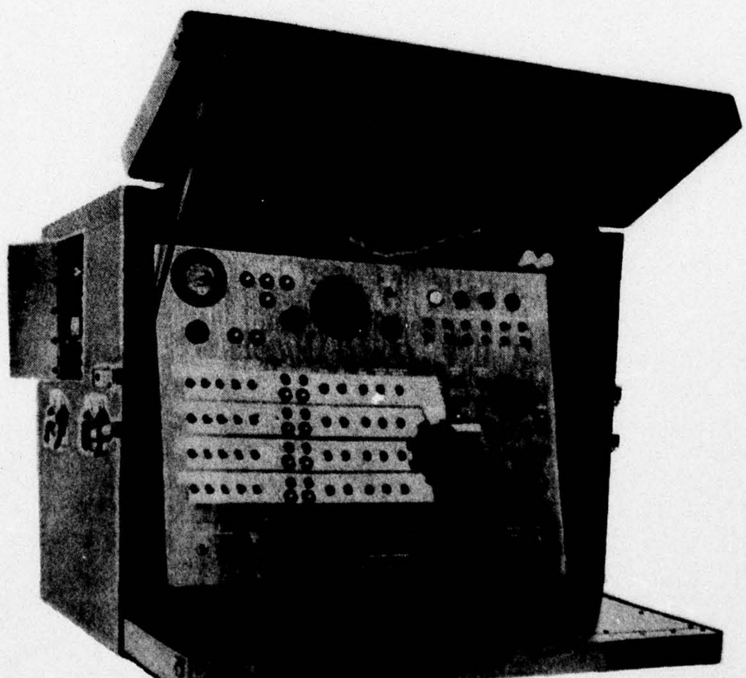

Figure 4. Frozen Panel

trainee pressed them or twisted them, they moved properly. This device represented a reduction in functional fidelity.

The third device was called the frozen panel (see Figure 4). Again, every part was identical in appearance to a corresponding part on the hot panel. However, no part on the frozen panel would operate. Not only would the lights, meters, intercom, and Handset-Headset not operate, but all switches were locked in one position. This device represents the minimum level of functional fidelity for a device which retains three dimensional quality.

Collection of the data.

Four groups of five men were trained to perform the 92-step procedure with each of the above devices. Two instructors each trained one five-man group and a third instructor trained two five-man groups with each device. Each instructor administered proficiency tests to those men whom he trained. Thus, 20 men were trained with each panel.

Analysis of the data and results.

Control of the effects of trainee intelligence was obtained through analysis of covariance in which proficiency scores were adjusted for variation associated with GT scores.[1/] The adjusted proficiency scores were tested for differences due to use of the three

1/ Tests of homogeneity of regression were performed to assess the legitimacy of this analysis, and the results have been presented in Appendix Tables C-2, C-3, and C-4. In each case, the hypothesis of homogeneity of regression was retained.

different panels, differences due to the three instructors, and interaction effects associated with panels by instructors. The overall unadjusted proficiency score mean was 84.7. When the affects of intelligence (as measured by GT) were removed from the proficiency scores, no differences in proficiency were found which were associated with training devices, instructors, or the interaction between devices and instructors ($p > .05$). The distributions of proficiency scores are presented in Appendix Table C-5. Results of the covariance analysis are presented in Appendix Table C-6. Appendix Tables C-7 and C-8 contain the unadjusted and adjusted mean proficiency scores.

The training procedure allowed the total training time for each five-man group to vary. The fastest group completed training in 2 hours, 15 minutes while the slowest group completed training in 3 hours, 30 minutes. The mean training time was 2 hours, 41 minutes. Since the mean training time for each group was not correlated with the mean GT score for the group ($r = .22$, $p > .05$), a covariance analysis of training time scores was not considered to be either necessary or useful. To determine if there were significant differences among training times for panels and instructor groups, an analysis of variance was performed (Lindquist, 1953, p. 156). The results, presented in Appendix Table C-9, showed that differences among training times for panels and instructors were within chance expectation ($p > .05$). The training time means for panels and instructors are presented in Appendix Table C-10.

Two-Dimensional vs. Three-Dimensional Devices-Study II

When a frozen panel was used for training, trainees could and did reach out and handle the various switches and knobs on the panel face. This tactile and kinesthetic behavior was conceived as endowing the frozen panel with some degree of functional fidelity. Thus, a panel which was a flat surface would represent a lower degree of functional fidelity because the flat surface would reduce sensory effects from touch and kinesthesis. Following this line of reasoning, the following training devices were prepared.

Training devices.

The first training device was the hot panel. This was the same device as was used in the first study. The frozen panel from the first study was also used here. These two panels were considered to represent the functional fidelity category "three-dimensional."

A full-sized black and white photograph of the hot panel was prepared. This photograph was mounted on plywood and installed in place of the frozen panel (see Figure 5). This device was considered to be one technique of representing the "two-dimensional" category of functional fidelity.

A full-sized black-on-white line drawing was used as another two-dimensional device. The spatial relationship of panel control elements was maintained by showing all parts on the panel face in as

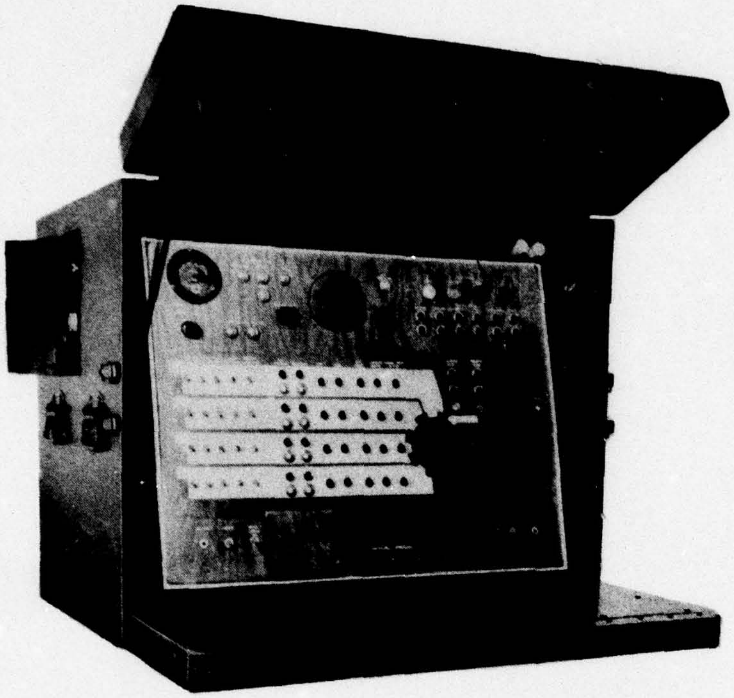

Figure 5. Photograph Panel

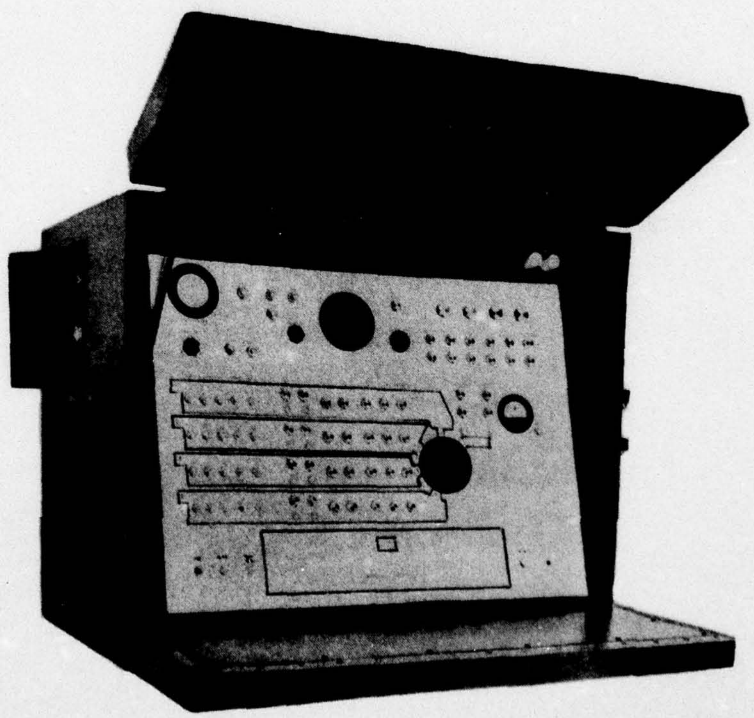

Figure 6. Drawing Panel

true size and configuration as the mode of representation permitted. The drawing was mounted on plywood, shielded with plastic, and installed just as the photograph had been (see Figure 6).

Recognition is given to the fact that there are appearance differences between each of the two-dimensional devices and any one of the three-dimensional devices. Thus, there is some confounding of appearance fidelity and functional fidelity in this study. Regardless of the confounding, the study seems worthwhile on a practical basis.

Collection of the data.

The data collected for the hot panel and frozen panel of Study I were used again in this study. Collection of data with the photograph and drawing panels followed the pattern described for Study I. Four five-man groups were trained using each device to train 20 men. Two instructors trained one five-man group with each panel, while the third instructor trained two groups with each panel. Since four training devices were used, a total of 80 trainees were used for this study.

Analysis of the data and results.

An analysis of covariance was performed on the proficiency scores, intelligence being controlled with GT scores.[1] The adjusted proficiency scores were tested for differences due to panels, differences

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[1] Tests of homogeneity of regression may be found in Appendix Tables C-11, C-12, and C-13.

due to instructors, and effects of panels by instructors interaction. The results of this analysis have been presented in Appendix Table C-14 and show that none of the above factors produced differences among adjusted proficiency scores larger than chance ($p > .05$). The overall unadjusted mean proficiency score was 84.4. A distribution of unadjusted proficiency scores appears in Appendix Table C-15. Unadjusted proficiency score means are in Appendix Table C-16, and adjusted proficiency score means are in Appendix Table C-17.

As in the first study, training time was found to be uncorrelated with GT scores ($r = .11$, $p > .05$). An analysis of variance was performed on the training times to determine if instructors or panels differed significantly in training time (Lindquist, 1953, p. 156). The results of this analysis are presented in Appendix Table C-18 and show that no significant differences in training times can be attributed to different instructors or to the use of different panels ($p > .05$). The fastest group completed training in 2 hours 15 minutes, the slowest group in 3 hours 30 minutes, and the mean training time was 2 hours 48 minutes. Appendix Table C-19 presents the mean training times for instructors and panels.

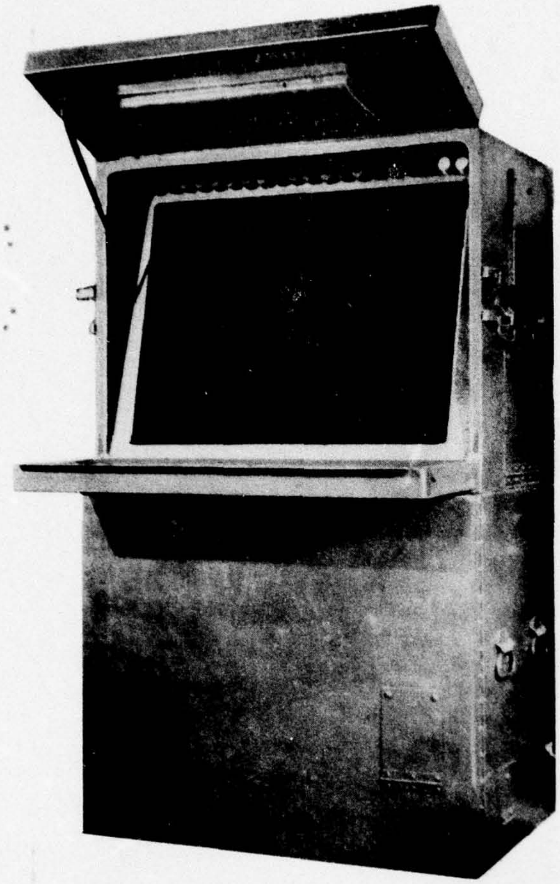
Reduced Housing Fidelity - Study III

This study differed from the previous ones in that appearance fidelity was the quality being investigated as opposed to functional fidelity. The specific appearance fidelity being considered was that of housing for a training device. During this task, the operator neither performs any actions on nor receives any procedural signals from the housing. The housing was a structure which supported the SCI panel. This meant that for the task being trained the housing should have no great importance to the trainee. Only if the trainee's attitude toward the device was negative because the housing looked unrealistic, and if attitude affected a trainee's proficiency score, would the appearance of the housing be important.

Training devices.

Since the previous work had shown that lower-than-perfect functional fidelity panel faces could be used to train men for this task without affecting proficiency level, a cold panel (see Figure 3) was selected for use in this study. The cold panel could be moved from housing to housing easily, a high fidelity housing already existed for it, and the panel was inexpensive to build.

The high fidelity housing was as near identical to the hot panel housing as a handmade cabinet could be. It represented the highest level of appearance fidelity in this study, and it has been shown as Figure 7. Another housing was prepared as a box. This device would hold the cold panel in the proper position and conceal the back side of the panel (see Figure 8). The box was painted the same gray color as was the high fidelity housing. This box represented a reduction in housing fidelity. The third housing was a simple frame (see Figure 9).



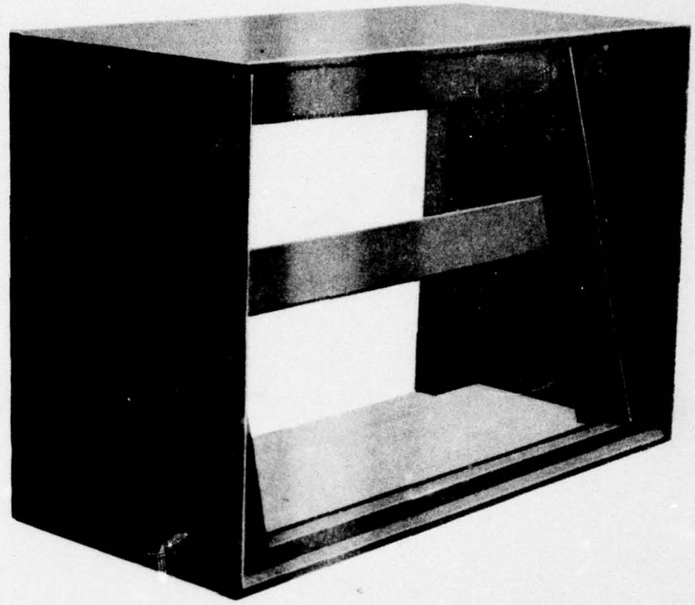


Figure 8. Box Housing

Figure 7. High Fidelity Housing

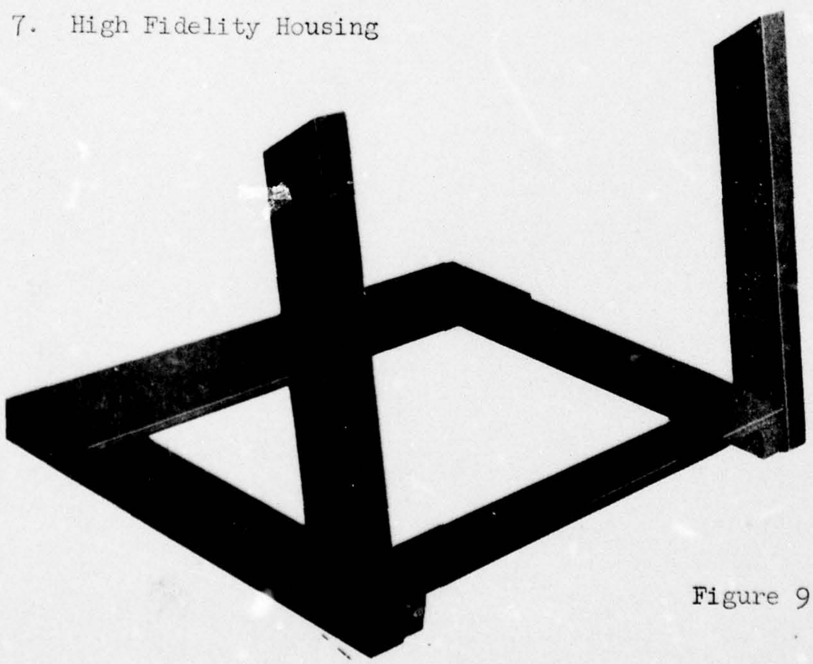


Figure 9. Frame Housing

This frame was neatly constructed but only supported the cold panel. It did not conceal the back of the panel. The frame represented the lowest level of housing fidelity used in this study.

Collection of the data.

Each of three instructors trained one five-man group with each of the housings using the cold panel. Proficiency scores were collected on 45 trainees, as previously described, using the hot panel for the test.

Analysis of the data and results.

A distribution of the proficiency scores is presented in Appendix Table C-20. The data were tested for homogeneity of regression within cells. The test, presented in Appendix Table C-21, showed that the assumption of homogeneity of regression within cells was not tenable. Thus, a two-way analysis of covariance which was originally planned was not legitimate.

A test was performed to determine the homogeneity of regression among the three housings. The test demonstrated that the assumption of homogeneity of regression was tenable for housing effects (see Appendix Table C-22.

A simple analysis of covariance was performed on the proficiency scores. In this analysis, proficiency scores were adjusted for individual differences associated with GT scores. As shown in Appendix

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Table C-23, no differences among adjusted housing means were found beyond those which chance would have produced ($p > .10$). The means for unadjusted and adjusted proficiency scores have been presented in Appendix Table C-24.

The training times for each of the nine groups were correlated with the mean GT score for that group. The resulting coefficient was $r = .15$, $p > .05$. Since the correlation was not significantly different from zero, no correction for GT differences was applied to the training times.

The training time scores were submitted to an analysis of variance to determine housing and instructor time differences. No significant differences in training time were found to be associated with housings or instructors ($p > .10$). These findings are summarized in Appendix Table C-25. Appendix Table C-26 presents the mean training times.

Cardboard Mock-Up--A Replication - Study IV

A suggestion was made to use a mock-up of the SCI fabricated from cardboard.[1] Accepting this suggestion not only meant development of the mock-up and testing its teaching effectiveness, but it gave the opportunity to repeat the test of two- vs. three-dimensional devices and to vary housing appearance.

1/ This suggestion was made by Mr. C. W. Polvogt, who was working for the U. S. Army Air Defense Human Research Unit as an artist illustrator.

Training devices.

Two devices from the previous studies were used again in this research; the hot panel and the cold panel. The third device was a cardboard mock-up of the SCI. A picture of this device is presented in Figure 11. The housing of this device was painted to match the color of the high fidelity housing. The face of the panel was drawn to scale and parts on the panel were painted in color to resemble those of the illuminated hot panel.

Thus, the hot panel represented full functional and housing fidelity. The cold panel represented a three-dimensional reduction in functional fidelity and full housing fidelity. The cardboard panel represented a two-dimensional reduction in functional fidelity and a reduction in appearance fidelity for both the panel and housing.

Collection of the data.

Collection of data followed the pattern previously described. Three instructors gathered the data. Each instructor trained one five-man group with each device. Thus, each instructor trained 15 men, and 15 men were trained with each device. Training was conducted using the hot panel, then the cold panel, and finally the cardboard mock-up. In all, 45 trainees were used in this study.

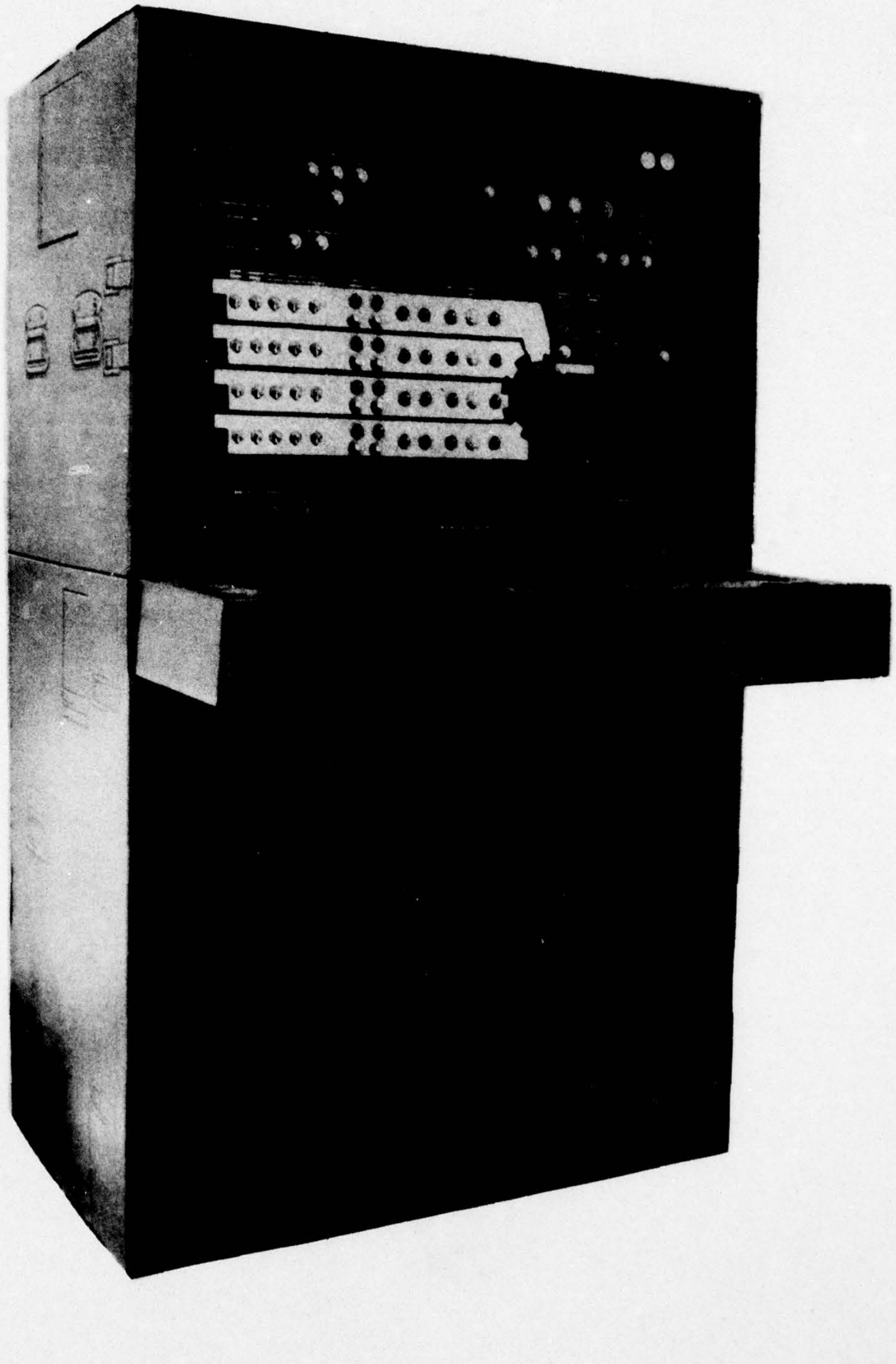

Figure 11. Cardboard Mock-UP

Analysis of the data and results.

An analysis of covariance was performed on the proficiency scores, intelligence variation being controlled with GT scores.[1] The adjusted proficiency scores were tested for differences associated with panels, with instructors, and with the panels by instructors interaction. The results of the covariance analysis showed that, when intelligence was controlled, there were no differences associated with proficiency which could be attributed to panels, instructors, or to panel by instructor interaction ($p > .10$). Distributions of proficiency scores are presented in Appendix Table C-30. Means of the unadjusted proficiency scores for the various groups are presented in Appendix Table C-31. The adjusted mean proficiency scores were prepared as Appendix Table C-32. A summary of the covariance computations has been placed in Appendix Table C-33.

The correlation between group training times and GT scores was computed. The resulting coefficient was $r = .23$ which was not significantly different from zero ($p > .05$). Thus covariance analysis to control for intellectual function was not performed. Rather, an analysis of variance was performed on the group training times. This analysis examined the training times for differences associated with

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1/ Tests of homogeneity of regression for these data may be found in Appendix Tables C-27, C-28, and C-29.

the three panels and the three instructors. No differences beyond chance ($p > .10$) were found to be attributable to either instructors or panels. The results of the analysis have been presented in Appendix Table C-34. Mean training times for panels and instructors are presented in Appendix Table C-35.

Reduced Size of Device--Study V

The objective of this study was to determine the effects on proficiency when the size of a training device was reduced. The results of the previous four studies were considered in designing the present investigation and produced changes which simplified the work.

Training devices.

Line drawings were used as training devices throughout the size investigation. Three facts affected this decision. Study II had demonstrated that a drawing was as effective as was a hot, cold, frozen, or photographic panel. Drawings were the least expensive to prepare of the five devices. And drawings were very easy to produce in the three sizes selected for this research. The following devices were used:

1. Full sized panel. This was a black-on-white line drawing of the hot panel. It was the same overall size (22" x 30") and the panel parts were the same size as those of the hot

panel. The lettering on this panel was somewhat larger than that on the hot panel. Otherwise, this device was the same as the panel shown in Figure 5.

2. Half sized panel. A photographic plate was made of the full sized panel, and 15" x 22" prints were made from the plate. These prints were one-half the area of the full sized panel, and each was mounted on stiff cardboard.

3. Small panel. A second plate was made of the full sized panel, and 5" x 7" prints were made from the plate. These prints were mounted on stiff cardboard for the small panels.

The relative sizes of the three panels is illustrated in Figure 12.

Training methods.

Use of the small panel forced a change in the training method used in previous studies. The reader will recall that heretofore the training device was displayed to a five-man group, and all training was given with the panel in a position such that every trainee could see it all the time.The 5" x 7" panel, however, was too small for group instruction and a copy would have to be given to each student. Since the size of the device would force a change in device/student ratio, the effect of the device/student ratio was evaluated in this study by using two different training methods.

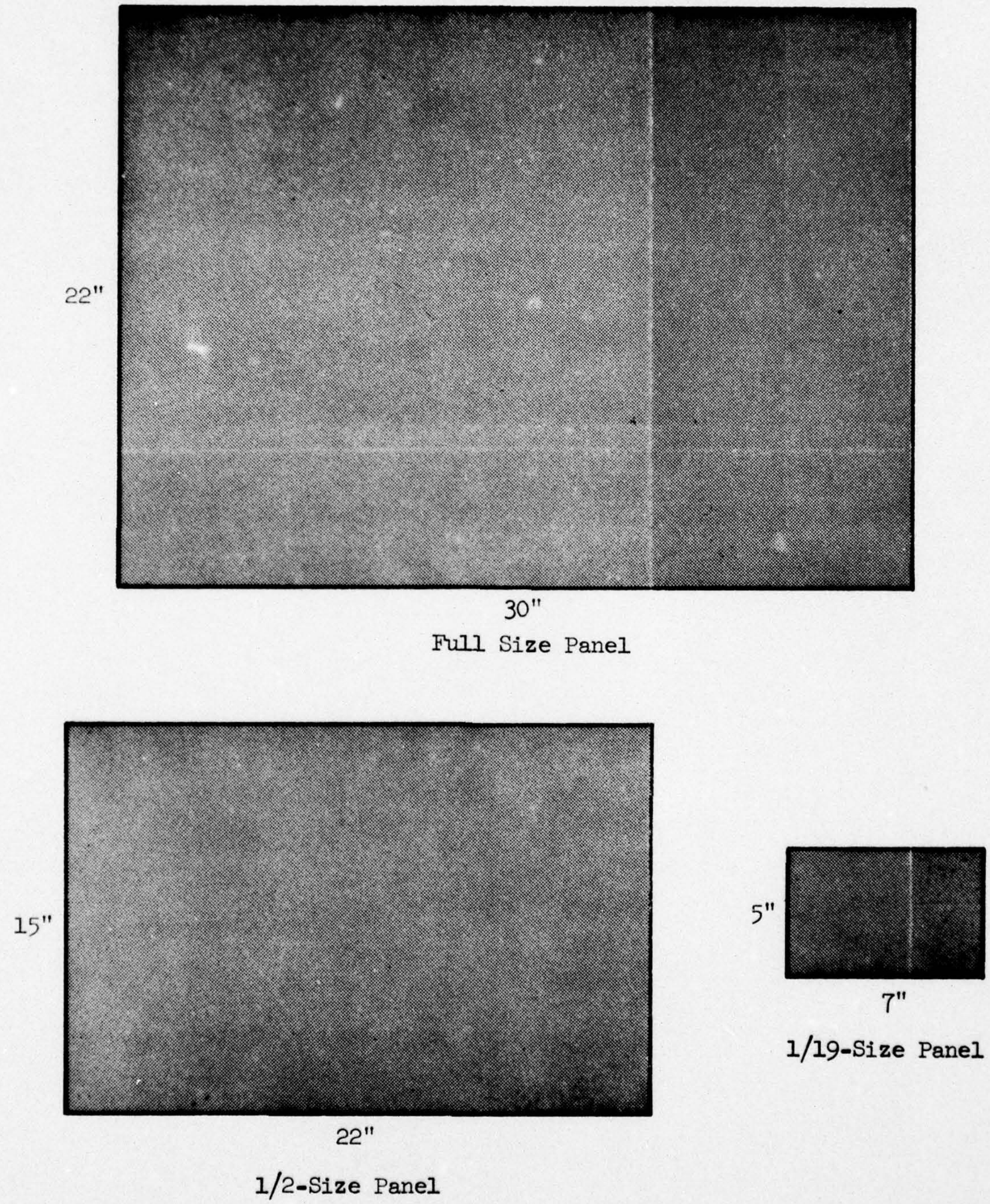

Figure 12

Relative Sizes of the Three Panels for Study V

Training Method I used the 5/1 student device ratio and training procedures described previously. This method was used both for the full size panel (22" x 30") and the 15" x 22" reduction. In Training Method II, each trainee was given a panel identical with that being used by the instructor. The instructor demonstrated the procedure as before, pointing to his panel as he proceeded. Each trainee followed the demonstration using his panel to see details and glancing at the instructor for general direction. After the demonstration, the instructor required one trainee to perform the procedure using his own panel, giving verbal responses and putting his finger on the panel part that was being operated. The other trainees were instructed to follow the performer on their own panels and to be prepared to give a correct action if called on to do so. When the performer made an error the instructor stopped him and asked one of the observers what the correct action should have been. When the correct action was identified, the performing trainee was required to give the correct verbal response and to continue the procedure. This process was continued until the performing trainee had completed all 92 steps. At this point, a second trainee acted as the performer and the first became an observer. This process was continued until each trainee had served as a performer twice and an observer eight times.

This training method was used with both the 5" x 7" panel and the 15" x 22" panel.

Trainees.

As in the previous studies, men for this research were in training for MOS 192. From this group, no man was selected whose GT score was below 70. Otherwise each of the 60 trainees used here was selected at random from the MOS 192 trainee group which was on post while the study was being performed.

Instructors.

Two of the researchers served as instructors in this study. Each of them had served as an instructor in the other four studies.

Training conditions.

Training was performed under four conditions, and three five-man groups were trained under each condition.

1. A full sized device was used with Method I.
2. A half sized device was used with Method I.
3. Half sized devices were used with Method II.
4. Small devices were used with Method II.

Randomization.

The reader will recall that several factors were statistically controlled in the previous four studies, and that of these factors only GT level was significantly associated with proficiency scores. To simplify the procedures, these controls were dropped in the present study. Trainees and instructors were randomly assigned to five-man groups. Groups were randomly assigned to the four training conditions. And trainees were randomly assigned to a position in a rotational order of training.

Collection of the data.

One five-man group was trained each day. Training began at approximately 0730 hours and was completed about 1000 hours. The group was released and returned at 1300 hours for proficiency testing. The proficiency test was the same as for the previous studies.

Analysis of the data and results.

Mean proficiency scores were computed for each of the four training conditions (see Appendix Table C-36). To estimate the effect of training method on proficiency, with device size held constant, the mean proficiency scores from conditions two and three were submitted to a t-test. The means were not significantly different from each other ($t = .77$, $p > .10$). This finding was interpreted to mean that method of training did not effect proficiency development in the present situation. Therefore, the proficiency scores were treated with analysis of variance to estimate the effect of size of device on proficiency development. Data from conditions two and three were pooled for this analysis. The result was an F - ratio of 1.08 which was not significant at the .10 level of confidence (see Appendix Table C-37).

A Field Study - Study VI

To this point, the studies had shown that various reductions in fidelity of training devices had not effected the development of proficiency nor increased the training time. However, the instructors had been researchers and the trainees had known that the training was experimental and not practical to them. Also, the training conditions had been controlled as in a laboratory. The above factors were not typical of the usual Army training circumstances. A field study was designed in which military instructors trained soldiers who knew that they would be assigned to duty requiring them to perform the task on which training was given. In addition, the training was given under circumstances much more like those usually found in Army training. This field study was conducted to determine if the reduction of device fidelity would still have no effect on proficiency development or training time under these more realistic conditions.

Training Devices

The low fidelity training device was the line drawing used in Study II installed on the frame housing. It was chosen because it seemed likely that if one of the reduced fidelity devices was selected for Army use, the drawing would be the choice because it was economical to develop and reproduce. The high fidelity training device was the actual tactical SCI, the equipment which was being used in the current Army training program. The panel of the tactical SCI, as installed for training, will function completely for one launcher and only partly for the other three launchers. At times, there is no power to the SCI because of malfunctions in other equipment in the system being used for training.

Instructors

Each instructor used in the field study was currently qualified and instructing in the 177 MOS. Selection of instructors was not controlled by the researchers. Rather, permission was obtained to use trainees for the study as they were received by the Batteries from Basic Combat Training. These trainees were routinely assigned to training groups and the groups were assigned to instructors. There is no reason to suppose that selection of instructors for the field study was other than random.

Trainees

From the above description, the reader can see that there was no reason to suspect that assignment of trainees to the field study was other than random. Each trainee had completed Basic Combat Training and had been assigned to Advanced Individual Training for MOS 177.

Treatments

The SCI panel drawing was used as the training device for the experimental treatment. The trainees were given a tour of the training site and shown each piece of Nike Hercules equipment. A short explanation of the function of each piece of equipment was also given the trainees. Then, trainees were assigned to groups of from 9 to 13 men each, and training began.

The trainees were taught to perform Blue Status and Red Status procedures, just as had been done in the previous studies. Each instructor used the training techniques he already knew. A researcher observed this training. The training was conducted in a room ordinarily used as an Army classroom and during the regularly scheduled training day.

As the instructor determined, through his own proficiency estimates, that a trainee had attained sufficient proficiency to proceed to other training, the trainee was taken to another building and given a proficiency test by one of the researchers. The observing researcher also noted the total number of hours of training required for each trainee to reach this proficiency level.

The tactical SCI was used for the control treatment. Trainees were given the same orientation and group assignment as described above for the experimental treatment. The same task was taught to them, and a researcher observed the training. The training was given outdoors in a sandbagged area to the front of which was the tactical SCI.

The instructors performed just as they normally did, using techniques which they already knew well. When an instructor determined a trainee to be sufficiently proficient, the trainee was given a proficiency test by a researcher. The observing researcher recorded the training time for each trainee as before.

Proficiency Test

The same proficiency test was used in this study as had been used in the previous studies, and all tests were administered by the same researcher.

Prior to use of the high fidelity simulator as the testing device for this field study, 16 trainees who had been trained on the tactical SCI were given the proficiency test on both the tactical SCI and on the high fidelity simulator. These two sets of proficiency scores were correlated, $r = .80$. This was considered sufficient evidence of the validity of the proficiency test administered with the high fidelity simulator to justify its use for proficiency testing in this field study.

Data Collection

A total of 36 men were trained with the experimental treatment by three instructors, each of whom trained one group of men. Training always began on Monday and was completed by Thursday of the same week. Another 35 men were trained by four different instructors who used the control treatment. The same general training schedule was followed as above.

Analysis and Results

Mean proficiency scores were computed for each of the above treatment groups. The mean proficiency score for the control group was 77.03 and for the experimental group 78.33. A t-test of the difference between these means was $t = .741$, and showed the difference was well within the chance level ($p > .05$). Mean training times were computed for the two treatment groups. The mean training time for the control group was 12.62 hours and for the experimental group, 10.35 hours. These two mean times were tested for differences with a t-test and found to be no more different than chance would allow ($t = 1.835$, $p > .05$).

The four instructors who used the line drawing for training were interviewed when training was completed. Each of these instructors had trained men with the tactical SCI as a part of their regular instructional duties. Three basic questions were asked of each instructor:

1. Was the proficiency level of men trained with the drawing as high as that of men trained with the tactical SCI? One instructor gave a definite negative response. This same man was negative in his attitude to the drawing throughout the experiment. However, he cooperated well. Two other instructors gave a qualified and mild "no" answer to the question. The other instructor gave a very positive "yes." Thus, the instructors were balanced about evenly in their attitudes toward the proficiency level of the drawing-trained trainees.

2. Was more training time required when the drawing was used than when the tactical SCI was used? One instructor said, "Yes." The other three gave negative replies saying that there was no time difference.

3. Was more work involved when the drawing was used? Two instructors replied, "Yes." They said that the extra explanation (observed by research instructors) made instructing with the drawing more work than instructing with the tactical SCI. The other two instructors replied, "No." They said that instructing with the drawing was easier, not because of the device itself, but because the training was indoors where the instructor had better control of the attention of trainees.

Discussion and Conclusions

Previous sections of the report have described the research objectives, the methods, and the results of the studies. The present section discusses the results and their implications.

Functional fidelity.

The first study varied functional fidelity at three categorical levels while maintaining the three-dimensional quality of the devices. The major finding of the first study was that men can be trained to perform a procedure as well with nonoperating devices as they can with a functional device. The second study extended the reduction of functional fidelity to two-dimensional devices. The second study revealed that men can be trained to perform a procedure as well with full size photographs and drawings as they can be with a perfectly functional device. The fourth study replicated the first two studies, varying the form of the two-dimensional device. The findings of the fourth study confirmed those of the previous two studies, which lends confidence to the validity of the results. The field study showed that the above findings apply where military instructors are training soldiers to whom the training is realistic.

Other investigators have reached similar conclusions. Denenberg (1954) studied the transfer of training effects of an inexpensive mock-up of a tank hull and found that, for starting and stopping procedures, the mock-up was as effective as was the tank itself. While studying the training of ground cockpit procedures for an aircraft, training on a simple cockpit mock-up was found to transfer very well to procedures performed in the aircraft (Prophet & Boyd, 1962). Training in flight procedures has been found to be successfully accomplished by use of a full fidelity simulator, a cold simulator, and a photograph mock-up (Dougherty, Houston, & Nicklas, 1957). Aircraft basic instrument and radio range training have been taught equally well with two devices at different levels of fidelity (Wilcoxon, Davy, & Webster, 1954). Torkelson (1954) trained ROTC students and recruits in the nomenclature and function of an antiaircraft weapon using a mock-up, a cutaway, and charts. No differences were found among device effectiveness for the ROTC group, while the recruits showed equal performance when trained with all devices except black-and-white charts, for which performance was low. When Air Force mechanics were being retrained on B-47 fuel, hydraulics, or rudder power control systems, several types of training devices were compared (Swanson, 1954). The level of functional fidelity was not a concern, but it logically did vary. The following types of devices were compared; an operating mock-up, a nonoperating mock-up, a cutaway, an animated panel, charts, and symbolic diagrams. No differences were found in proficiency by training device, and there were still no differences in proficiency by device, six to eight weeks later.

The evidence presented above, both from the present studies as well as from other research, forms a rather firm conclusion. When men are being trained to perform a procedure, and a training device is to be used as a method of training them, the requirements for functional fidelity in the device are quite low.

In spite of the facts presented above, there are limitations on the conclusion. The conclusion is limited to procedural tasks. No evidence is presented which should encourage generalization to psychomotor tasks, decision making tasks, or any work classification other than procedures. The reader should also recognize that the whole training process melds to produce the proficiency of trainees. The training device did not train these men by itself. The orientation, the techniques of instructors, and the psychological atmosphere of the situation all affected trainees and their acquisition of proficiency at the task. In each of the studies, some variations occurred in using verbal signals to replace visual and auditory signals. In the present studies, these variations produced no significant differences in performance. But changes in the training environment in which the training device is used may be such that differences in the effectiveness of devices would occur at different levels of functional fidelity.

Within the above limitations, there is still a powerful implication emerging from the conclusion. The cost of equipment for training must be large when tactical equipment is the training device. For example, cost of the SCI itself has been quoted by a training officer as about $11,000. To use it in a "full fidelity" mode, a power generator, a Launcher Control Trailer, one launcher, and a missile are required. The authors estimate the full fidelity simulator (Hot Panel) used in this research would cost approximately $3,000.00 each. The cold panel and frozen panel cost estimate in high fidelity housing is $1,000.00 each. The photograph panel and housing cost estimate is $100. The drawing panel and housing cost estimate is $75. If the cardboard device was bought in quantity, its cost would be about $1.50 each. Thus, for a procedural task, training can be just as effective from a device costing $1.50 as that training conducted with a device costing more than $11,000. The designer of training programs should be able to select training methods, including training devices, so that the program uses less expensive, low functional fidelity training devices for procedures training and more expensive higher functional fidelity devices for training on tasks other than procedures, with a very substantial monetary saving.

<u>Appearance fidelity</u>.

Housing fidelity was studied as a dimension within the category of appearance fidelity. The housing was not operated upon by the job incumbent while he was performing the task used in this research. Thus, verying the housing did not affect the functional fidelity of the device but did affect the appearance fidelity.

The question to which the housing study was addressed was, "What is the effect on development of task proficiency when the housing of the device is degraded in appearance?" When the housing of the device was varied at three categorical levels, and men were trained with the three variations, no differences in proficiency were found which were due to housings. In addition, there was no difference in the amount of time used in training men with each housing. In Study IV a confirmation of this result was obtained with a cardboard housing. The field study also confirmed the above findings.

An answer to the above question has been given by results in this report. Under the limitations imposed by the task studied here, there is no effect on the level of proficiency development which is related to appearance fidelity on the housing dimension.

The implication is that the lowest cost housing available should be used which will adequately support and protect the man-machine interface. This conclusion is justified only when the procedural task being trained does not require the job incumbent to perform any operations on the housing.

In the study of size reduction of training devices, the appearance fidelity dimension of size was confounded with a training method factor. When the 5" x 7" device was used, the method of training had to be changed so that each trainee had his own training device to use rather than all five men using a single training device. As a result, data were collected to estimate the effect of the two training methods, and showed that training method had no effect on proficiency. Analysis of the data by the three size categories showed that men can be trained with a small device as effectively as they can with a full sized device.

This size study extends the implications of the other four studies. It now appears that when a training device is to be used to train small groups of men to perform a procedural task, small pictures or drawings can be used as the training device, each trainee having his own device on which to study and perform. The limitation on size reduction seems to be only that the trainee must be able to visually identify the elements on the device and to read any lettering.

Instructor work load.

The research instructors observed that the work load placed on them by all the devices which were reduced in fidelity was greater than the work load required when using the hot panel because the instructor, rather than the device, had to provide signals. The hot panel required the least work from an instructor because the panel itself presented many signals to the trainee and gave him knowledge of results directly. For example, the hot panel made a noise like the motor of a launcher when the Launcher Elevation switch was placed in UP position. This noise was both a signal to the trainee and knowledge that the previous action, positioning the switch to UP, was correct. None of the other panels gave these signals to the trainee, and so the instructor was required to give them verbally. This requirement meant that the instructor's attention was focused directly on the immediate training process during every moment of training when a panel other than the hot one was being used. The instructor was continually giving the trainee verbal signals.

When a three-dimensional panel was being used, the instructor told the trainee to manipulate the switches just as if the panel was functional (or to try to operate them for the frozen panel). The trainees then tended to "go through the motions" without further instruction. This allowed the instructor to observe the trainee's actions readily and to correct him if necessary. However, when a two-dimensional panel was used, trainees had to be reminded several times to "go through the motions" by putting a finger on the panel part which was being operated. Even when the trainee did this, the instructor had to observe more closely than before and had to rely on verbal substitutions from the trainee for actions the trainee should be taking.

This added work load did not effect the time required to train or the proficiency level developed. Research instructors were able to absorb the added work without an effect on the training output. The field study data showed that military instructors were able to perform as well under high fidelity circumstances as under low fidelity conditions, even though definite lack of confidence in the low fidelity device was expressed by some instructors.

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APPENDIX A

Proficiency Test

Standard Blue Status Procedures

Operator is standing before the SCI which is open but "cold." He is monitoring for Blue Status light and Alarm buzzer to sound.

SIGNAL	ACTION
1. Buzzer and Blue Status light.	1. Throw Power switch to ON.
	2. Throw Panel Light switch to ON
	3. Put hand under Panel Light to check for illumination level.
	4. Adjust light level with control knob.
	5. Throw all 4 Intercom switches to ON.
	6. Throw all 4 Launcher Power switches to ON.
	7. Plug HH (Handset-Headset) set into station 2.
	8. Announce over HH set "Blue Status received, Section A."
	9. Put Intercom switch to TALK and hold.
	10. Announce on IC (Intercom) "Blue Status."
	11. Check and adjust mike level while announcing.
	12. Release IC switch to LISTEN.
	13. Press Alarm shut-off button till buzzer stops.

	14. Monitor for "All crewmen present," on IC.
2. "All crewmen present" on IC.	15. Announce "All crewmen present, Section A" on HH set.
	16. Monitor for "Battle Stations," on HH set.
3. "Battle Stations" on HH set.	17. Announce "Battle Stations received, Section A," on HH set.
	18. Operate IC switch.
	19. Monitor for green ON DECK light.
	20. Announce "Battle Stations," on IC.
4. Green ON DECK light.	21. Monitor for "Launcher prepared," on IC.
5. "Launcher #1 prepared," on IC.	22. Press PREPARED button for #1.
	23. Monitor for green #1 PREPARED and SAME light.
6. #1 green PREPARED and SAME light on.	24. Monitor for "Launcher prepared," on IC.
7. "Launcher #2 prepared," on IC.	25. Press PREPARED button for #2.
	26. Monitor for green #2 PREPARED and SAME light.
8. #2 green PREPARED and SAME light on.	27. Monitor for "Launcher prepared," on IC.
9. "Launcher #3 prepared" on IC.	28. Press PREPARED button for #3.

	29. Monitor for green #3 PREPARED and SAME light.
10. Green PREPARED and SAME light on #3.	30. Monitor for "Launcher prepared," on IC.
11. "Launcher #4 prepared" on IC.	31. Press PREPARED button for #4.
	32. Monitor for #4 green PREPARED and SAME light.
12. #4 green PREPARED and SAME light on.	
	33. Monitor for "Launcher ready" on IC.
13. "Launcher #1 ready" on IC.	
	34. Operate IC switch.
	35. Announce "Stand clear, launcher #1 going up," on IC.
	36. Throw LE (Launcher Elevation) switch for #1 to UP.
14. Noise on IC.	37. Monitor noise on IC till it stops.
	38. Throw LE switch for #1 to OFF.
	39. Monitor for "Launcher ready," on IC.
15. "Launcher #2 ready" on IC.	40. Operate IC switch.
	41. Announce "Stand clear, launcher #2 going up," on IC.
	42. Throw LE switch for #2 to UP.
16. Noise on IC.	43. Monitor noise on IC till it stops.
	44. Throw LE switch for #2 to OFF.

45. Monitor for "Launcher ready" on IC.

17. "Launcher #3 ready" on IC.

46. Operate IC switch

47. Announce "Stand clear, launcher #3 going up," on IC.

48. Throw LE switch for #3 to UP.

18. Noise on IC.

49. Monitor noise on IC till it stops.

50. Throw LE switch for #3 to OFF.

51. Monitor for "Launcher ready" on IC.

19. "Launcher #4 ready" on IC.

52. Operate IC switch.

53. Announce "Stand clear, launcher #4 going up," on IC.

54. Throw LE switch for #4 to UP.

20. Noise on IC.

55. Monitor noise on IC till it stops.

56. Throw LE switch for #4 to OFF.

57. Wait for Section Chief.

21. Section Chief comes into revetment.

58. Throw all 4 IC switches to OFF.

22. Section Chief turns safety keys to FIRE.

59. Monitor for 4 amber LAUNCHER READY lights.

23. All four LAUNCHER READY lights on.

60. Throw H&G (Heaters & Gyros) switch for #1 to ON.

61. Record time on log.

62. Monitor for green READY TO FIRE light for #1.

24. Green READY TO FIRE light

25. Green LAUNCHER DESIGNATE light on.

26. Smooth movement of needle full left to full right twice.

27. SECTION READY green light on.

28. Section Chief says, "Blue Status checks complete."

63. Turn DESIGNATE switch to #1 strip.

64. Press LAUNCHER DESIGNATE button.

65. Monitor for green LAUNCHER DESIGNATE light.

66. Press SLEW button & hold through check.

67. Throw SECTION READY switch to READY.

68. Check for green SECTION READY light.

69. Wait for Section Chief to OK.

70. Announce "Blue Status checks complete, Section A," on HH set.

Standard Red Status Procedures to Fire

Two Missiles in Automatic Mode

Operator is standing in front of open SCI. Power is on. Blue Status is on. Checks are complete. Operator is wearing HH set and is monitoring for Red Status.

SIGNAL	ACTION
	1. Monitor for Red Status light.
1. Red Status light on.	2. Announce over HH set, "Red Status received, Section A."
	3. Monitor for green SELECTED light.
2. Green SELECTED light on.	4. Throw H&G switch for #2 to ON.
	5. Log starting time.
	6. Monitor for buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights.
3. Buzzer, green FIRE, LAUNCH ORDER, and MISSILE AWAY lights on.	7. Throw SECTION READY switch down (OFF).
	8. Throw LAUNCHER ELEVATION switch for #1 to DOWN.
	9. Monitor for green READY TO FIRE light on #2.
	10. Move LAUNCHER ELEVATION switch for #1 to OFF.

4. Green READY TO FIRE light for #2 on.

5. Green LAUNCHER DESIGNATE light on.

6. Smooth movement of needle left to 0, right to 0, twice.

7. Green SECTION READY light on.

8. Green SELECTED light on.

9. Buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights on.

11. Move DESIGNATE switch to #2 strip.

12. Press LAUNCHER DESIGNATE button.

13. Monitor for green LAUNCHER DESIGNATE light.

14. Press SLEW button.

15. Monitor SLEW METER for correct check.

16. Throw SECTION READY switch up (ON).

17. Monitor for green SECTION READY light.

18. Monitor for green SELECTED light.

19. Throw H&G switch for #3 to On.

20. Log starting time.

21. Monitor for buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights.

22. Thr-w SECTION READY switch down (OFF).

APPENDIX B

Orientation to the Nike Hercules Site and The Section Control Indicator (SCI)

ORIENTATION TO THE NIKE HERCULES SITE AND THE SECTION CONTROL INDICATOR

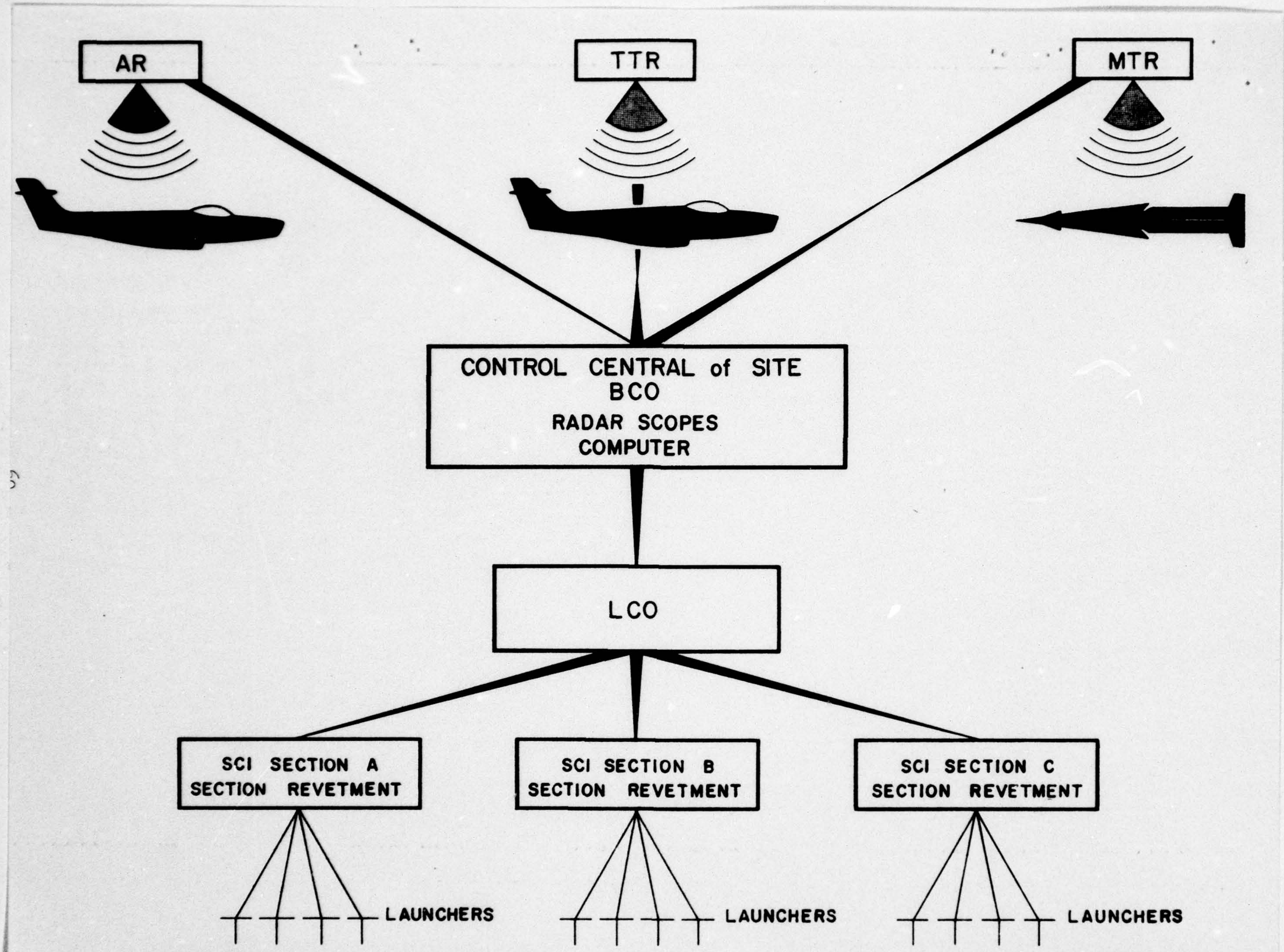
The Nike Hercules is primarily an antiaircraft missile and can be armed with a nuclear warhead. The site consists of approximately eight major pieces of equipment. The layout varies from site to site depending on geographic conditions and here you see one example of a basic site layout on this chart. This could represent an area of several miles and the only consistency is the separation of the IFC (Integrated Fire Control) area (the upper half of the diagram) from the launching area.

Acquisition Radar (AR)

The acquisition radar operates continually as it searches the area of protection. When a target has been acquired, the acquisition radar sends azimuth and range data to the Target Tracking Radar through the computer.

Target Tracking Radar (TTR)

The TTR locks on the target and tracks it until the target is either released by the Battery Control Officer (BCO) or destroyed by the selected missile. The tracking data is fed to the computer to enable it to plot the missile course to the intercept point.


AR
TTR
MTR
CONTROL CENTRAL of SITE
BCO
RADAR SCOPES
COMPUTER
LCO
SCI SECTION A
SECTION REVETMENT
SCI SECTION B
SECTION REVETMENT
SCI SECTION C
SECTION REVETMENT
LAUNCHERS
LAUNCHERS
LAUNCHERS

Missile Tracking Radar (MTR)

When the missile is fired the MTR controls the flight pattern and sends missile position data to the computer.

The three radars have operators constantly monitoring the display scopes.

Battery Control Officer (BCO)

The computer information is monitored by the BCO and makes the final decision whether a missile should be launched.

Launcher Control Officer (LCO)

The LCO relays the commands from the BCO to the Section Control Indicator (SCI) operators. The LCO controls twelve missiles through three SCI panels and it is his responsibility to select a missile for firing.

Section Control Indicator (SCI)

The operator of the SCI coordinates his duties with his Section Chief and the LCO. He checks the SCI daily and maintains communication between the LCO and the launcher crew. The SCI supplies the power to the four missiles on the launchers. The SCI operator is responsible for the crewmen and the status of the missile during this procedure.

You are here to learn the SCI procedures in Blue Status and Red Status. Blue Status is the procedure taken to prepare a missile for firing, and Red Status is the actual firing procedure.

Do you have any questions?

Pages 62 through 64 deleted.

APPENDIX C

Tables

Table C-1

Distribution of GT Scores for
65 Men in MOS 177
and for 15 and 20 Case Samples

Study I

Actual Distribution of MOS 177	Range of GT Scores	Frequency per Panel Sample (N = 15)	Frequency per Panel Sample (N = 20)
6	80 and below	1	2
18	81 - 90	5	6
11	91 - 100	3	3
10	101 - 110	2	3
10	111 - 120	2	3
5	121 - 130	1	2
5	131 and above	1	1
$\Sigma = 65$		$\Sigma = 15$	$\Sigma = 20$

Table C-2

Test of Homogeneity of Regression -- Cells

Study I

Source of Variance	df	Errors of Estimate SS	MS
Deviation from average regression within cells	52	3141.071	
Deviation from individual cell regressions	44	2555.571	58.081
Differences among cell regressions	8	585.500	73.187

$F = 1.260$, $p > .20$

Table C-3

Test of Homogeneity of Regression - Panels

Study I

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviations from average regression within panels	56	3468.564	
Deviations from individual panel regressions	54	3336.962	61.795
Differences among panel regressions	2	131.602	65.801

$F = 1.064$, $p > .20$

Table C-4

Test of Homogeneity of Regression - Instructors

Study I

Source of Variance	df	Errors of Estimate SS	Errors of Estimate MS
Deviations from average regression within instructors	56	3532.083	
Deviations from individual instructor regressions	54	3518.016	65.148
Differences among instructor regressions	2	14.067	7.033

$F < 1.00$

Table C-5

Distribution of Proficiency Scores

for Each Training Group

(N = 20/Group)

Study I

Hot Panel	Cold Panel	Frozen Panel
92	92	92
92	92	92
92	91	91
92	91	91
91	91	89
91	90	89
91	89	88
91	89	87
91	89	86
90	88	84
89	88	83
89	86	83
88	85	83
88	85	83
88	84	82
87	84	81
86	81	74
70	79	69
60	74	68
57	70	54
Mean = 85.8 Median = 89.5	Mean = 85.9 Median = 88.0	Mean = 82.4 Median = 83.5

Table C-6

Covariance Analysis of Proficiency Scores Controlling for

Variance on GT Scores

Study I

Source of Variance	df	Sums of Squares and Products			Correlation Coefficient	Regression Coefficient	Errors of Estimate			F	P
		SSx	SP	SSy			SS'y	df	MS		
Panels	2	11.634	41.850	152.100	.995	3.597	131.999	2	65.999	1.07	>.20
Instructors	2	18.451	17.700	77.100	.469	.959	69.993	2	34.997	< 1.00	
P x I	4	103.099	41.050	270.900	.246	.398	257.538	4	64.384	1.04	>.20
Within	51	19911.000	4540.500	4176.500	.497	.228	3141.071	50	61.589		
Total	59	20044.184	4641.100	4676.600	.479	.232	3600.601	58			

Table C-7

Proficiency Score Means for

Instructors and Panels

Study I

Instructor	Hot Panel	Cold Panel	Frozen Panel	Total
1	86.4	82.4	85.8	84.9
2	83.6	88.0	76.8	82.8
3	86.5	86.6	83.6	85.6
Total	85.8	85.9	82.4	84.7

Table C-8

Adjusted Proficiency Score Means and Correlation Coefficients

for Instructors and Panels

Study I

Instructor	Hot Panel	Cold Panel	Frozen Panel	Total	r
1	86.0	82.9	85.5	84.9	.451
2	83.9	87.2	78.6	83.2	.478
3	86.1	86.2	83.9	85.4	.498
Total	85.5	85.6	82.9	84.7	
r	.472	.488	.521		.479

Table C-9

Analysis of Variance of Training Times:

Panels and Instructor Groups

Study I

Source of Variance	df	Sums of Squares	Mean Square	F
Panels	2	704.160	352.070	1.207[a]
Instructor Groups	2	129.160	64.580	< 1
P x I	4	1166.680	291.670	
Total	8[b]	2000.000		

[a] $p > .05$

[b] One instructor trained two five-man groups per panel. This instructor's two training time scores for each panel were averaged. These means were used as the entries for the appropriate cells in the above analysis.

Table C-10

Training Time Means[a] for Panels

and Instructor Groups

Study I

Instructor	Mean	Panel	Mean
1	156.7	Hot Panel	154.2
2	160.0	Cold Panel	155.0
3	165.7	Frozen Panel	173.3
Total	160.8	Total	160.8

[a]Time is shown in minutes.

Table C-11

Test of Homogeneity of Regression: Cells

Study II

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviation from average regression within cells	67	3760.771	
Deviation from individual cell regressions	56	3535.716	63.137
Differences among cell regressions	11	225.055	20.459

$F < 1.00$

Table C-12

Test of Homogeneity of Regression: Panels

Study II

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviations from average regression within panels	75	3793.864	
Deviations from individual panel regressions	72	3520.682	48.898
Difference among panel regressions	3	273.182	91.060

$F = 1.862,\ p > .10$

Table C-13

Test of Homogeneity of Regression: Instructors
Study II

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviations from average regression within instructors	76	3874.674	
Deviations from individual instructor regressions	74	3738.597	50.521
Differences among instructor regressions	2	136.077	68.038

$F = 1.346$, $p > .20$

Table C-14

Covariance Analysis of Proficiency Scores Controlling for

Variance on GT Scores

Study II

Source of Variance	df	Sums of Squares and Products			Correlation Coefficient	Regression Coefficient	Errors of Estimate			F	P
		SSx	Sp	SSy			SS'y	df	MS		
Panels	3	25.850	-71.150	201.500	-.986	-2.752	235.357	3	78.452	1.486	>.20
Instructors	2	8.850	28.400	168.900	.734	3.209	156.273	2	78.136	1.480	>.20
P x I	6	161.050	-96.450	205.600	.530	.599	102.313	6	28.267	< 1	
Within	68	24101.800	5544.500	4811.200	.514	.230	3535.716	67	52.771		
Total	79	242975.550	5598.200	5387.200	.501	.236	4029.659	78	237.626		

Table C-15

Distribution of Proficiency Scores
for Each Training Group
(N = 20/Group)

Study II

Hot Panel	Frozen Panel	Photograph Panel	Drawing Panel
92	92	90	91
92	92	90	91
92	91	90	91
92	91	89	90
91	89	88	89
91	89	88	88
91	88	87	87
91	87	86	87
91	86	86	87
90	84	86	86
89	83	84	86
89	83	83	85
88	83	82	85
88	83	80	81
88	82	80	77
87	81	79	76
86	74	79	74
70	69	78	70
60	68	77	67
57	54	72	53
Mean = 85.75	Mean = 82.45	Mean = 83.70	Mean = 82.05
Median = 89.5	Median = 83.5	Median = 84.5	Median = 86.0

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Table C-16

Proficiency Score Means for Instructors and Panels

Study II

Instructors	Panels				
	Hot	Frozen	Photo	Drawing	Total
1	86.4	85.8	81.0	79.8	83.2
2	83.6	76.8	84.4	78.0	80.7
3	86.5	83.6	84.7	85.2	85.0
Total	85.8	82.4	83.7	82.0	83.5

Table C-17

Adjusted Proficiency Score Means for Instructors and Panels

Study II

Instructors	Panels				
	Hot	Frozen	Photo	Drawing	Total
1	86.01	85.59	81.25	80.19	83.08
2	83.39	75.36	84.06	77.88	80.63
3	87.05	83.80	84.68	84.65	85.05
Total	85.68	82.31	83.68	81.79	83.50

Table C-18

Analysis of Variance of Training Times:

Panels and Instructors Groups

Study II

Source of Variance	df	Sums of Squares	Mean Square	F
Panels	3	934.89	311.63	< 1
Instructor Groups	2	303.13	151.56	< 1
P x I	6	3326.05	554.34	
Total	11[a]	4564.07		

[a]One instructor trained two five-man groups per panel. This instructor's training time scores for each panel were averaged. These means were used as the entries for the appropriate cells in the analysis.

Table C-19

Training Time Means[a] for Panels and Instructor Groups

Study II

Instructor	Panels				Mean
	Hot	Frozen	Photo	Drawing	
1	2.67	2.67	3.25	2.58	2.79
2	2.75	2.75	2.75	3.50	2.94
3	2.29	3.25	2.79	2.38	2.68
Mean	2.57	2.89	2.93	2.82	2.80

[a]Time is shown in hours.

Table C-20

Distribution of Proficiency Scores

for Each Training Group

(N = 15/Group)

Study III

High Fidelity Housing	Box Housing	Frame Housing
91	91	92
89	91	90
89	91	89
88	90	88
87	89	88
85	88	86
85	88	84
84	88	83
83	86	82
79	86	81
79	77	80
77	75	80
72	74	79
72	73	79
69	70	77
Mean = 81.9 Median = 84	Mean = 83.8 Median = 88	Mean = 83.8 Median = 83

Table C-21

Test of Homogeneity of Regression - Cells

Study III

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviation from average regression within cells	35	1301.190	
Deviation from individual cell regressions	27	451.014	16.704
Differences among cell regressions	8	850.176	106.272

$F = 6.362$, $p < .001$

Table C-22

Test of Homogeneity of Regression - Housings

Study III

Source of Variance	df	Errors of Estimate SS	MS
Deviations from average regression within housings	42	1289.770	
Deviations from individual housing regressions	40	1276.902	31.922
Differences among housing regressions	2	12.868	6.434

$F < 1.00$

Table C-23

Analysis of Covariance - Housings
Study III

Source of Variance	df	SSx	SP	SSy	Errors of Estimate			F
					SS'y	df	MS'y	
Housings	2	10.711	19.600	36.133	28.245	2	14.122	< 1.00
Within	42	14929.067	2738.400	1791.067	1289.770	41	31.458	
Total	44	14939.778	2758.000	1827.200	1318.015	43		

Table C-24

Means, Correlation Coefficients and

Regression Coefficients

Study III

Housing	Mean GT	Mean Proficiency	Mean Adjusted Proficiency	Correlation Coefficient	Regression Coefficient
High Fidelity	99.53	81.93	82.06	.50	.195
Box	100.60	83.80	83.73	.55	.208
Frame	100.53	83.87	83.81	.56	.143
Total	100.22	83.20	83.20	.53	.185

Table C-25

Analysis of Variance of Training Time

Housings

Study III

Source of Variance	df	SS	MS	F	P
Housings	2	.118	.056	1.018	> .10
Instructors	2	.078	.039	< 1.00	
Housings x Instructors	4	.220	.055		
Total	8	.416			

Table C-26

Table of Mean Training Times[a]

Housings

Study III

Instructor	High Fidelity	Box	Frame	Mean
1	3.00	2.83	3.00	2.94
2	2.83	2.83	3.00	2.89
3	3.17	2.50	2.50	2.72
Mean	3.00	2.72	2.83	2.85

[a]Time is shown in hours.

Table C-27

Test of Homogeneity of Regression - Cells

Study IV

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviation from average regression within cells	37	3063.683	
Deviation from individual cell regressions	29	2304.388	49.461
Differences among cell regressions	8	759.295	94.911

$F = 1.194$

$p > .20$

Table C-28

Test of Homogeneity of Regression - Panels

Study IV

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviations from average regression within panels	42	3411.943	
Deviations from individual panel regressions	40	3223.344	80.583
Differences among panel regressions	2	188.599	94.300

$F = 1.170$

$p > .20$

Table C-29

Test of Homogeneity of Regression - Instructors

Study IV

Source of Variance	df	Errors of Estimate	
		SS	MS
Deviations from average regression within instructors	42	3435.839	
Deviations from individual instructor regressions	40	3378.090	84.451
Differences among instructor regressions	2	57.749	28.874

$F < 1.00$

Table C-30

Distribution of Proficiency Scores

for Each Training Group

(N = 15/Group)

Study IV

Hot Panel	Cold Panel	Cardboard Panel
92	92	91
92	92	91
91	92	90
90	91	88
89	91	87
88	90	86
88	89	86
87	89	85
87	89	85
86	86	84
86	85	83
78	85	73
60	83	70
57	70	65
55	60	63
Mean = 81.7 Median = 87.5	Mean = 85.6 Median = 89.5	Mean = 81.8 Median = 85.5

Table C-31

Means - Proficiency Scores

Study IV

Instructor	Hot	Cold	Cardboard	Total
1	83.6	88.0	78.6	83.4
2	82.6	86.8	80.8	83.4
3	79.1	82.0	86.0	82.3
Total	81.7	85.6	81.8	83.0

Table C-32

Adjusted Means - Proficiency Scores

Study IV

Instructor	Hot	Cold	Cardboard	Total
1	82.5	87.8	79.3	83.2
2	82.4	86.3	80.7	83.2
3	79.8	82.4	86.0	82.5
Total	81.5	85.5	81.0	83.0

Table C-33

Covariance Analysis of Proficiency Scores Controlling for

Variance on GT Scores

Study IV

Source of Variance	df	SSx	SP	SSy	b	r	Errors of Estimate			F
							SS'y	df	MS	
Panels	2	24.045	20.889	146.978	.869	.35	136.574	2	68.266	< 1.00
Instructors	2	54.589	24.889	11.379	.456	1.00	1.340	2	.670	< 1.00
P x I	4	76.478	104.911	292.355	1.372	.70	235.725	4	58.931	< 1.00
Within Cells	36	15378.800	4626.000	4455.200	.301	.56	3063.683	35	87.533	
Total	44	15533.912	4776.689	4905.912	.308	.55	3437.322	43		

Table C-34

Analysis of Variance of Training Time
Hot, Cold, and Cardboard Panels

Study IV

Source of Variance	df	SS	MS	F	P
Panels	2	.222	.111	< 1.00	
Instructors	2	.722	.361	1.76	> .20
P x I	4	.820	.205		
Total	8	1.764			

Table C-35

Table of Mean Training Times[a]
Hot, Cold, and Cardboard Panels

Study IV

Instructor	Hot	Cold	Cardboard	Mean
1	2.75	2.50	3.75	3.00
2	2.25	2.75	2.50	2.50
3	2.50	2.50	2.25	2.33
Mean	2.50	2.50	2.83	2.61

[a]Time is shown in hours.

Table C-36

Proficiency Score Distributions and Distribution Statistics

Study V

Full Size Method I	Half Size Method I	Half Size Method II	Small Size Method II
91	90	91	90
89	90	91	89
87	90	89	89
87	89	88	88
87	89	87	87
86	87	87	86
86	86	85	84
84	86	83	84
84	84	83	82
81	84	83	80
79	84	81	80
78	83	78	79
75	83	78	79
72	79	76	70
63	73	76	70
M = 81.9	85.1	83.7	82.4
Md = 84.0	86.0	83.0	84.0
S.D. = 7.5	5.1	5.5	6.9

Table C-37

Analysis of Variance of Proficiency Scores
From Three Sizes of a Training Device

Study V

Source of Variance	df	SS	MS	F	p
Between groups	2	76.95	38.47	1.082	> .10
Within groups	57	2026.05	35.54		
Total	59	2103.00			

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Report	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SOME RESEARCH FINDINGS ON FIDELITY OF TRAINING DEVICES FOR FIXED PROCEDURES TASKS		5. TYPE OF REPORT & PERIOD COVERED Research Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John A. Cox, Robert O. Wood Jr., Lynn M. Boren and H. Walter Thorne		8. CONTRACT OR GRANT NUMBER(s) DA 44-188-ARO-2
9. PERFORMING ORGANIZATION NAME AND ADDRESS Human Resources Research Organization (HumRRO) 300 North Washington Street Alexandria, Va. 22314		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2J024701A712-01
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Office of the Chief of Research and Development		12. REPORT DATE 21 July 1964
		13. NUMBER OF PAGES 99
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This research was performed by HumRRO Division No. 5 (Air Defense), Fort Bliss, Texas under Task RINGER.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Training devices
proficiency development
fidelity requirements
proficiency measurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Research was performed to determine the effects on proficiency development of using devices of less-than-perfect fidelity for training a lengthy fixed procedure. The fidelity of a training device was the degree to which it resembled the tactical equipment for which the training device was substituted. The fidelity of training devices was lowered in either appearance or functional quality. A fixed procedure was a part of a job in which all signals to the incumbent and actions by the incumbent were specified in an

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued...

invariable sequence.

Conclusions reached are as follows: (1) when men are being trained to perform a fixed procedure, the requirements for functional fidelity in the training device are quite low. A line drawing of the man-machine interface will train men as effectively in this circumstance as will a device of higher fidelity; (2) no effect on proficiency development is likely to occur due to reducing housing fidelity of the man-machine interface on a training device. The least expensive housing which will adequately support and protect the man-machine interface should be used; (3) Lowering the fidelity of a training device by reducing its size has no effect on proficiency development, so long as the parts of the device remain clearly visible to the individual trainee.