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DEVELOPMENT AND COMPARISON OF TACAMO ICON DESIGN FORMATS

by

William D. Sanders

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Thesis Advisor: Judith H. Lind

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Development and Comparison

of

TACAMO Icon Design Formats

by

William D. Sanders
Lieutenant, United States Navy
B.S., United States Naval Academy, 1984

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March 1992

Author: ______________________________
William D. Sanders

Approved by: ______________________________
Judith H. Lind, Thesis Advisor

____
Frank C. Petho, Second Reader

____
Peter Purdue, Chairman
Department of Operations Research

ABSTRACT

The purpose of this study was to develop and evaluate a set of icons for the next generation message processing system for the TACAMO airborne strategic communications platform. An icon set for a proposed interface was developed through the use of an icon production method test, that is, potential users designed candidate icons that were meaningful to them. These icons were then refined for discriminability via input from a user survey. To determine if well-developed icons with alphanumeric labels yield a significant performance advantage over the same icons without labels, an experiment involving trained users was conducted using a response time model. Subtractive logic was used to measure icon identification times as a function of whether they were or were not labeled. When speed of performance and rate of errors were compared, labeling of icons resulted in significantly longer response times, yet did not result in fewer errors for the tested icon set. It is recommended that the unlabeled set of icons be used for TACAMO's next generation message processing system, and that the icon production method be used more widely to involve users in interface design.

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I. INTRODUCTION

A. TACAMO STRATEGIC COMMUNICATIONS

With the weight of the United States strategic nuclear triad shifted firmly to the Navy's ballistic missile submarine (SSBN) fleet (Schmitt, 1991, and Talbott, 1991), the TACAMO[1] communications system has assumed a vital role in the world of nuclear deterrence. TACAMO's primary mission is to provide the National Command Authorities (NCA) a survivable and endurable means to command the nation's strategic fleet of ballistic missile submarines. Despite a rapidly changing world, at the core of all long-range defense planning remains the need to minimize the likelihood of the extreme case—the all-out nuclear attack. Deterrence against any attack requires the assured survival not only of powerful retaliatory forces, but also of the command and control system that controls them (Iklé and Wohlstetter, 1988, p. 35).

Conceived during the height of cold war tensions, the TACAMO communications system was originally envisioned as a temporary fix until a hardened shore-based system could be developed to communicate with the ballistic missile submarine fleet. But, as the accuracy of Soviet missiles improved, it became

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[1]TACAMO, a term used interchangeably for a specific TACAMO aircrew or the entire TACAMO communication system, is derived from the command "take charge and move out." In 1963, the Director of Naval Communications, then Rear Admiral Bernard F. Roeder, U.S. Navy, coined the phrase at the first meeting of the then highly-classified project to determine if an airborne Very Low Frequency (VLF) communications system was feasible.

apparent that any fixed geographical locations would be vulnerable. In September 1973, TACAMO assumed the key role of providing a continuously airborne and survivable method of relaying retaliatory orders to deployed ballistic missile submarines in the event of a nuclear attack. (Sanders, 1991, p. 175)

TACAMO is a part of the Worldwide Airborne Command Post System (WWABNCP) which provides alternative command and control. The WWABNCP ensures that the NCA will retain connectivity with U.S. strategic forces in the event of a nuclear attack. TACAMO receives uplinked encrypted and unencrypted message traffic over the spread of the radio frequency spectrum (see Figure 1.1).

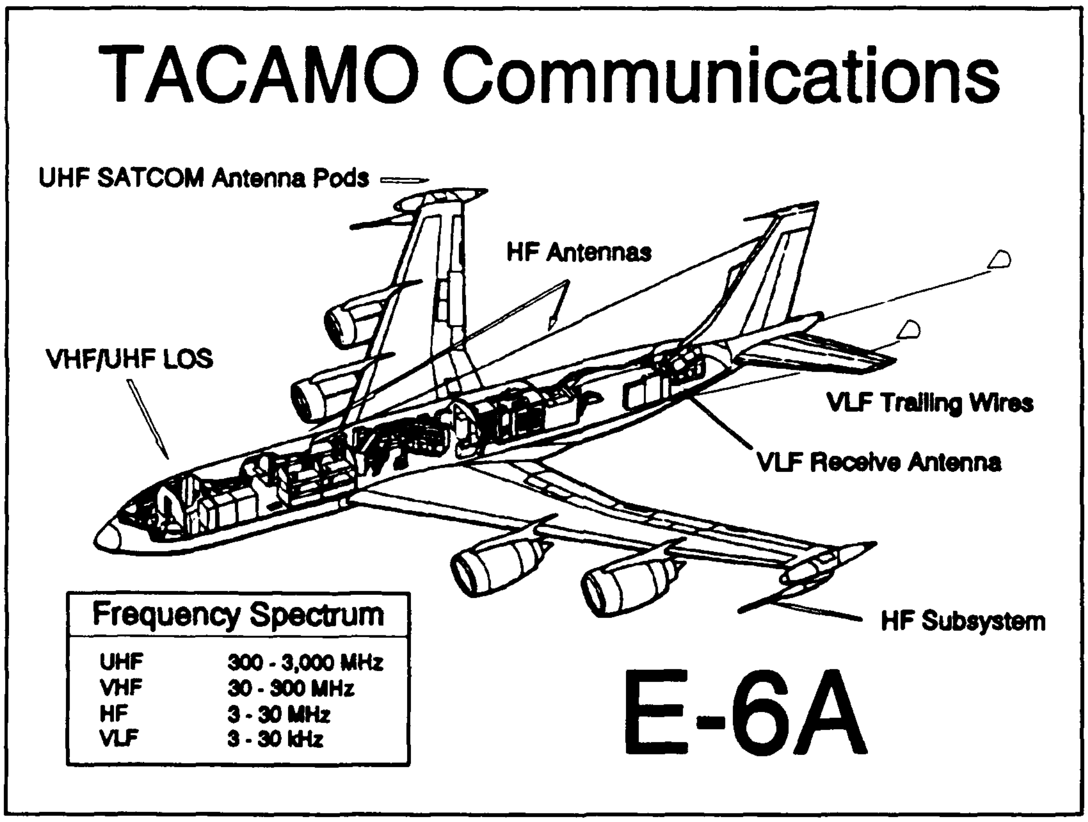


Figure 1.1. TACAMO Airborne Communications Platform

Messages are sorted and prioritized for routing by the Airborne Communications Officer(ACO) and communications crew aboard the aircraft. The TACAMO Message Processing System (TMPS) is used for automated message storage and forwarding to the aircraft's very low frequency (VLF) transmitter.

The next TACAMO communications upgrade, scheduled for the mid-1990s, entails the modification of the E-6A aircraft to include a Military Strategic and Tactical Relay (MILSTAR) system with the associated MILSTAR Message Processing System (MMPS), which is an upgrade of the older TMPS. MILSTAR is a joint development program with the Air Force which will incorporate anti-jam extremely-high frequency capabilities, providing the Navy with additional spread-spectrum survivable satellite communications.

Federman (1988) has described human factors guidelines for developing software for the TMPS upgrade and recommended further experimental studies in designing display formats for the TMPS. Budget restrictions have limited further studies; current plans are to adapt the existing command-line processor of the TMPS into an operating system for the MMPS with little or no alteration. The study reported here has integrated Federman's recommendations into a graphical interface design and specifically developed and evaluated a set of icons for the TACAMO MMPS.

B. GRAPHICAL INTERFACE FOR MILITARY COMPUTER APPLICATIONS

1. Performance Criteria

Computer processing power and high-resolution graphics for military computer applications have improved dramatically during the past decade. Software designers and developers are turning to graphical interfaces and display formats including icons, because pictorial symbols can generally be recognized more rapidly and accurately than words (Green and Pew, 1978, p. 103). Haber (1970), for example, suggests that it is easy for humans to recall pictorial stimuli and that the capacity of memory for pictures may even be unlimited. Icons offer established benefits when developed with creative design methods, because they reduce memorization of commands and syntax (Brown, 1986, p. 87) and produce quicker and easier recall from memory when compared to nonpictorial symbols (Florence and Geiselman, 1986, p. 404). It makes sense, therefore, to use selectively screened icons to facilitate performance within graphical interfaces.

Replacing the vague and misleading notion of "user friendliness" with measurable human factors performance criteria should be a top priority of human-computer interface design. Shneiderman (1987) proposes that debates over user friendliness can be avoided by using five quantitative acceptance criteria:

1. Subjective acceptance by user.
2. Initial training time.
3. Retention of skills over time.

4. Speed of performance.

5. Rate of errors by the user.

Once a decision about the relative importance of each of these human factors criteria has been made, specific acceptance tests should be established to guide designers and inform prospective users (Shneiderman, 1987, pp. 396-397). While icons are only one of many interface methods that can be employed, they offer great potential for use in military software applications.

2. Designing the Optimal Icon

While the design of icons cannot be summarized with a few rules, Lodding (1983, p. 19) offers guidelines that can be used to characterize an optimal icon:

1. When first encountering the icon, a viewer should be able to infer its intended meaning. Additionally, once learned, the meaning should be perceived as appropriate.

2. When selecting an icon from a menu or icon set, only one icon should appear as appropriate.

3. The icon should not have any unnecessary ambiguous connotations.

Clarity, consistency, familiarity, and simplicity are the key attributes of good icon design (Marcus, 1991). Yet rational analysis and good graphic design practice alone cannot guarantee an optimal icon. The targeted user must be included in the development process to establish the suitability and interpretability of the design (Cahill, 1975, p. 380).

3. Icons: The Label Debate

While it is clear that a careful and creative design process is required to develop a successful set of icons, the literature indicates a lack of consensus regarding the use of icons, alphanumeric formats, and labels. While Steiner and Camacho (1989, p. 14) argue that, for large amounts of information, users perform better with icons than with alphanumeric formats, Ells and Dewar (1979, p. 167) found that for small amounts of information users perform just as well with alphanumeric formats as with icons, and sometimes perform even better.

Kantowitz (1985) notes that redundancy, such as that supplied by labels, tends to slow down a system somewhat while raising its reliability; however, redundant information perceived through two sensory channels simultaneously (e.g. the eyes and ears) actually speeds up processing time, compared to cases where information is perceived through a single channel. In contrast, Pellegrino, Siegel, and Dhawan (1975) warn against the supplementary use of labels, using the dual-coding hypothesis that pictures are encoded both visually and acoustically, while labels are primarily acoustically encoded and thus may distract from pictures. Yet another view is presented by Guastello, Traut, and Korienek (1989, pp. 118-119), who found that mixed modality icons, consisting of pictorial icons with alphanumeric labels, are rated as more meaningful than icons that consist of verbal or pictorial elements only.

MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment and Facilities (1989) requires the use of labels for icons. Paragraph

5.15.4.8.3 of that document states, "Where icons are used to represent control actions in menus, verbal labels shall be displayed with each icon to help assure that its intended meaning will be understood." The varied results reported in the literature suggest that the strict labeling requirements of *MIL-STD-1472D* may be imposing unrealistic requirements on military interface designers. Experiments on the effect of icon design format in military applications are urgently needed. With the controversy surrounding speed of recognition and rate of errors by the user, studies should focus on analyses based on Shneiderman's last two acceptance criteria.

C. GOALS AND OBJECTIVES

The goal of this study is to determine if well-developed icons with alphanumeric labels yield a significant performance advantage over the same icons without labels. This study has concentrated on a set of icons proposed for a computer display format for TACAMO's anticipated message processing system upgrade. Several objectives have been met to achieve the primary goal.

1. **Screen Layout and Tasks.** A prototype display format for the MMPS system was designed, a set of screen design guidelines was documented, and a set of tasks to be represented on the screen by icons was determined.

2. **Initial Icon Design.** TACAMO aircrew personnel were used to sketch symbols and to suggest labels for the TACAMO MMPS task descriptions. The resulting set of icons was refined to enhance discriminability.

3. **Icon Identification Survey.** Recognition and confusability of the proposed icons were determined by surveying TACAMO aircrew personnel, to obtain a final set of icons for evaluation.

4. **Icon Design Evaluation.** Two icon design formats, with and without labels, were tested to measure speed and accuracy of identification under the two conditions.

D. SCOPE

The scope of this study is limited a single set of icons developed specifically for use with the TACAMO MMPS. Speed and accuracy of recognition were measured for the icons alone and for icons that were labeled, to determine whether a significant performance difference could be noted. Tests were conducted in a controlled environment without stress or the requirement to carry out supplementary tasks. It is not the intent of this study to validate the use of icons in general for military computer applications. The goal is to present a method of developing icons, to evaluate the resulting icons, and to make recommendations that may be used during the development of the TACAMO MMPS.

II. INTERFACE DEVELOPMENT AND INITIAL ICON DESIGN

A. TACAMO HUMAN FACTORS ANALYSIS

Several human factors analyses have been carried out that are directly applicable to the TACAMO systems and especially to the TACAMO Message Processing System (TMPS). An analysis of the TACAMO Communications Central conducted by Dean and Schlumbrecht (1981) details a typical TACAMO mission scenario, including descriptions of the tasks required for operating Communications Central. Tasks related to the preflight, mission assumption, mission relief, landing, and post landing phases are described in the report.

Dean and Mitchell's (1981) study outlines human factors guidelines for the TACAMO airframe replacement project. General guidelines centered on reducing crew station work load by designing Communications Central operator consoles to minimize stress and compensate for types of errors that are most likely to occur (Dean and Mitchell, 1981, p. 31). Moreover, Dean and Mitchell note that sleep loss and rest disruption are among the most severe stresses on TACAMO crew members, and many of the tasks most vulnerable to sleep-loss effects are centered on the operation of the TMPS. These tasks include the following:

1. Monitoring tasks (such as checking radio circuits).
2. Tasks that are new or require learning on the job (e.g., training of new TMPS operators).

3. High-workload tasks that require time-sharing with other primary and secondary tasks (e.g., receiving and transmitting Emergency Action Messages).

4. Tasks that require continuous attention and steady performance (e.g., monitoring the TMPS and the overall communications central system).

Given the in-flight refueling capability of the E-6A, much longer TACAMO missions than those currently flown are being envisioned. The anticipated resultant increase in sleep loss highlights the importance of crew rest procedures and of careful mission planning for coordinated work-rest cycles. The established need for an upgrade to the TMPS has reached a new level of urgency with foreseeable TACAMO mission lengths of up to 72 hours (Sanders, 1991, p. 179).

Federman (1988) makes specific recommendations to correct existing TMPS deficiencies, based on a field survey conducted at the VQ-4 squadron, Naval Air Station, Patuxent River, Maryland. Primary areas of concern are data entry, data display, interaction control, feedback, prompts, error management, and data protection. Several factors to consider in satisfying a "well human factored screen" are outlined by Federman (1988, p. 11):

1. Reduction of memory load.
2. Consistency in language and appearance on the screen.
3. Orderly, clean, and clutter-free screens.
4. Understandability of abbreviations, acronyms, and natural language.
5. Use of headings, captions, instructions, and options for improved meaningfulness.
6. A simple way of retrieving information that is stored in the system.

7. Display of the "right amount of information" on the screen without overloading it.

8. Help for the user when difficulty arises.

B. MMPS PROTOTYPE SCREEN LAYOUT AND MENU DESIGN

Federman's screen characteristics form a sound basis for designing a human-computer interface that is well accepted by TACAMO users. With the human factors deficiencies of the current TMPS thoroughly documented (Federman 1988), careful consideration and planning should go into the development of software for the next generation MILSTAR Message Processing System (MMPS).

The TACAMO MMPS, a dual Rolm Hawk/32 computer with increased memory storage, is scheduled to replace the current TMPS after 1995 (Sanders, 1991, p. 181). Current plans are to modify the existing TMPS operating system software into an Ada-compiled version for the MMPS until funding can be secured for new software. An initial prototype design for the TACAMO MMPS interface has been developed, incorporating the design recommendations of Federman and other TACAMO Airborne Communications Officers (ACOs) stationed at the Naval Postgraduate School.

The TACAMO MMPS prototype is designed to encompass many of the functions currently accomplished with separate pieces of equipment in Communications Central. The majority of equipment function settings can be controlled at an MMPS terminal with the addition of an enhanced data bus. Design guidelines have centered on creating an interface that includes not only current

TMPS functions, but functions that are currently accomplished at other crew positions in Communications Central. Communications Central ideally will have two MMPS terminals, a primary terminal and a secondary terminal serving as a training center, document database, and operational backup. This second terminal would permit conversion of aircraft maintenance manuals and operational documents into CD-ROM format, saving significant weight and storage space that could be better used for survival supplies and aircraft spare parts.

Based on the human factors analyses discussed earlier, recommendations have been documented for the TACAMO MMPS prototype screen layout and menu design. These recommendations are included in Appendix B. In anticipation of increased color and graphics capabilities, a graphical human-computer interface was developed for the MMPS prototype. Appendix B.1 outlines guidelines for the MMPS interface, including design principles, general display characteristics, interaction characteristics, information presentation formats, and user assistance. Menu structure recommendations are outlined in Appendix B.2.

C. PICTORIAL SYMBOLS AND INITIAL MMPS ICON DESIGNS

Over 300 years ago, the German philosopher and mathematician Baron Gottfried Wilhelm Von Leibniz (1646-1716) planted the seeds of symbolic logic and computer design (Kreiling, 1968, p. 100). Leibniz' dream was that someday a universal system of pictorial symbols would exist that could be read in all languages without having to be translated. A symbol can give an identity to a subject and, by repeated use, can come to equal it (Holmes, 1990, p. 11). By presenting user commands and system information in the form of pictorial symbols (often referred to as icons), graphic displays reduce the time and effort of learning, facilitate user performance, and reduce errors (Lodding, 1983, p. 11).

Most symbols have meaning only within a given context. The context in which the icons developed here are meaningful is that of the MMPS terminal and the tasks performed there. Appendix B.3 lists 20 tasks that will be carried out on an MMPS; these were selected for initial icon representation. The task descriptions were developed from thumbnail sketches provided by TACAMO ACOs at the Naval Postgraduate School (NPS).

Three approaches to design of pictorial symbols were considered in developing the MMPS task icons. The first approach considered assembling general ideas of what a group of ACOs think task icons should look like. The second approach considered consulting the *Symbol Sourcebook* (Dreyfuss, 1972) and *Handbook of Pictorial Symbols* (Modley, 1976) to identify icons for these tasks based on symbols developed by industrial designers for various purposes. Neither of these methods, however, qualifies as a scientific approach to the development of a satisfactory set of icons specific for the MMPS. The third approach considered is referred to as the population-stereotype production method (Mudd and Karsh, 1961; Howell and Fuchs, 1968; Green, 1979). This was the primary approach selected for MMPS icon development, with some modifications, to generate a set of icons that could be used for further study.

III. ICON PRODUCTION METHOD TEST

A. BACKGROUND

The production method technique solicits users of an unbiased subject population to draw symbols for specific concepts. Karsh and Mudd (1962) compared the accuracy of identification of vehicle control symbols developed by designers with and without data from the production method technique. Their results showed that the production-aided symbols were significantly superior to symbols developed without the production method, indicating that the "design and effectiveness and ultimate effectiveness of any symbol is entirely dependent upon the prevailing concepts that the specific user population may have of its existing equipment."

The production method for designing icons is an effective, low-cost technique for generating new symbols representing software tasks in a graphical format. There are four essential steps in the icon production method:

1. Determine concepts for software tasks from the user population.
2. Identify the subject population that will draw icons.
3. Elicit icons from the subjects.
4. Summarize and analyze the data.

Candidate icons are then developed from categories suggested by the subjects' drawings. Green (1979, p.77) notes that subjects' drawings are strongly influenced by their limitations as artists and their responses should be viewed as suggestive and not definitive. A thorough qualitative analysis of the test data combined with human factors design strategies will yield a superior set of candidate icons.

B. METHOD

1. Questionnaire Development

The TACAMO Icon Production Questionnaire presented in Appendix C.1 was developed to gather the data, using guidelines outlined by Tull and Albaum (1973). The questionnaire had three parts. The first part requested biographical data. The second section solicited respondents' opinions on menu structure development, not directly related to icon production. The final section consisted of one-inch square boxes in which the participants were asked to sketch proposed drawings and write out suggested labels.

2. Participants

A sample of 12 TACAMO aircrew personnel was drawn from the VQ-4 squadron, Naval Air Station, Patuxent River, Maryland. Ten participants completed the test, while two aircrewmen were unable to complete the testing due to an unscheduled TACAMO alert launch. All participants were Airborne Communications Officers (n=6) or enlisted Airborne Communications Supervisors (n=6) and ranged in age from 22 to 36. Various levels of TACAMO experience were reflected in the sample, with a mean of 2.5 years of experience and standard deviation of 1.3 years. While the sample of participants was not completely random due to the operational constraints and scheduling of aircrew personnel, the participants were deemed to be a reasonable cross-section of TACAMO aircrew personnel.

3. Procedure

Participants were assembled as a group for testing. An introduction to the purpose and goals of the study was presented verbally by the proctor (Appendix C.2). TACAMO Icon Production Questionnaires were then distributed and participants supplied biographical data and opinions on menu structure development. MMPS task descriptions, randomly-ordered, were then presented verbally and on an overhead projector one at a time. Participants were asked to provide a drawing and alphanumeric label in separate boxes for each task. Two minutes were allotted for each icon task. Total time required for the test was 50 minutes.

C. RESULTS

After the test was administered, the respondents' drawings and labels were cut into squares and assembled by task description. Reduced versions of the participants' drawings appear in Appendix C.3. A list of the proposed alphanumeric labels is contained in Appendix C.4. A listing of all of the picture elements that participants used to represent task descriptions is included as Appendix C.5. Where an objective appraisal of the free-response drawings might be seen as a difficult task, respondents were encouraged to explain their drawings with short notes if they felt that their drawings might be misinterpreted.

The drawings were created without much difficulty for most of the task descriptions. A majority of the respondents reported that the test was challenging and interesting. Review of the drawings, labels, and picture elements indicates that the participants were strongly influenced by the wording of the task description. Despite a limited level of artistic experience, respondents developed a variety of original ideas for drawings, presumably based on their varying levels of TACAMO experience. With the success of icon development largely contingent on the development of initial ideas, the production method was an important step in generating candidate icons for further analysis.

IV. ICON CANDIDATES

A. OVERVIEW OF ICON DEVELOPMENT

Two or three versions of each of the 20 candidate icons (see Appendix D.1) were developed using the sketches obtained from TACAMO aircrew personnel during the icon production method test described in Chapter III. The original sketches were revised to improve the general quality of the icons, while retaining the intended users' suggestions. Based on a compendium of guidelines for the design of icon-based interfaces (Gittins, 1986), the various versions of each icon were then studied and refined until one final candidate icon was prepared for each concept, based on icon production method data, improved legibility, and a discriminability analysis. The refined set of 20 icon candidates then was presented to an additional group of TACAMO aircrew personnel for evaluation, using standard survey procedures. The methodology used for development of the candidate set of icons is described in greater detail below.

B. REFINEMENT

Legibility, the perceptual quality of an icon's structural features, is central to an icon's capability to convey meaning (Webb, Sorenson, and Lyons, 1989). The goal of the icon identification survey was to test whether TACAMO aircrew personnel could interpret the meanings of the candidate MMPS icons. Refinements were made to the original TACAMO icon sketches to make identification and interpretation easier.

While the literature on icon refinement is limited, the research on symbol refinement techniques and effect on identification is more extensive. For example, Green (1979) recommends enhancing pictographic symbol discriminability by exploring length-to-width ratio, frontal plane orientation, symbol element repetition, strokewidth, and the extent to which enclosed areas are filled in. The results of Remington and Williams (1986) suggest that a symbol set is in some respects like a list that must be learned, indicating that intra-set similarity plays an important role in improving performance or decreasing response times. However, training and retention of icons is not anticipated as a problem since Hawkins, Reising, Woodson, and Bertling (1984, p. 121) have concluded that even if symbols are not intuitive at first glance, they can become easily recognizable after a brief learning period and are generally robust to changes in complexity and polarity.

This study chose to concentrate on the findings of Green and Pew (1978) and Green (1979) who suggest that, in developing pictographic symbols such as icons, designers should concentrate on enhancing legibility and discriminability to raise recognition and lower confusion. High recognition and low confusion lead to meaningfulness, a forerunner to memorability. Memorability of the icons is in turn a precursor to efficient operation of the system (Guastello and Traut, 1989, p. 119).

Gittins (1986) provides an excellent summary of available icon design guidelines drawn from a variety of fields, including human factors and ergonomics (Easterby, 1970; Caron, Jamieson, and Dewar, 1980; Shneiderman, 1980), graphic arts (Dreyfuss, 1972; Marcus 1982), and computer science (Carroll and Thomas, 1982; Lodding, 1982). In summarizing these sources, he discusses the strength of metaphors, graphic design alternatives, and icon implementation factors.

Cautioning against the overuse of graphical sophistication, Gittins (1986, p. 538) notes that "considerable psychological and human factors evidence gained from studies of pictographic symbols and signs suggests that simpler icon designs are as, or more, usable than complex ones." Appendix D.2, which details the actual refinements made to each set of original icon sketches, provides an overview of the design techniques used on the TACAMO icons. The final set of candidate icons used in the test is shown in Figure 4.1.

C. DISCRIMINABILITY ANALYSIS

To provide a performance-based criterion for selecting icons, the final set of candidate icons was subjected to the discriminability-index formula developed by Geiselman, Landee, and Christen (1982). The discriminability-index formula is based on the conclusion that symbols are judged more or less similar on the basis of the number of shared versus unique configural attributes, as opposed to primitive attributes (number of lines, arcs, etc.). The indices obtained from the formula provide an objective predictor in reducing search times for a specific symbol set.

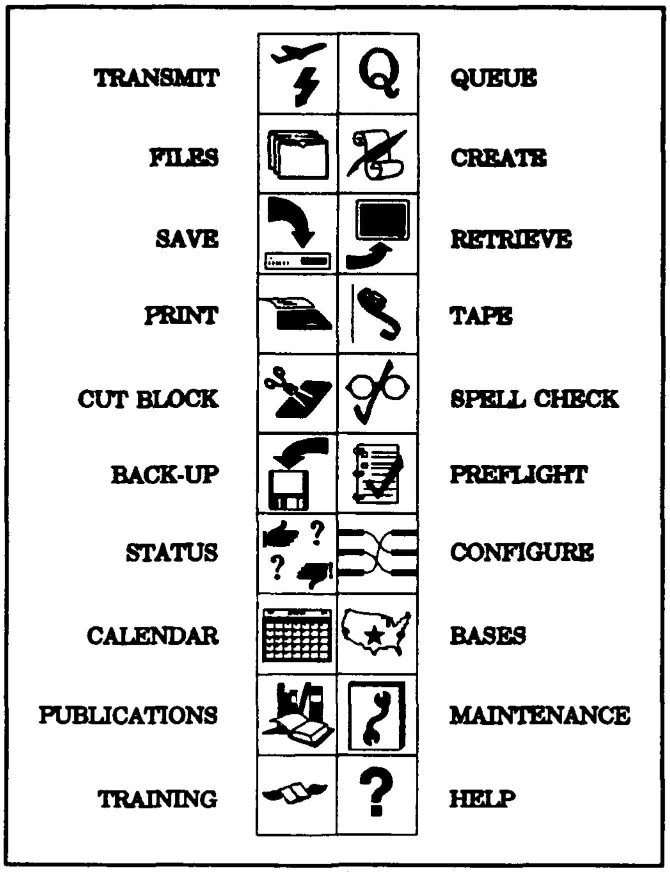


Figure 4.1. TACAMO Candidate Icons

The number of common attributes, unique attributes of each icon, and unique attributes of the sample icon domain were tallied as follows:

C = Number of common attributes $= \sum x_i$, where x is the number of the 20 icons in the sample icon domain having the configural attribute i.

U = Number of unique attributes $= \sum y_i$, where y is the number of the 20 icons in the sample icon domain not having the configural attribute i.

S = Number of unique attributes of sample domain $= 25 - z$, where z is the number of common attributes. (There were 25 instances of attributes in in total making up the 20 symbols in the sample domain).

Geiselman, Landee, and Christen (1982) used standardized regression weights from their multiple regression analysis to develop their discriminability-index (D) formula:

$$D_c = 0.07 [U_c + S_c] - 0.31 C_c , \qquad (4.1)$$

where the subscript *c* corresponds to a specific icon.

While Geiselman, Landee, and Christen (1982) developed their discriminability-index formula for specific use with graphic-display symbology, their research provided a logical precursor for predicting search times for icons used in human-computer interfaces. For example, the candidate icon for *Transmit* has two configural attributes, an aircraft and an arrow (refer back to Figure 4.1). The aircraft is unique and the arrow is held in common with four of the 20 icons in the candidate icon set shown in Figure 1. Thus from equation (4.1):

$$DI = \{0.07[(20\text{-}1) + (20\text{-}4) + (25\text{-}5)]\} - \{0.31[5]\} = 2.30.$$

Discriminability indices calculated for the original 20 candidate icons are provided in Appendix D.3 along the revised discriminability indices calculated when the icon set was reduced to 18 icons (as discussed later).

D. ICON IDENTIFICATION SURVEY

1. Questionnaire Development

A TACAMO Icon Identification Survey, contained in Appendix D.4, was developed to gather recognition and confusion data on the candidate icons using guidelines outlined by Tull and Albaum (1973) and Green and Pew (1978). The survey consisted of three sections. The first section explained the background and purpose of the survey with a brief description of the respondents' tasks. Instructions were outlined and biographical data was requested in the second section. The final section consisted of 22 task descriptions for matching 20 1-inch square candidate icons.

2. Respondents

Surveys were distributed to 60 TACAMO aircrew personnel at the VQ-4 squadron, Naval Air Station, Patuxent River, Maryland, and among TACAMO ACOs at the Naval Postgraduate School. TACAMO aircrewmen who participated in the icon production method test were ineligible to participate in the survey. Respondents included Airborne Communications Officers (n=15) or enlisted Airborne Communications Supervisors (n=6) and ranged in age from 25 to 34. Various levels of TACAMO experience were reflected in the sample, with a mean of 3.5 years of experience and standard deviation of 0.9 years.

3. Task

Survey participants were asked to study each icon and select the one best meaning from the list of task descriptions. Letter codes corresponding to the task descriptions were written underneath each candidate icon. Estimated time to complete a survey was 20 minutes.

E. RESULTS

Results of the icon recognition survey were favorable, with icon recognition rates high and confusion between icons low (see Appendix D.5). Icon recognition rates averaged 94.5%, far exceeding the minimum 75% recognition rate recommended by Heard (1974). Only two combinations of icons fell outside Heard's maximum 5% confusion criteria: the *Retrieve a Message* and *Backup a Message* icons were confused 10% of the time and the *Status of Aircraft* and *Help* icons were confused 14% of the time.

The icon recognition survey verified that candidate icons had been successfully refined. The *Calendar* and *Bases* icons were dropped from the study after additional input from TACAMO ACOs at NPS resulted in adjusted task priorities, with a definitive set of 18 TACAMO icons left for final testing (see Figure 4.2).

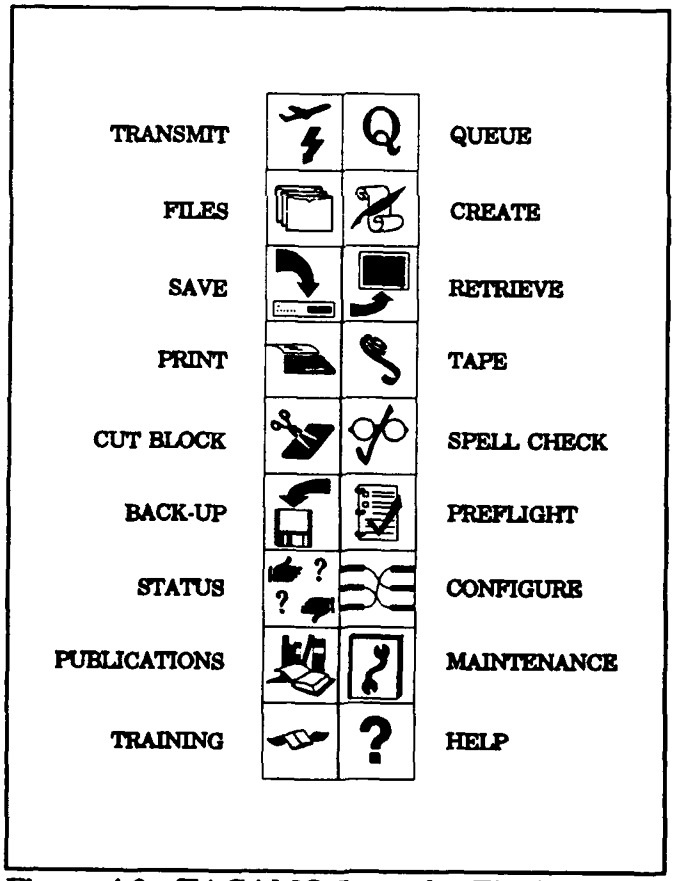


Figure 4.2. TACAMO Icons for Final Testing

V. ICON DESIGN FORMAT EXPERIMENT

A. BACKGROUND

While icons that satisfied discriminability criteria could have been arbitrarily selected from acceptable candidates, an empirical validation of symbol effectiveness is highly desirable (Cahill, 1975, p. 379). Of specific interest for this study are the speed of performance and rate of errors by the user for icons with and without alphanumeric labels. The labels for the TACAMO icon set were generated in a manner similar to the way the initial icon sketches were provided. During the icon production method test, participants were asked to provide alphanumeric labels to represent task descriptions (see Appendix C.4).

To meet minimum legibility requirements prescribed by Siebert, Kosten, and Potter (1959), Baker and Nicholson (1967), and Vartebedian (1971), a 15-point *WP Courier Simplex* font from WordPerfect Corporation's *DrawPerfect*™ presentation graphics software was used to label the icons on a standard VGA 640×480-pixel display monitor. The resulting label was 10/16-inch high, or approximately 10 to 12 scan lines per character height. The TACAMO label suggestions were revised slightly in order to meet size and font restrictions and can be seen in Figure 5.1 (note that the legibility of the printed labels does not necessarily correspond to the legibility of the same labels on a graphics display).

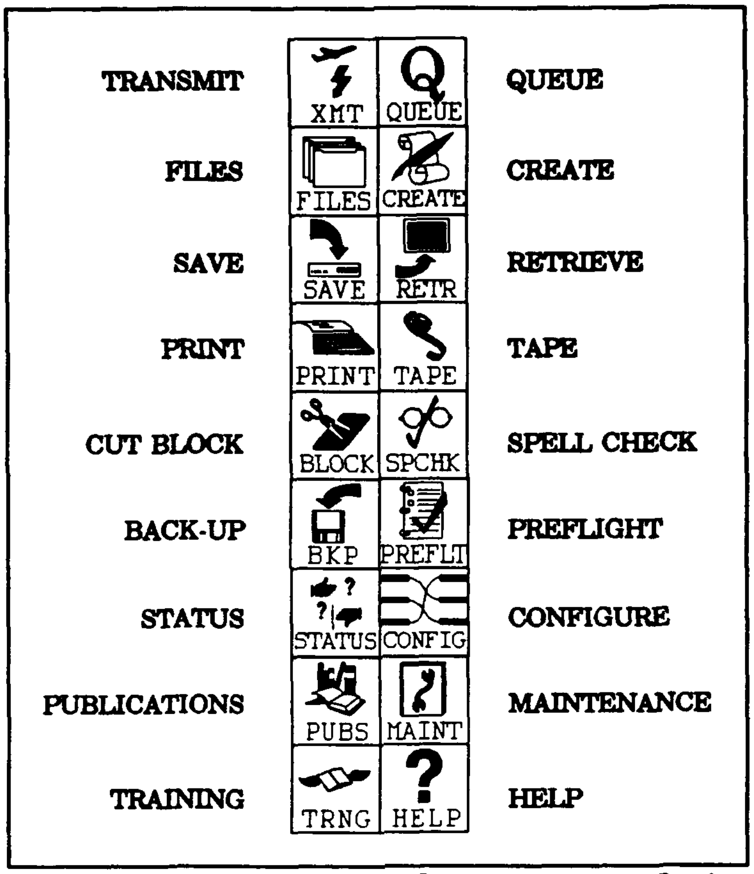


Figure 5.1. Labeled TACAMO Icons for Final Testing

B. EXPERIMENTAL DESIGN

The design used for this experiment was a one-way between-subjects comparison of labeled and unlabeled icon stimuli (see Figures 4.2 and 5.1). A between-subjects design was chosen to avoid confounding with a training bias due to learning the same icon set twice. All subjects received an 18-icon training sequence, review training, baseline reaction testing, additional review training, and icon recognition testing. Presentation order was completely randomized along with icon position in the 3×3-icon matrices.

1. Reaction Time Model

The selection of skill-based actions generally has been studied by measuring reaction time (Wickens, 1992, p. 313). The time to react in a situation in which any one of several signals may occur must include time to complete four processes (Welford, 1980).

1. Reception of the signal by a sense organ and conveyance of data by afferent nerves to the brain.
2. Identification of the signal.
3. Choice of the corresponding response.
4. Initiation of the action that constitutes the response.

Card, Moran, and Newell (1982) model the human as an "information-processor" through a specific, simple model of perceptual, cognitive, and motor processes. The Keystroke-Level Model developed by these researchers defines the time to complete a unit task as the sum of acquisition time and response or execution time:

$$T_{unit\ task} = T_{acquire} + T_{execute} \,. \qquad (5.1)$$

For the icon design format experiment, acquisition time for a unit task depends on the time required to locate and identify an icon. Execution time is the time required to respond manually to the stimulus and depends on motor skills and system response times.

2. Measuring Acquisition Time

This experiment focused on acquisition time. To measure acquisition time, it was necessary to measure total response time, then to subtract out the time required for manual response. The subtraction logic technique developed by Donders (1869, trans. 1969) and refined by Wickens (1992, p. 335) was used for this purpose. That is, a simple baseline reaction-time test (described later) was administered to measure subjects' response times. Average reaction time for each subject was subtracted from total response time to obtain acquisition time.

C. METHOD

1. Subjects

Subjects for the experiment consisted of 36 active duty military officers enrolled in various master's degree programs at the Naval Postgraduate School. Subjects ranged in age from 27 to 40, with a mean of 31.9 years of age and standard deviation of 3.8 years. Four subjects were female and 32 were male; four subjects were left-handed and 32 were right-handed. Various levels of computer experience were reported by the subjects. The subjects were randomly divided into two groups; 18 were tested using icons with alphanumeric labels and 18 were tested on the unlabeled icons.

2. Stimuli

The set of 18 TACAMO icons with and without alphanumeric labels were used as test stimuli. In addition to the 18 TACAMO icons, 18 "distractor" icons with and without alphanumeric labels were also included to increase search complexity, as suggested by Murdock (1982, p. 20). The distractors were developed from Modley's (1976) pictorial symbols to approximate discriminability-index ratings of corresponding TACAMO icons. Both the test icons and the distractor icons were presented as black images in 0.75-inch white squares on a non-glare light-gray background. The stimuli were presented in the form of 324 3×3 randomized icon matrices (see Figure 5.2). The complete sets of TACAMO icons and distractor icons used for testing are shown in Appendix E.1.

3. Apparatus

The experiment was conducted on a Unisys 386 IBM-compatible personal computer with an Intel 80387™ math coprocessor, running at 16 mHz. The graphics

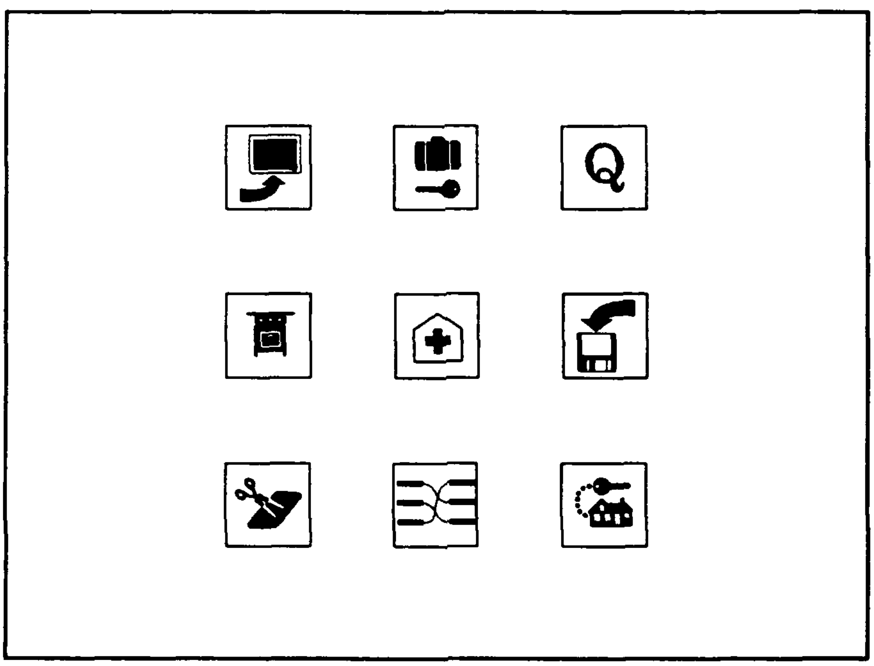


Figure 5.2. Icon Recognition Test Matrix Including TACAMO Icons and Distractor Icons

were displayed on a 14-inch Unisys color VGA 640×480 monitor. Genus Microprogramming's *Proteus*™ prototyping software was used to conduct all phases of the experiment. Reactions were captured on the keyboard's numeric keypad keys "1" through "9." A time-stamping program written in C was used to capture response times from the Unisys system clock (Appendix E.2).

4. Procedure

Complete instructions for the experiment were read aloud to each subject and biographical data was documented (see Appendices E.3 and E.4, respectively). The experiment consisted of five phases: initial icon training, review training, baseline reaction testing, additional review training, and icon recognition testing.

a. Training

Icon training phases presented a set of 18 TACAMO icons with task descriptions. Training was self-paced and identical, except for icon labels, for all subjects. Review training phases allowed for self-paced study of the same icons with abbreviated task descriptions.

b. Baseline Reaction Time Testing

Baseline reaction time testing consisted of a simple search for a black block in a 3×3 matrix (see Figure 5.3) and a one-finger response corresponding to the location of the stimulus within the matrix. All subjects used the index finger of the right hand, starting at a common point 5.5 cm directly below the centrally-located "5" key on the numeric keypad. The index finger was then returned to the common

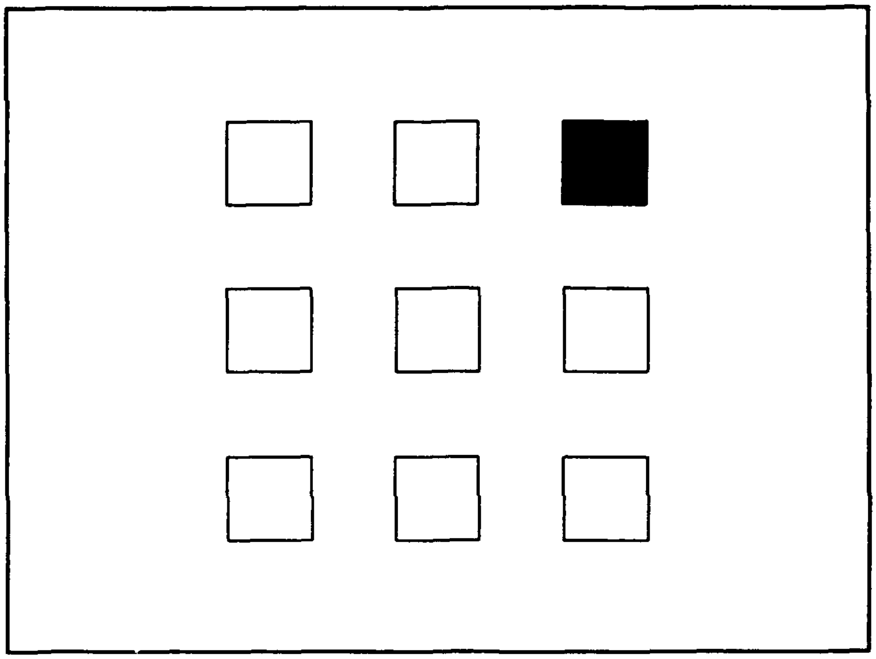


Figure 5.3. Baseline Reaction Test Matrix

starting point before continuing to the next screen for the next test. A total of 27 reaction times were recorded for each subject. The first nine responses for each subject were discarded as warmup trials.

c. *Icon Recognition Tests*

For the icon recognition test, a text-only screen told the subject to observe the matrix that would be displayed and to select the icon which best represented an abbreviated task description which was provided on the screen (see Appendix E.5). As recommended by Murdock (1982, pp. 20-23), subjects were instructed to expect that a 50% mix of distractor icons would be randomly included in the icon matrices. When the subject was ready to continue, pressing the spacebar presented a 3×3 icon matrix. As with the baseline reaction time testing phase, subjects used their index fingers to press the key of the numeric keypad which corresponded to the described icon, always starting at and returning to the common starting point. Each subject was tested once on every icon in the set. Presentation order and matrix position were completely randomized through the use of 324 screens of 3×3 matrices.

5. Performance Measures

Three performance measures were collected in addition to the measurement of baseline reaction time. Response times were recorded for each numeric keypad key push. Errors (incorrect key pushes) were recorded, and the length of time the subject studied the task descriptions before beginning each test was noted.

D. RESULTS AND DISCUSSION

1. Subject Variables

An examination of the intercorrelations for the subject descriptors revealed no significant correlations of baseline reaction time and icon identification response time to age, sex, or primary hand. Types of computer experience also did not correlate to better or worse performance.

2. Baseline Reaction Test

An analysis of variance for baseline reaction times showed the subject [$F_{35,324}$ = 19.23, $p < 0.001$] and the icon's position in the matrix [$F_{8,324}$ = 2.65, $p < 0.01$] to be significant. The interaction between subject and position was not significant.

The matrix-position effect was compensated for in the main icon recognition test by complete randomization of all icons in the nine matrix positions. The subject effect was minimized by subtracting each subjects' average baseline reaction time from his or her individual icon recognition times to achieve a handicapping effect, essentially lining up subjects' mean reaction times while not disturbing variation (see Appendix E.6). Baseline reaction time correlated weakly with total recognition time ($r = 0.29$). However, total recognition time showed strong correlation ($r = 0.997$) with icon identification time; that is, after baseline reaction time was subtracted from the total. The correlation between baseline reaction time and icon identification time was very weak ($r = 0.08$). This indicates that subtracting the baseline reaction time from the total response time was a satisfactory technique for obtaining icon acquisition and identification times.

3. Performance Measures

Response times (with mean baseline reaction times subtracted), error rates, and study times were analyzed with both one-way analysis of variance and the Kruskal-Wallis test. The exploratory data analysis (Velleman and Hoaglin, 1981) revealed a pattern of outliers, leading to the use of the Kruskal-Wallis nonparametric method (Conover, 1980). Significant experimental factors were found to be the subject [$H_{35} = 145.03$, $p < 0.001$], icon design [$H_{17} = 134.71$, $p < 0.001$], icon position [$H_8 = 31.35$, $p < 0.001$], and labeling [$H_1 = 4.81$, $p < 0.03$].

Minitab 7.2™ was used to generate 95% sign confidence intervals for all icons, for labeled icons, and for unlabeled icons (see Appendix E.7). Figure 5.4

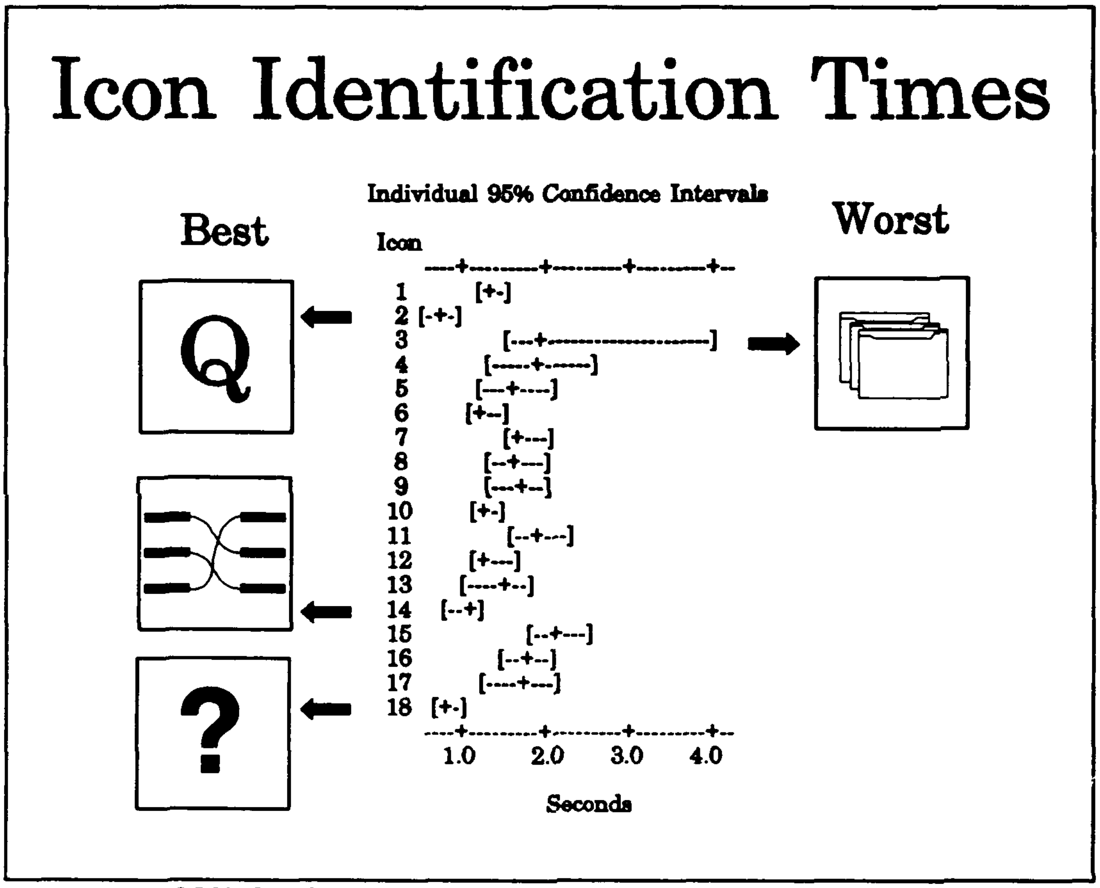


Figure 5.4. 95% Confidence Intervals on TACAMO Icon Identification Times (Combined Labeled and Unlabeled with Baseline Reaction Time Subtracted)

shows the 95% confidence intervals (calculated by the sign method) for identification times for the set of 18 TACAMO icons (combined labeled and unlabeled, after baseline reaction time was subtracted). All icons were recognized with little response time variation with the exception of the *Files* icon, which fell back on a standard desktop metaphor instead of a TACAMO-specific symbol.

Applicable two-way analysis of variance showed no significant interactions. Study time was weakly correlated to icon identification time ($r = 0.21$). The discriminability indices were also only weakly correlated ($r = 0.22$) to identification time for unlabeled icons. A multi-factor analysis of variance model could not be calculated due to rank deficiencies resulting from five errors.

4. Error Analysis

A qualitative analysis of errors showed five incorrect responses (see Figure 5.5). Surprisingly, only one of the confusion errors occurred with a subject using unlabeled icons; the remaining four errors were committed during subjects'tests with labeled icons. Since the main purpose of the icon label was to provide redundant information to avoid confusion, the results warrant a closer investigation of the effect of alphanumeric labels on icons. The effect of the labels on the tested icon set appears not only to have a detrimental effect on speed, but also to have no effect on reducing errors.

5. Labels—A Closer Look

For the 643 data points, median acquisition time for icons without labels was 1319 ms; for icons with labels, the median time was 1507 ms. Figure 5.6 shows the median identification times for each icon, labeled and unlabeled, in the TACAMO icon set. Comparative results show that unlabeled icons yielded quicker response times for 15 of the 18 icons. For four of these icons, labeling added over 400 ms to the median response time. Of interest in Figure 5.6 are the results for the *Files* icon, which show that almost all of the sizable variability shown in Figure 5.4 comes from the labeled version of the *Files* icon. Nonparametric sign confidence intervals for all icons combined (labeled and unlabeled), for labeled icons, and for

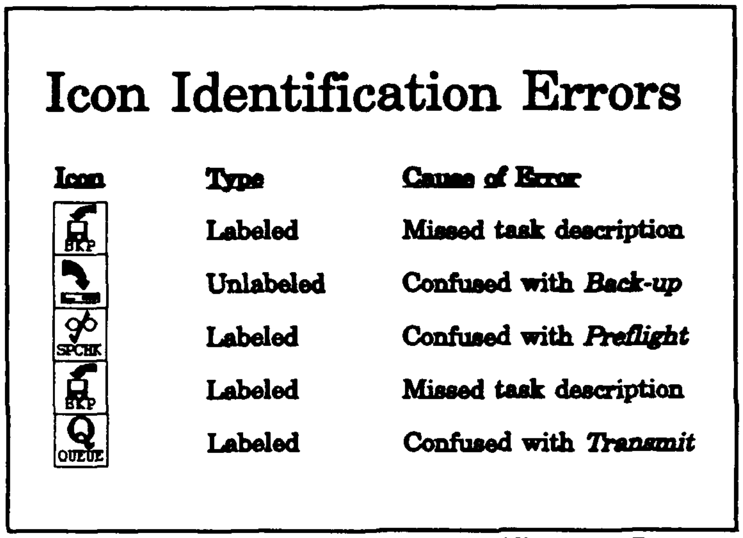


Figure 5.5. Errors from Icon Identification Test

unlabeled icons are contained in Appendix E.7. The Kruskal-Wallis test statistic using a comparison of average ranks was calculated as $H_1 = 4.81$ with p-value = 0.029; thus the results are significant at $\alpha = 0.05$.

Power was analyzed using *StatGraphics 5.0™* statistical software and verified with operating characteristic curves as described in Duncan (1986). Assuming normal distributions with means of 1645 ms for icons without labels and 1807 ms for icons with labels, and a pooled standard deviation of 1361 ms, an analysis of power shows $\beta = 0.14$. Estimating power with the nonparametric medians of 1320 ms for icons without labels and 1510 ms for icons with labels lowers β to 0.03. The null hypothesis that labels will result in faster response times must be rejected at $\alpha = 0.05$. These results indicate strongly that the alphanumeric labeling of well-developed icons does not significantly improve identification times or reduce errors.

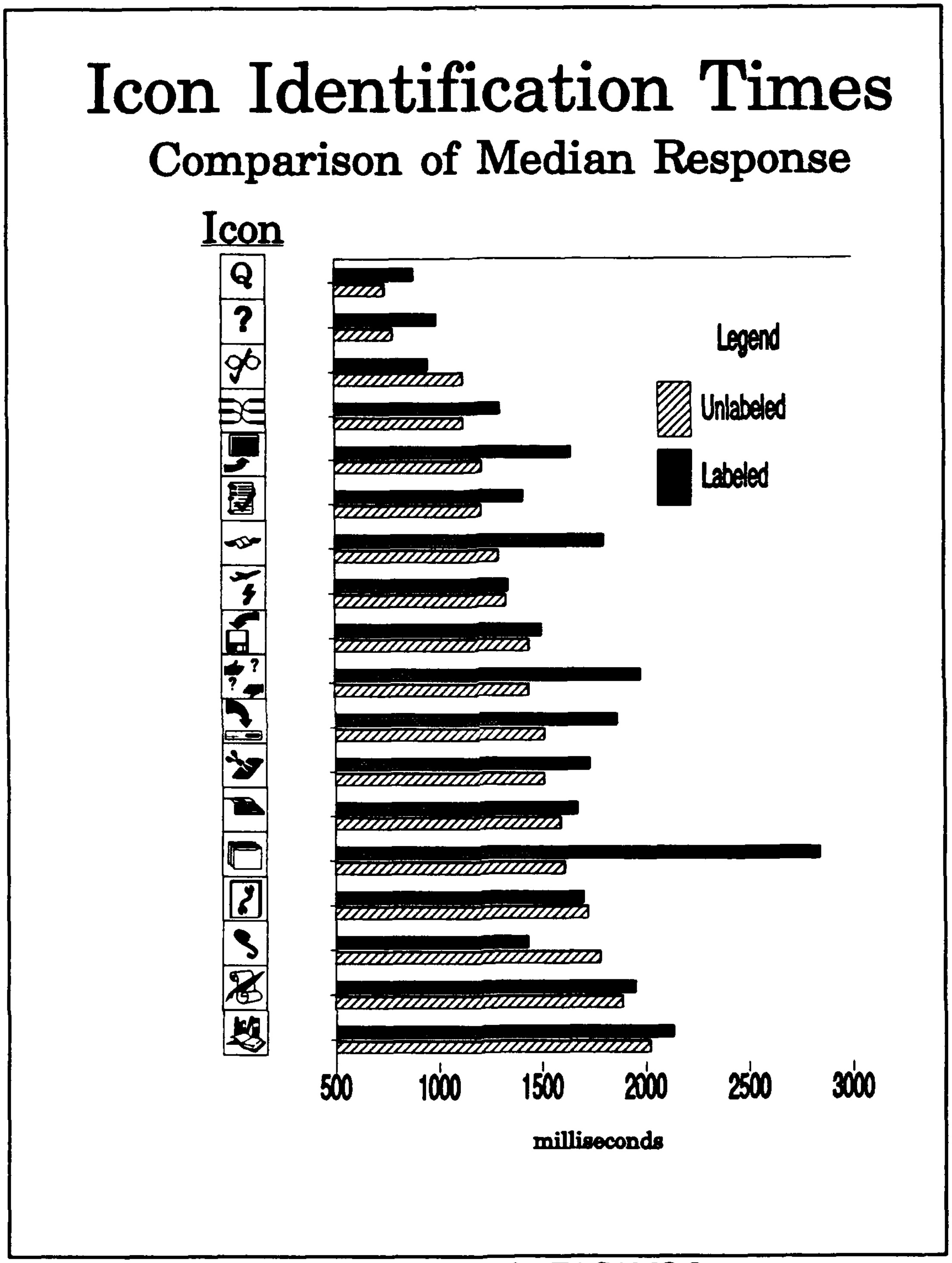


Figure 5.6. Median Identification Times for TACAMO Icons

VI. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY CONCLUSIONS

This study provided important results in two areas. First, more rapid response times and lower error rates expected for icons with alphanumeric labels did not materialize. In fact, alphanumeric labels were shown to increase response times significantly, yet did not result in a lower error rate, for the TACAMO icon set. Second, actively involving the targeted user community in the development of icons was shown to be a valid method of generating useful icons. The low-cost approach used for the evaluation and refinement of icon candidates should be of particular value to designers of future military human-computer interfaces.

B. TACAMO ICONS FOR THE MILSTAR MESSAGE PROCESSING SYSTEM

1. Icon Designs

The primary result of this study is a set of icons validated for use in TACAMO's MILSTAR Message Processing System (MMPS). Use of these icons is expected to reduce the need for menu commands substantially. The icons should provide a faster, more satisfactory human-computer interface since they incorporate much more descriptive information using the same (or less) physical display space (Gittins, 1986, p. 519). Since the icons were developed with the input of TACAMO aircrew personnel, they are expected to be well-suited for their distinct mission, and their meanings should be intuitively obvious to the intended users. It is strongly recommended that the Naval Air Warfare Center, Aircraft Division, develop and test a prototype graphical interface for TACAMO's MMPS that will include these icons.

2. Labeling of Icons

Labeling the TACAMO icons is not recommended. This study has shown that labels do not effectively aid in identification. Furthermore, it is recommended that the Department of Defense revise *MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment and Facilities*, to reflect the findings of this study. Namely, Section 5.15.4.8.3 *Supplementary verbal labels* should be deleted and Section 5.15.4.8.2, *Iconic menus*, be rewritten as follows:

> *Iconic interfaces*. Graphical system interfaces should incorporate icons to represent control options when practical. Where icons are used to represent control actions in menus, they shall be designed through production method testing and preference surveys of the targeted user. Icons should be supplemented with verbal labels only when targeted users are shown to be unsuccessful in developing appropriate icons that map to control actions.

The indiscriminate use of supplementary labels with icons should be discouraged as a "band-aid" approach to human factors engineering, an inadequate substitute for proper designs.

C. ICON DEVELOPMENT METHOD

The icon production method test used during this study provided a quick and direct source of reasonable designs for candidate icons. Response to and participation in the drawing of candidate icons was positive; the only disappointment came from the relatively small sample size of TACAMO aircrew personnel available to assist in the process. With significant benefits achieved at little cost, it is recommended that the icon production method technique demonstrated here, followed by icon refinement through user surveys, be used on a routine basis by designers and developers responsible for graphical user interfaces for military systems.

D. LIMITATIONS OF GRAPHICAL INTERFACES

Icons are not a panacea; they cannot completely replace words in complex situations. Every set of new icons should be extensively researched, developed, and tested before being introduced into a new application (Marcus, 1991). Based on experience gained during this study, several specific cautions about developing icons for military systems, such as TACAMO's MMPS, are offered.

1. Before any interface format is implemented, a human factors analysis of the system must be conducted. A thorough task analysis logically precedes valid icon development.

2. An icon designer should not fixate on a particular type of metaphor (e.g., the "office metaphor" prevalent in many of today's icon interfaces). In essence, this shows a lack of originality and an absence of the use of thoughtful design methods.

3. Blanket labeling of icons is an admission of failure by the interface designer. The unrestricted addition of alphanumeric labels is a confession that the targeted user will not be able to map icons successfully to the task descriptions they represent.

There are two major criticisms leveled against the use of icons. The first is that the lack of empirical study and understanding of the cognitive mechanism of icon interpretation makes it difficult to recommend design guidelines; thus any particular implementation is arrived at subjectively. The second criticism is that, while icon designs can indicate associations between underlying data or functions, this is often all that can be achieved. That is, the design can indicate the association, but not the actual underlying feature, because of the limits of graphical design techniques. (Halasz and Moran, 1982) This study has indicated that both problems can be minimized, at least for military systems, by including the intended users in the design process.

These cautions and criticisms warn of the hidden snare of icons—extending their use beyond their obvious efficiency as signifiers. Context forms the foundation to effective icon development in which a user finds using an interface as obvious as, say, ringing a doorbell to enter a house. Icons are quickly becoming the choice of many interface designers, since they provide the only interface in which the user does not have to remember dozens of facts and processes. Yet the military must employ icons judiciously, insisting that each interface be tailored with icons specific to the mission at hand.

Future research on icon development for military applications should focus on additional complex issues such as effects of color, long-term memory retention, and developing an effective icon-discriminability index. For example, many icons employ color while it is clear that the thoughtless use of color can interfere with and overload the user's perceptual process (Murch, 1985). Consideration must be given to human perceptual characteristics, physiological factors, cognitive processing, and response capability, for research leading to the optimum design of graphical user interfaces for military applications.

While the scope of this study was limited to the comparison of icons with and without labels for a set of icons developed for the TACAMO MMPS, it is hoped that the approach taken follows the resourceful path of Jules Henri Poincaré: "avoiding the constructing of useless combinations, while constructing the useful combinations which are in an infinite minority." Properly developed and designed, icons deliver a sophisticated capability, transparent to the operator who must concentrate on the mission at hand.

APPENDIX A

ABBREVIATIONS AND ACRONYMS

ACO	Airborne Communications Officer
HF	High Frequency
LOS	Line of Sight
MILSTAR	Military Strategic and Tactical Relay System
MMPS	MILSTAR Message Processing System
NCA	National Command Authorities
NPS	Naval Postgraduate School, Monterey, California
SATCOM	Satellite Communications
SSBN	Nuclear-powered Ballistic Missile Submarine
TACAMO	Take Charge and Move Out Navy Airborne Relay
TMPS	TACAMO Message Processing System
UHF	Ultra High Frequency
VGA	Video Graphics Adapter
VHF	Very High Frequency
VLF	Very Low Frequency
WWABNCP	Worldwide Airborne Command Post System

APPENDIX B

TACAMO MMPS PROTOTYPE INTERFACE DESIGN

APPENDIX B.1

TACAMO MMPS INTERFACE GUIDELINES

1. **Goal.** The goal of these guidelines is to aid in developing a human-computer interface that allows TACAMO aircrew personnel to perform required tasks accurately and efficiently. These guidelines are not meant to restate or replace existing government and military guidelines, but are designed as a basis for developing system-specific operational rules for TACAMO's MILSTAR Message Processing System (MMPS), taking the considerations of Federman (1988) and the opinions of fellow ACOs stationed at NPS into account.

2. **Design Principles.** The following three principles are recognized by many sources (often in varying forms) as underlying a satisfactory human-computer interface (Brown, 1986; Card, Moran, and Newell, 1983; Ehrich and Williges, 1986; Shneiderman, 1986; Helander, 1988; Laurel, 1990; and Neumann, 1991). The TACAMO MMPS prototype was designed with these summary guidelines in mind.

a. *Efficiency*. Information should be easy to find. Only information that is essential for performing a task should be displayed, minimizing operator effort and reducing memory load. Grouping, placement, and sequence characteristics should be used to display information in a way compatible with the way operators use the information in a given task. The vocabulary of TACAMO aircrew personnel should determine data labels, display titles, menu options, command language, and error messages.

b. *Consistency.* Consistency in format and operation of the interface enhance operator efficiency. Displays can be searched faster for crucial information. In particular, location of similar types of information should be consistent from screen to screen. General methods of interaction, or habit patterns, should be the same regardless of where the operator is in the TACAMO MMPS. Coding, or special meanings, such as "blinking red" for alarms, should be applied consistently to ensure that meanings are clearly interpreted.

c. *Feedback.* Every operator action should invoke a noticeable response from the computer. Specifically, when the operator has made an error or performed an action that the TACAMO MMPS does not understand, the TACAMO MMPS should provide a message of explanation and method of recovery. When an operator performs an action that has potential destructive effects, the TACAMO MMPS should require confirmation before processing the request. When the TACAMO MMPS is busy performing a lengthy process, it should notify the operator through a system message or display graphic. When it is appropriate for an operator to select objects of the display to manipulate, the system should indicate that an object has been selected (by image reversal highlighting or color coding) so the operator knows on what object the selected action will be directed.

3. **General Screen Characteristics.** Figure B-1.1 shows the TACAMO MMPS prototype display format. A graphical interface with pull-down menus and an iconic interface should make the TACAMO MMPS simpler and easier to use than the current TACAMO Message Processing System (TMPS) (Hildebrand, 1991). Constant monitoring of all radio circuits was deemed a high priority, as was establishing a visual message alarm system, distinguishing the message editing screen, and providing an extensive online help capability.

a. *Pull-down Menus.* Pull-down menus are displayed as a horizontal list of options at the top of the screen. Proposed MMPS menu structure is listed in Appendix B.2. The menus were ordered by grouping similar tasks as described by Harpster (1987) and McDonald, Dayton, and McDonald (1988). Surprisingly, it appears that the names given to commands have little effect on menu selection times (Smelcer and Walker, 1990). Operator search time is significantly shorter for the vertical list format (Backs, Walrath, and Hancock, 1987). The menu commands should be mixed case with double spacing between menu commands (Williams, 1988).

b. *Iconic Interface.* An appropriate icon may be easier to recognize and comprehend than any amount of text (Brown, 1987, p. 91). By presenting user command and system information in the form of icons, the TACAMO MMPS can capitalize on the new capabilities of graphic displays, reducing both time and effort of learning and facilitating performance while reducing errors (Lodding, 1983, p. 11). Ordering of the icons corresponds to ordering of the menu commands. While not all menu commands have a corresponding icon, all icons have a corresponding menu command.

With the established superiority of icons over alphanumerics for many applications (Steiner and Camacho, 1989), an iconic interface is strongly endorsed as an alternative interface for the TACAMO MMPS. While icon interfaces are aimed primarily at the novice (Blankenberger and Hahn, 1991), studies have shown that icons produce faster search and selection times (Camacho, Steiner, and Berson, 1990) and in some cases they are even preferred by experienced operators (Guastello and Traut, 1989).

c. *Monitoring Radio Circuits*. The bar at the bottom of Figure B-1.1 will be used to monitor incoming radio traffic. Current system capabilities do not allow the operator to monitor all of the circuits received aboard TACAMO at the TMPS operator position. Each circuit identifier would consist of a small blue button with an abbreviated circuit label in dark gray. When a circuit is actively monitored, the label would turn bright white, indicating normal functions. A circuit under repair or malfunctioning would be indicated by a light gray button. Incoming traffic would turn the labels yellow. Red labels on yellow buttons with a "3-D popped circuit breaker" effect should be used for Flash or higher precedence message traffic. By clicking on any button, the operator should be able to directly access the desired circuit. The "3-D popped circuit breaker" effect would reset itself after the operator had inspected the incoming message traffic to ensure Flash or higher message traffic was promptly handled.

d. *Message Alarm System.* A visual alarm system for incoming messages would eliminate the need for the current aural alarm that is rarely used due to its ineffectiveness (Federmann, 1988, p. 2-3). Figure B-1.1 shows a half-circle fan in the upper right-hand corner of the screen. This half-circle would serve as a dual-purpose gauge, normally used to indicate space remaining on the fixed-disk drive, but turning into a visual alarm for incoming messages. The half-circle would be light gray with blue right-to-left shading when indicating the amount of space remaining on the fixed disk. The blue fill would turn to amber, to warn when the disk capacity exceeds a specified percentage. The half-circle would become a spinning yellow-red fan when a Flash or higher precedence message arrives aboard the aircraft.

e. *Editing Screen.* An extremely serious error occurs when the operator is confused about whether the present screen displays a message that has been received or a message that is being edited. A clear distinction between the two types of screens is definitely needed, as several TMPS operators have registered complaints with the split screen used in current equipment (Federman, 1988, p. 2-2). The message monitoring screen should have a light yellow background with text displayed in a blue, sans serif font similar to that used with older teletype machines. The editing screen should be paper white with a black serif font for high legibility (Oborne and Holton, 1988). For higher resolution screens, light-colored type on dark backgrounds produces much slower reading times (Shneiderman, 1987, p. 360).

If additional distinction is needed between the two display formats, simulated perforation tracks could displayed on the right and left edges of the message monitoring screen. Operators should have the option of toggling quickly between screens and also the option of viewing more than one screen at a time, each in a separate window. For message editing purposes, a temporary "paste-up" buffer space should be made available to cut, store, and paste sections of different messages.

f. *Screen Colors*. In this proposal, menu bars are dark blue with white lettering. Bright yellow is used for the single-letter "speed-keys" within each menu command. Reverse video (white background with blue letters) should be used to highlight pending menu selections. Icons are drawn with dark blue details on a white background for discriminability. Similar to the menus, reverse video (dark blue background with white details) indicates a pending icon selection. Unusable space should be designated with a separate color, such as light blue.

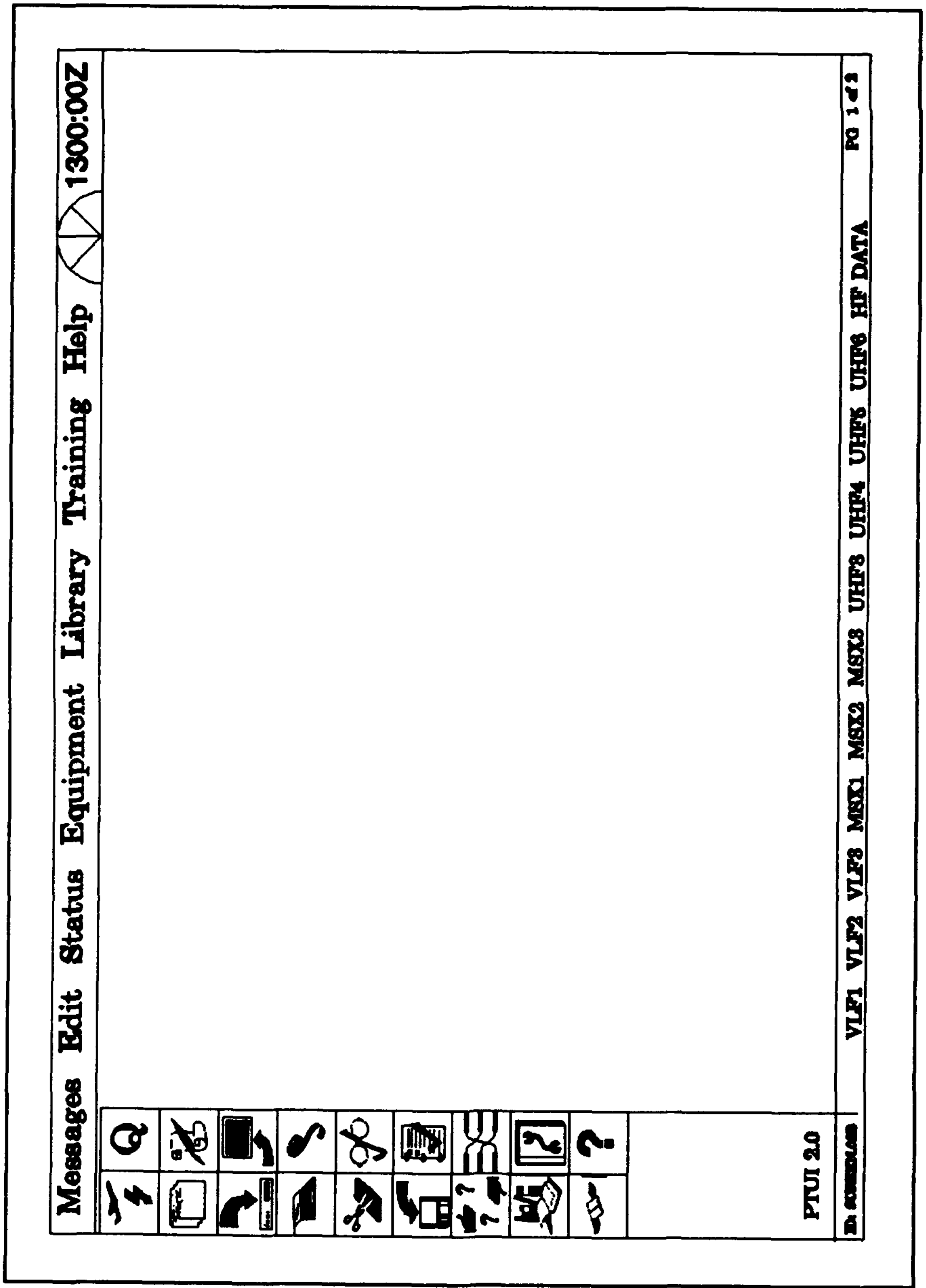


Figure B-1.1. Prototype Interface for TACAMO MMPS *g. Online Help and Training.* Online help should be made available so the operator can access information about features of the software and can obtain aid in problem recovery. Easily accessed information helps the user cope, facilitates browsing, and results in the rapid learning of new features or advanced techniques (Heckel, 1991, p. 57). Context-sensitive help is especially valuable in giving operators quick answers to specific problems. Prototype testing and evaluation should provide detailed documentation of problem areas in need of context-sensitive help.

The TACAMO MMPS should be used extensively for training purposes. An ideal TACAMO aircraft would have more than one MMPS, with one terminal available at all times for training or as a backup to the main terminal. CD-ROM-based training and publications storage would fully exploit the capabilities of a well-planned TACAMO MMPS, reducing aircraft weight and enhancing survivability.

4. Interaction Methods.

a. Menu Selection. For the process of selecting an item from a menu, cursor keys, a trackball, scrolling bars, and "speed-keys" should be implemented. Cursor keys operate pull-down menus and can even control icon menus, if desired. Trackballs have been shown to be an effective method of interaction, providing direct access by point and click. The trackball is preferred over the mouse for applications involving high stress and limited space (Shneiderman, 1987, p. 242).

The usual wisdom is that pointing devices, such as a trackball, mouse, or joystick, are faster than keyboard controls; however, studies have shown that for tasks that mix typing and pointing, keyboard input is often preferred and results in less muscular strain (Shneiderman, 1987, p. 247). Scrolling bars should be provided to allow operators to screen message traffic quickly. The use of "speed keys," single keypresses that access a command directly (usually indicated via a single highlighted letter on a menu command), offers advantages common to both cursor keys and the trackball. Eliminating the requirement of pressing the *Enter* key translates to a more direct method of entry, often preferred by experienced users.

Menus should always be available for repeated use if desired. For example, if an operator desires to switch radio frequencies for multiple circuits and for each radio must access the frequency control menu that is three levels down and three levels up, the operator will quickly become annoyed. Operators should always have instant access to the top level menu if desired. The most important aspect of menu selection control is providing all reasonable methods of control so that the individual operator can develop a style of operation that he or she is most comfortable with.

b. Data Entry. For data entry, direct entries are significantly faster and preferred by system operators (Gould, et al., 1988). This finding should not discourage the use of pre-filled data fields for common entries, such date-time-group entries, latitude-longitude entries, and pre-formatted message forms.

c. *Innovative Graphical Displays*. Electronic *Post-It*™ notes, scheduling aids, and other real-world conveniences should be made available to the operator. Open communication lines between the prototype designer and the actual TACAMO operators will ensure that such conveniences will be provided in Version 1.0 and not as a later add-on.

5. **Development of a Prototype**. Full development of a TMPS MMPS prototype should directly involve the TACAMO community at all stages of testing. Early evaluation and thorough iterations will produce a satisfying end product. The use of PC-based design and prototyping tools will result in a better design process, allowing the interface designers to involve TACAMO aircrew personnel actively, resulting in a significantly better user interface design (Koster and Wilkinson, 1988, p. 360).

Melkus and Torres (1988) provide excellent guidelines for using prototyping with a minimum of problems. For a more thorough treatment on prototyping, Wilson and Rosenberg (1988) describe available tools and evaluation techniques to aid in prototyping from the "tangible speculation" stage to the final testing and analysis.

APPENDIX B.2

MMPS MENU STRUCTURE

- MESSAGES⇒
  - Transmit ⇒
    - Select message and parameters
  - Monitor ⇒
    - EHF or MILSTAR
    - UHF
    - VLF
    - HF DATA
  - Queue of outgoing messages

- EDIT⇒
  - Create
  - Retrieve
  - Save
  - Print
  - Punch tape
  - Spellcheck
  - Block
  - Display message files⇒
    - Flash messages
    - General catalog
    - Standard message forms

- STATUS ⇒
  - Comm Central⇒
    - Power
    - AN-USC/13
    - Reel assembly
  - Aircraft systems⇒
    - Status
    - PMS
  - TACAMO bases
  - WWABNCP⇒
    - Basing
    - Airborne schedule

- **EQUIPMENT**
  - Pre-Flight tests
  - Configure Comm Central
    - Set circuits
    - Set alarms
    - Verify FTS
  - Back-up mission data

- **TRAINING**
  - PQS training
  - Crew training
  - Mission goals
  - Squadron goals

- **LIBRARY**
  - Abbreviations & acronyms
  - Dictionary
  - Thesaurus
  - Professional
    - COG
    - TOP
    - OPORDERS
    - NATOPS
    - Maintenance

- **HELP**
  - Help
  - Index
  - Version

APPENDIX B.3

INITIAL TASK DESCRIPTIONS FOR MMPS ICONS

1. Preflight tests and checklists
2. Display message catalog (files)
3. TACAMO aircrew basing information
4. Transmit a message
5. Retrieve an existing message
6. Print a paper copy of a message
7. General help index for MMPS software
8. Aircraft systems readiness status information
9. Configure Comm Central equipment
10. Spell check a message
11. Block and cut a section of a message
12. Create a message
13. Operational, NATOPS, and maintenance publications
14. PQS syllabus training, programmed texts
15. Thesaurus
16. Cut a teletype tape of a message
17. Display the outgoing message queue
18. Backup mission data from the hard disk to floppy diskette
19. Calendar of scheduled events
20. Save a message

APPENDIX C

ICON PRODUCTION METHOD TEST

APPENDIX C.1

TACAMO ICON PRODUCTION QUESTIONNAIRE

Name (optional): ________________________________

Rank/Rate: _____ **Age:** _____ **Sex:** M F

TACAMO experience:

Crew position(s) ______________________ ____

Aircraft flown ______________________________

Time in TACAMO community ________ yrs. ________ mos.

Education:

High School/GED

Some College Courses

Associate's Degree ____________________

College Degree ______________________

Postgraduate ________________________

Computer experience (circle as many as applicable):

IBM PCs	Macintosh	Mainframe terminals
Amiga	Commodore	Other __________

Subject number ___

MENU STRUCTURE SURVEY

For each question, please darken the circle nearest the level of importance you would place on each task for inclusion on the Milstar Message Processing System.

1. Preflight tests and checklists.
2. Display message catalog.
3. TACAMO aircrew basing information.
4. TACAMO abbreviations and acronyms dictionary.
5. Transmit a message.
6. Chain of command organization chart.
7. Retrieve an existing message.
8. Print a paper copy of a message.
9. General help index for MMPS software.
10. Aircraft systems readiness status information.
11. Standard dictionary.
12. Configure Comm Central equipment.
13. Spell check a message.
14. Squadron goals.
15. Mission commander goals.
16. Comm Central readiness status information.
17. Crew deployment training goals.
18. Monitor a radio circuit.
19. Block and cut a section of a message.
20. Create a message.
21. Operational and maintenance publications, NATOPS.
22. PQS syllabus training, programmed texts.
23. Thesaurus.
24. Cut a teletype tape of a message.
25. WWABNCP basing and deployment status information.
26. Version number for MMPS software.
27. Display the outgoing message queue.
28. Backup mission data from the hard disk to floppy diskette.
29. Calendar of scheduled events.
30. Save a message.

MENU STRUCTURE SURVEY

	Not Important	Not As Important	Important	More Important	Very Important
1.	0	0	0	0	0
2.	0	0	0	0	0
3.	0	0	0	0	0
4.	0	0	0	0	0
5.	0	0	0	0	0
6.	0	0	0	0	0
7.	0	0	0	0	0
8.	0	0	0	0	0
9.	0	0	0	0	0
10.	0	0	0	0	0
11.	0	0	0	0	0
12.	0	0	0	0	0
13.	0	0	0	0	0
14.	0	0	0	0	0
15.	0	0	0	0	0
16.	0	0	0	0	0
17.	0	0	0	0	0
18.	0	0	0	0	0
19.	0	0	0	0	0
20.	0	0	0	0	0
21.	0	0	0	0	0
22.	0	0	0	0	0
23.	0	0	0	0	0
24.	0	0	0	0	0
25.	0	0	0	0	0
26.	0	0	0	0	0
27.	0	0	0	0	0
28.	0	0	0	0	0
29.	0	0	0	0	0
30.	0	0	0	0	0

Subject number: ______

ICON PRODUCTION TASK DESCRIPTIONS

The following task descriptions were presented verbally and on an overhead projector slide in this random order:

1. Preflight tests and checklists.
2. Display message catalog (files).
3. Create a message.
4. Operational and maintenance publications, NATOPS.
5. General help index for MMPS software.
6. Aircraft systems readiness status information.
7. Block and cut a section of a message.
8. TACAMO aircrew basing information.
9. Retrieve an existing message.
10. Print a paper copy of a message.
11. Display the outgoing message queue.
12. Transmit a message.
13. PQS syllabus training, programmed texts.
14. Thesaurus.
15. Cut a teletype tape of a message.
16. Configure Comm Central equipment.
17. Spell check a message.
18. Save a message.
19. Calendar of scheduled events.
20. Backup mission data from the hard disk to floppy diskette.

TACAMO SYMBOLOGY

Subject number ___________

Subject number __________

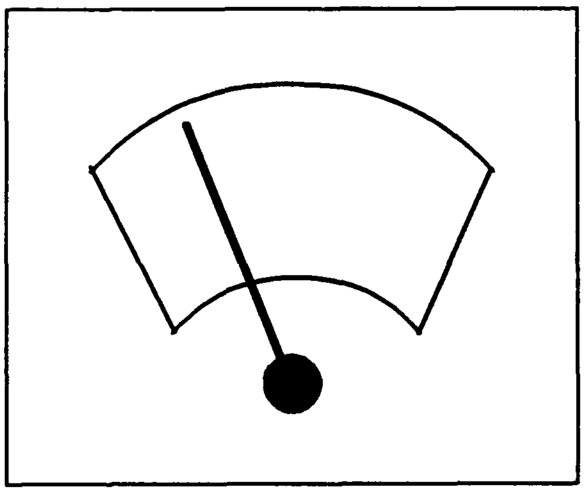
APPENDIX C.2

ICON PRODUCTION INSTRUCTIONS

I am interested in developing icons for use in a graphical interface for the next-generation MILSTAR Message Processing System (MMPS). Go ahead and fill out the background information on the first page of your questionnaire before we begin. I have focused on the use of icons in the MMPS because icons seem to be recognized more rapidly and accurately than command lines that are currently used in the TACAMO Message Processing System (TMPS). Standard symbols and pictograms are currently in use in automobiles, public transit systems, and highway signs.

The key to developing strong TACAMO icons is your participation here today. The method I'm using today is refered to as the icon production method which has been used to succesfully develop Army vehicle controls, automobile labels, and more recently Army battlefield symbology.

So, what makes a good icon? A strong pictorial representation, for example (draw figure on board): This windshield wiper is an excellent example of an icon that provides a strong image with an image of limited complexity. Today we're going to try and create symbols for TACAMO icons



Control Symbol for Automobile Wiper

with similar strengths.

Basically, a good icon will be:

1. Meaningful,

2. Simple, yet bold,

3. Different looking from those that already exist—especially those that exist on your nieghbor's paper.

Don't be afraid to explain your artwork. This is not a test of your artistic talent. Try to draw each icon as large as the space allows. For each task description, please draw a picture in the top box and an alphanumeric label in the bottom box provided. You will be given two minutes to draw each icon.

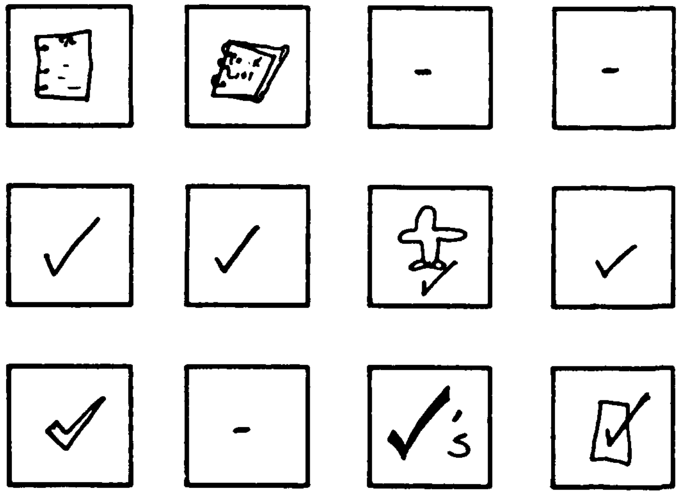
Do you have any questions?

Thank you for your time and cooperation.

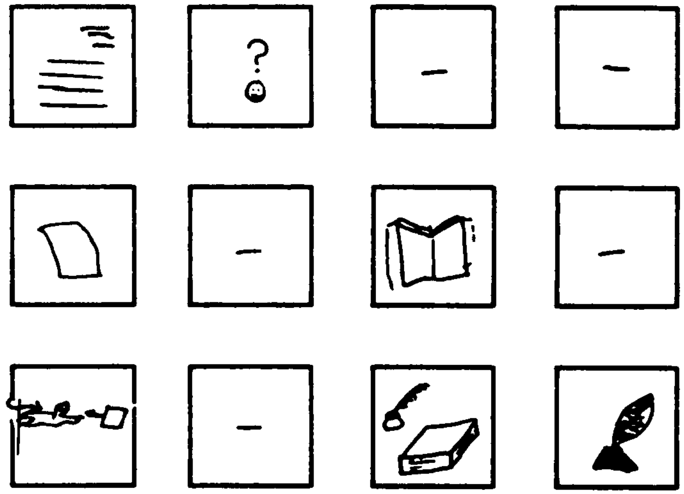
APPENDIX C.3

ICON PRODUCTION METHOD DRAWINGS

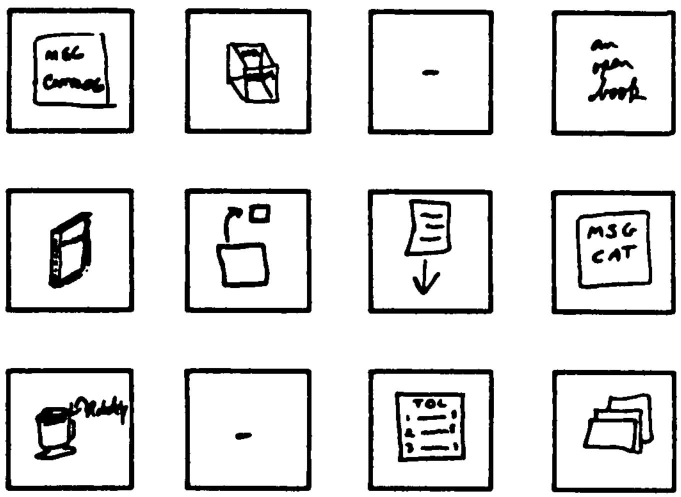
Preflight tests and checklists



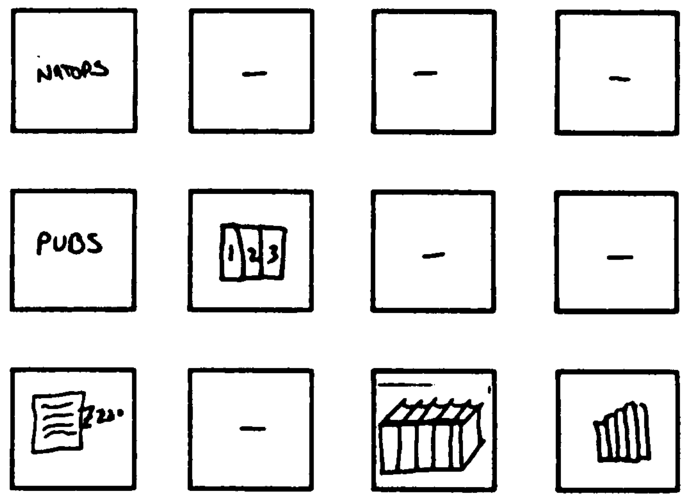
Create a message



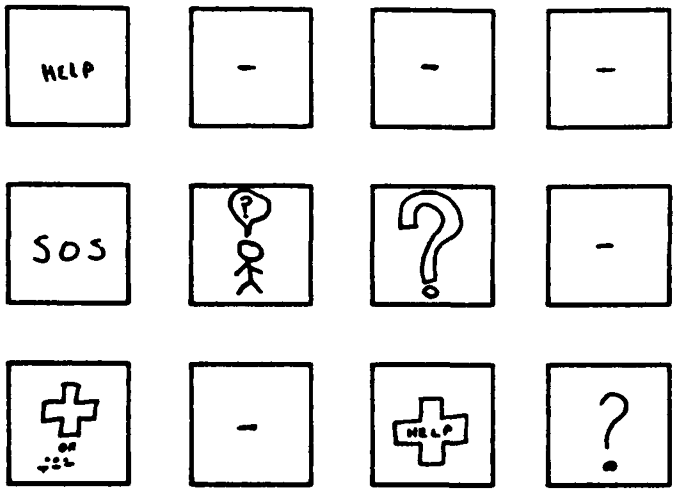
Display message catalog (files)



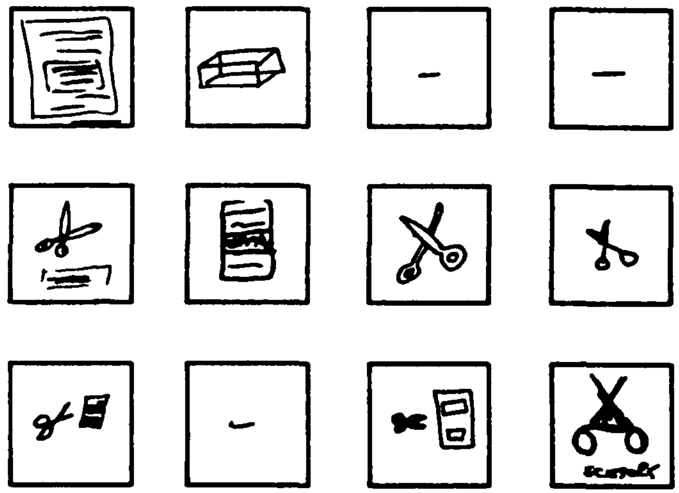
Operational and maintenance publications, NATOPS



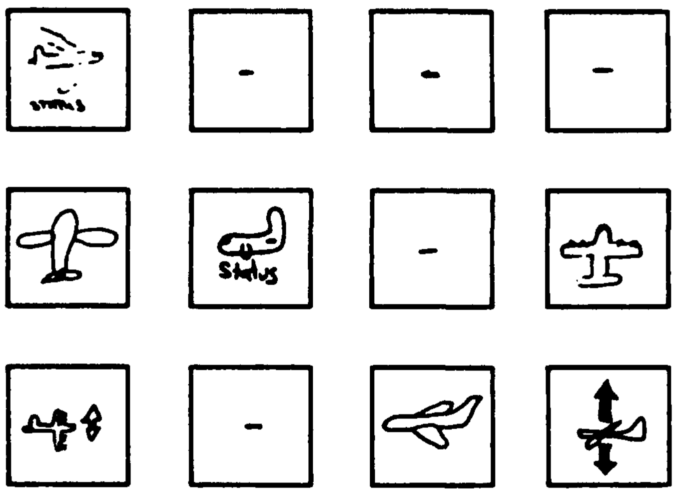
General help index for MMPS software



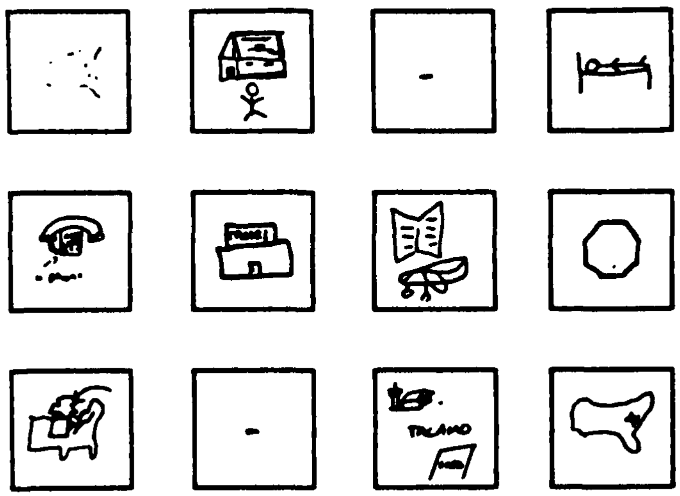
Block and cut a section of a message



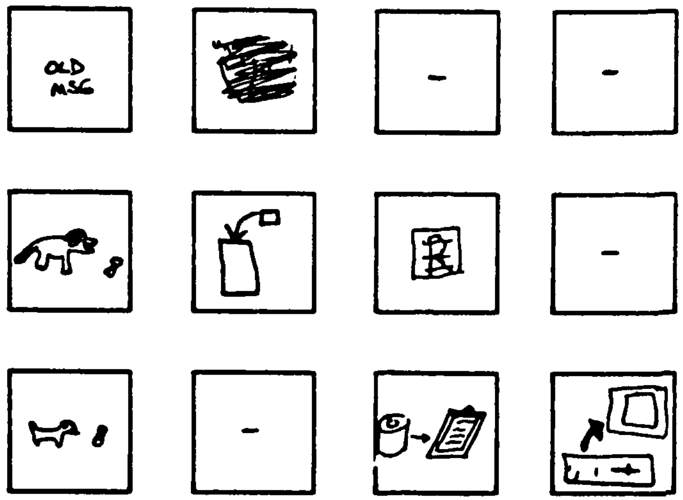
Aircraft systems readiness status information



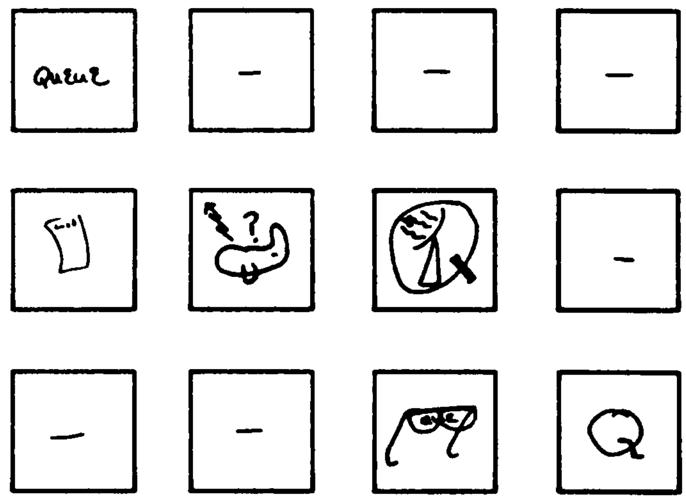
TACAMO aircrew basing information



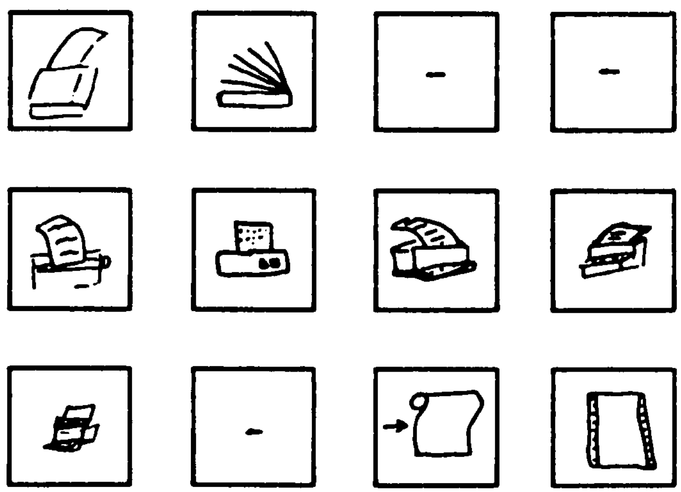
Retrieve an existing message



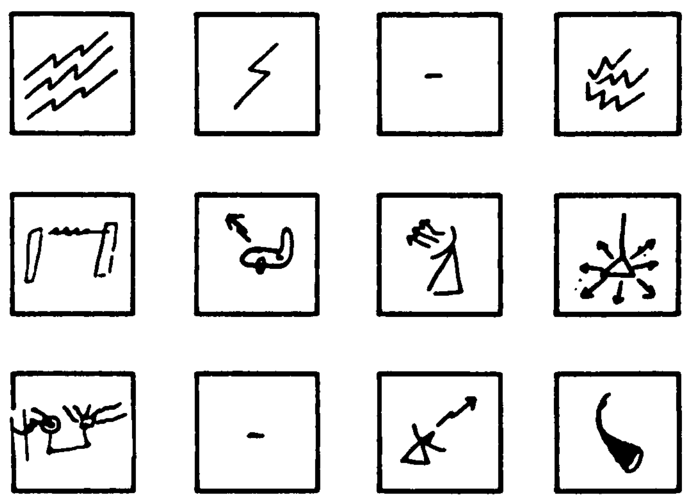
Display the outgoing message queue



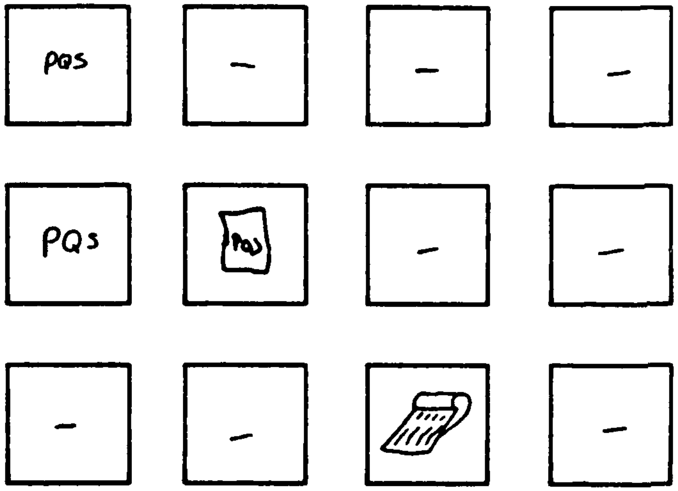
Print a paper copy of a message



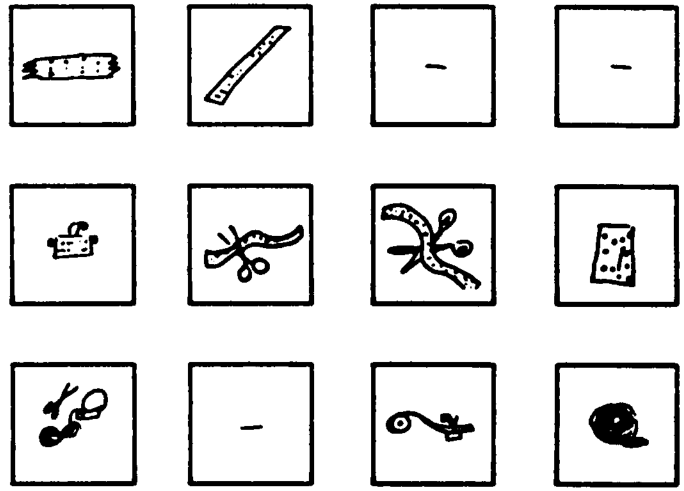
Transmit a message



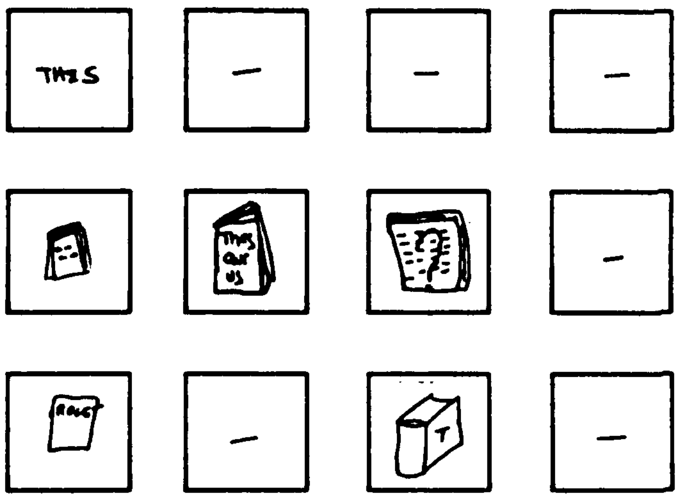
PQS syllabus training, programmed texts



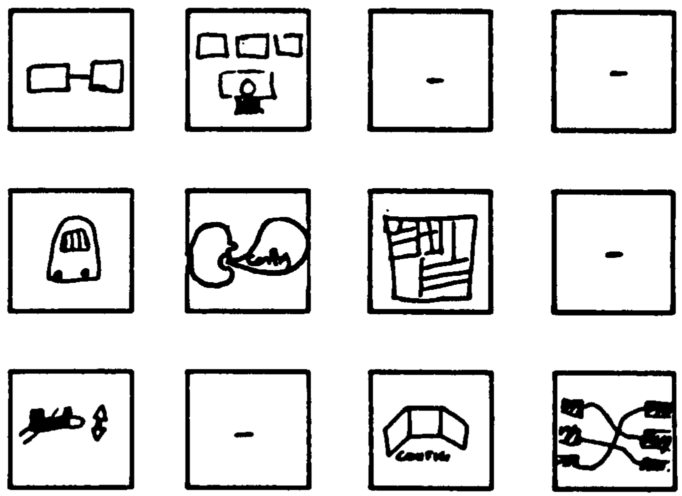
Cut a teletype tape of a message



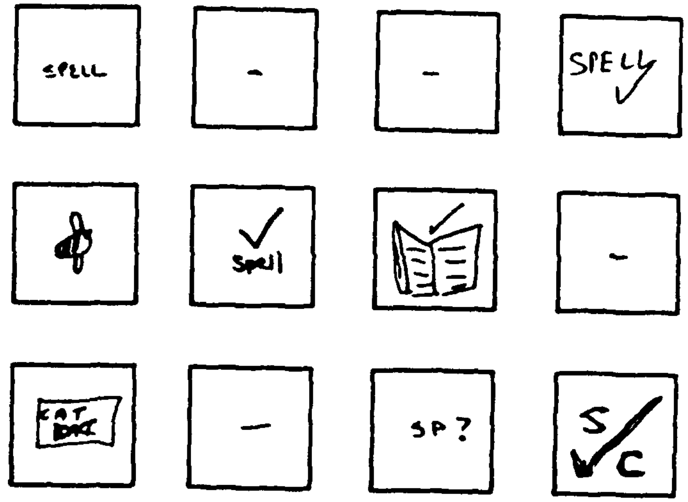
Thesaurus



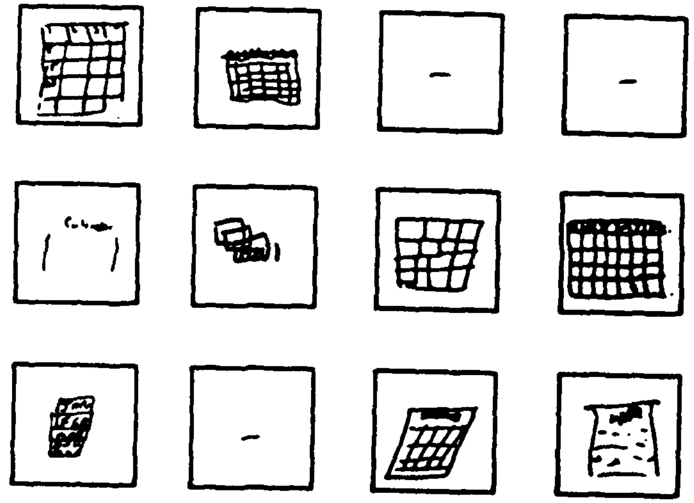
Configure Comm Central equipment



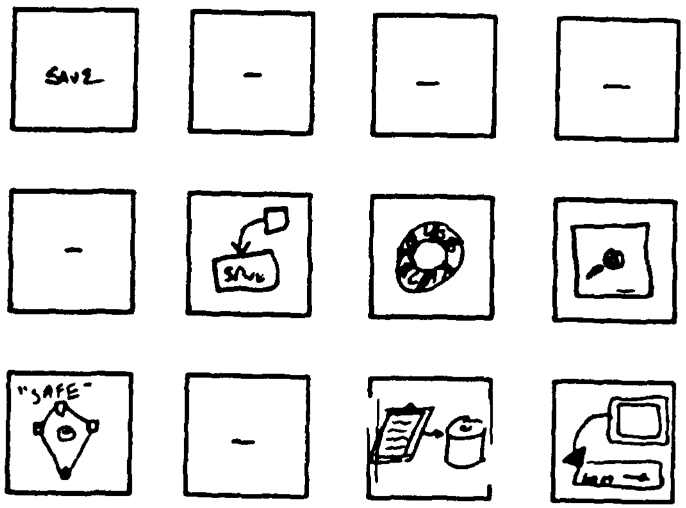
Spell check a message



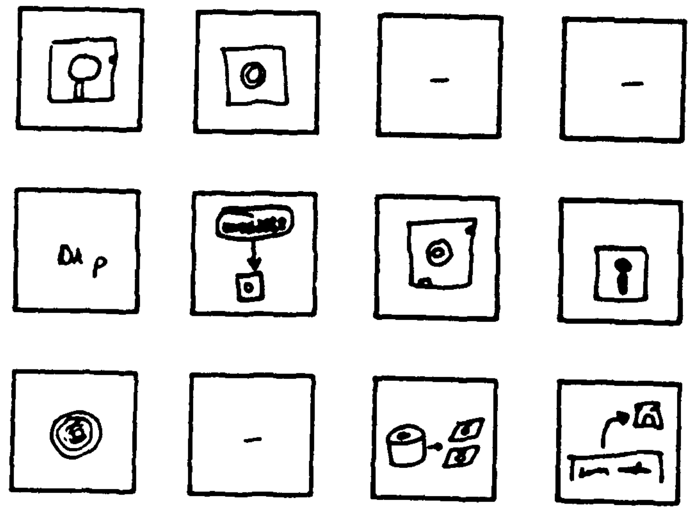
Calendar of scheduled events



Save a message



Backup mission data from the hard disk to floppy diskette



APPENDIX C.4

LABELS FROM ICON PRODUCTION METHOD

	Task description	Proposed labels (responses)
1.	**Preflight tests and checklists.**	PREFLT (5) PREFL PREFLIGHT PFCL CL LISTS
2.	**Display message catalog (files).**	DMC (4) CAT (2) FILES(2) CATALOG MESSAGE MSG CATALOG
3.	**Create a message.**	CREATE (4) CREATE MSG (2) NEW (2) NEW MSG (2) MSG
4.	**Operational and maintenance publications, NATOPS.**	PUBS (6) NATOPS (4)
5.	**General help index for MMPS software.**	HELP (6) HLP GEN HELP MMPS INDEX
6.	**Aircraft systems readiness status information.**	ACFT STATUS (3) ACFT A/C STATUS SYSSTAT STATS STS

7.	**Block and cut a section of a message.**	CUT (7) BLOCK (5) BLK PASTE INPUT/OUTPUT MSG
8.	**TACAMO aircrew basing information.**	BASING (5) BASES (2) TACBASING TACBAS BSE
9.	**Retrieve an existing message.**	RETRIEVE (3) RETR (2) RTMSG RTVMSG OLD RECALL GET
10.	**Print a paper copy of a message.**	PRINT (4) PRT (3) PRINTMSG PRTMSG PTMSG
11.	**Display the outgoing message queue.**	QUEUE (4) MSGQUE (2) DSPYQUE DISPLAY OUTGOING OUTMSG
12.	**Transmit a message.**	XMT (4) XMIT (3) TMT TRANSMIT TRANXMSG
13.	**PQS syllabus training, programmed texts.**	PQS (8) TRNG (2) TRAING

14.	**Thesaurus.**	THESAURUS (5) THSRS TSURS THES THS
15.	**Cut a teletype tape of a message.**	TTYTAPE (3) TAPE (2) TTY CUTTTYTAPE CUTTAPE REPERF
16.	**Configure Comm Central equipment.**	CONFIG (4) CONFIGURE (2) COMMCENT STATUS REDSTAT COMM CCC
17.	**Spell check a message.**	SPELLCHECK (5) SPELL (4) SPELLCHK
18.	**Save a message.**	SAVE (6) SAVEMSG (3) SMSG
19.	**Calendar of scheduled events.**	CALENDAR (6) CAL (2) CALDR
20.	**Backup mission data from the hard disk to floppy diskette.**	BACKUP (3) FLOPPY (2) BACKMSG BKP DISK COPY

APPENDIX C.5

PICTURE ELEMENTS FROM ICON PRODUCTION METHOD

Task description	Picture elements (responses)
1. **Preflight tests and checklists.**	
	Checkmark (5)
	Pocket checklist (2)
	Aircraft with checkmark
	Check on paper
2. **Display message catalog (files).**	
	Paper files (5)
	Paper with arrow (2)
	Book (2)
	Rolodex file
3. **Create a message.**	
	Paper (2)
	Person with paper
	Person with question mark
	Pen, ink, and paper
	Pen and ink
	Open book
4. **Operational and maintenance publications, NATOPS.**	
	Books (3)
	Paper with zzz's
5. **General help index for MMPS software.**	
	Question mark (2)
	Help cross (2)
	Person with question mark
	S-O-S in morse code
6. **Aircraft systems readiness status information.**	
	Aircraft outline (5)
	Aircraft with up/down arrows (2)

7. **Block and cut a section of a message.**

Scissors with message (3)
Scissors (2)
Message with highlights (2)
Block

8. **TACAMO aircrew basing information.**

Map of the United States (3)
Motel (3)
Aircraft with message
Bed
Telephone
Stopsign

9. **Retrieve an existing message.**

Computer, arrow to paper (2)
Dog with bone (2)
Computer, arrow to monitor
Monitor with "R"
Hand grabbing

10. **Print a paper copy of a message.**

Printer with paper output (6)
Stack of paper
Piece of paper
Arrow to paper

11. **Display the outgoing message queue.**

Letter "Q" (2)
Aircraft, lightning bolt, question mark
Satellite dish
Message

12. **Transmit a message.**

Lightning bolts (3)
Satellite dish with lightning bolts (2)
Circuit symbols (2)
Aircraft with lightning bolt
Drogue with arrows
Drogue

13. **PQS syllabus training, programmed texts.**
"PQS" in box
Clipboard

14. **Thesaurus.**
Book with "T" or thesaurus
Book with question mark

15. **Cut a teletype tape of a message.**
Teletype tape and scissors (2)
Teletype tape (3)
Reperforator (2)
Roll of teletype tape

16. **Configure Comm Central equipment.**
Comm central likeness (4)
Patch panel
Oldtime radio
Face with "CONFIG" bubble
Aircraft with up/down bubble

17. **Spell check a message.**
"SPELL" with checkmark (3)
Spelling bee
Book with checkmark
CAT/KAT misspelling

18. **Save a message.**
Monitor, arrow to computer (2)
Message, arrow to computer
Diskette
Life ring
Baseball diamond

19. **Calendar of scheduled events.**
Calendar month (10)

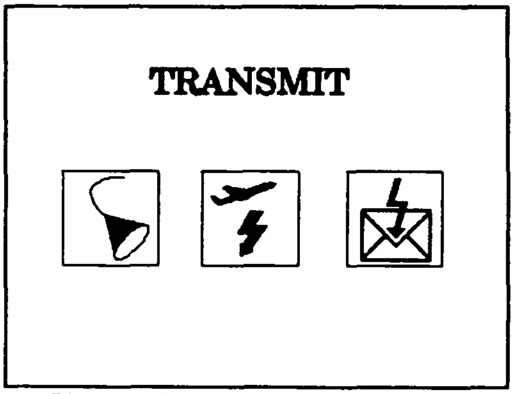
20. **Backup mission data from the hard disk to floppy diskette.**
Diskette (5)
Computer, arrow to diskette

APPENDIX D

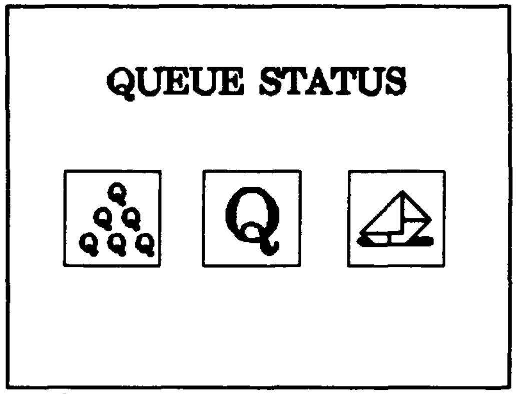
ICON CANDIDATES

APPENDIX D.1

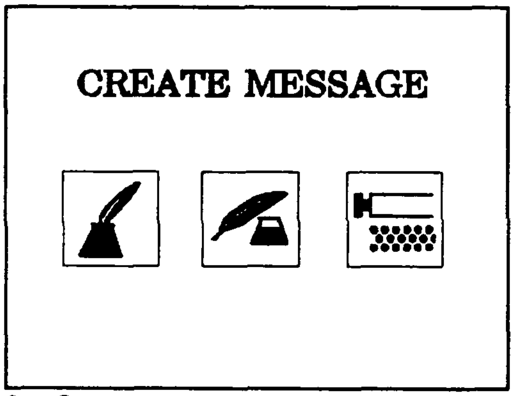
INITIAL TACAMO CANDIDATE ICONS



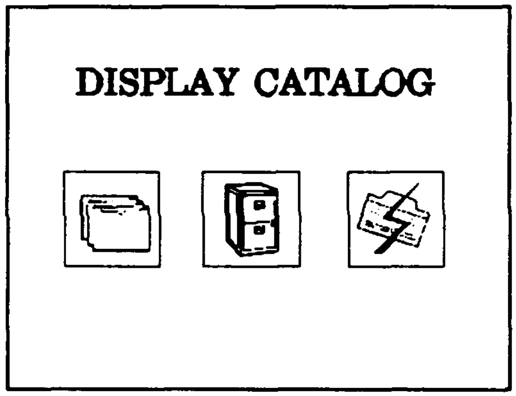
1. Transmit a message



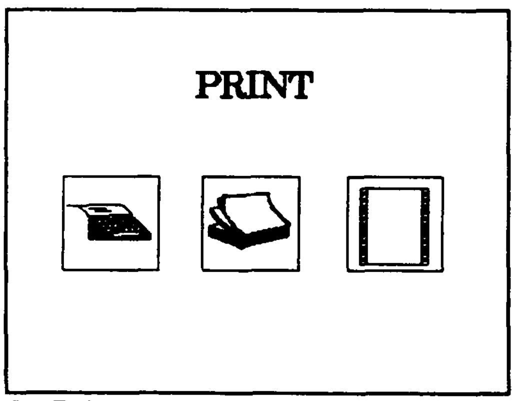
2. Queue of outgoing messages



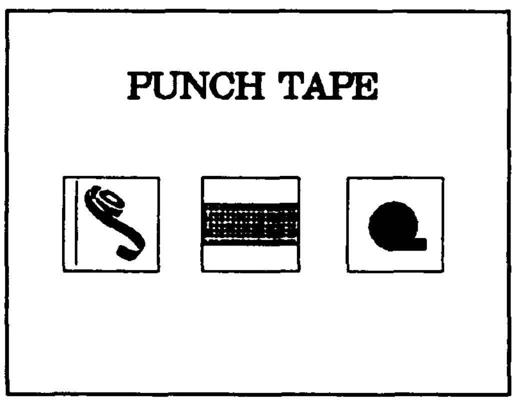
3. Create a message



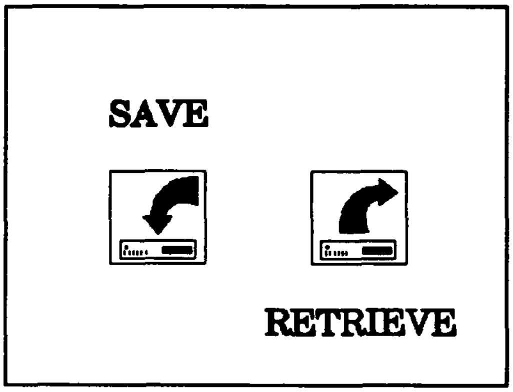
4. Display message files



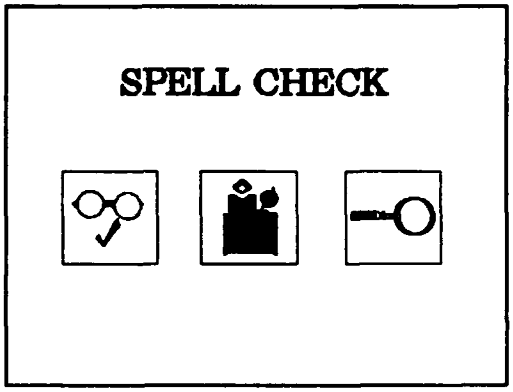
5. Print a message



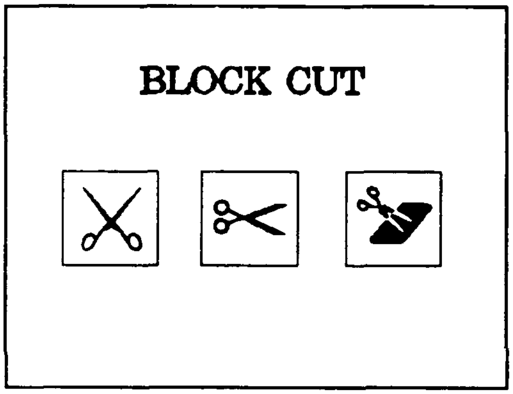
6. Punch a teletype tape



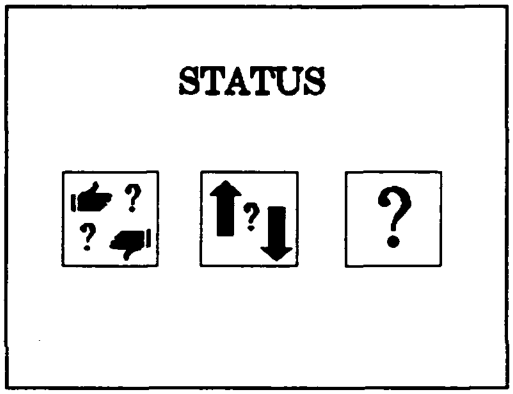
7. Save and retrieve messages



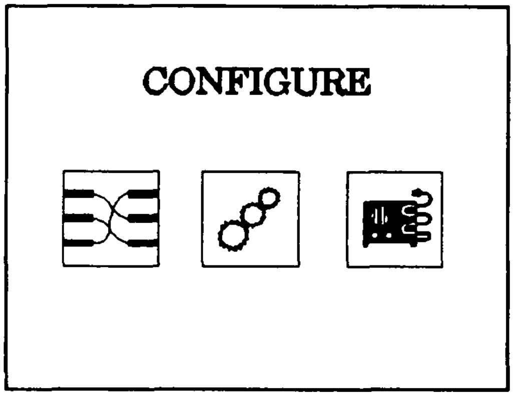
8. Spellcheck a message



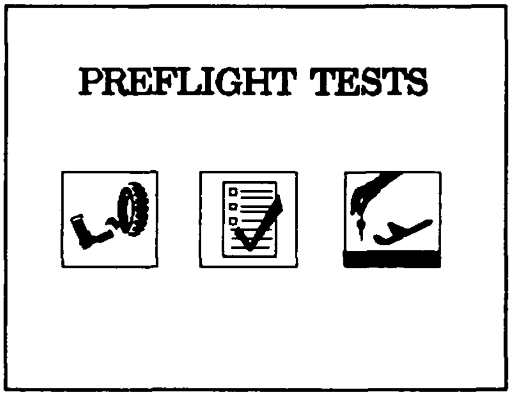
9. Cut a block of a message



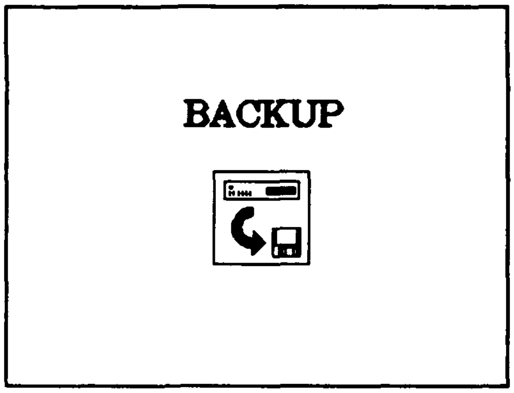
10. Status of aircraft equipment



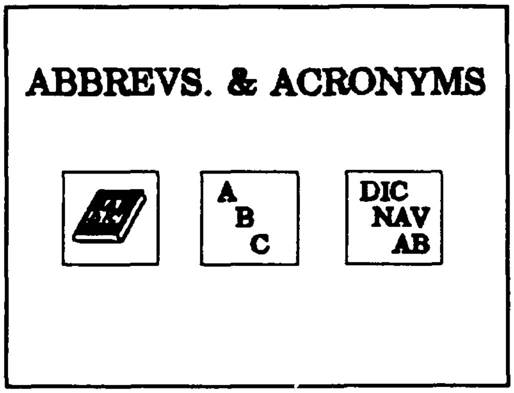
11. Configure Comm Central



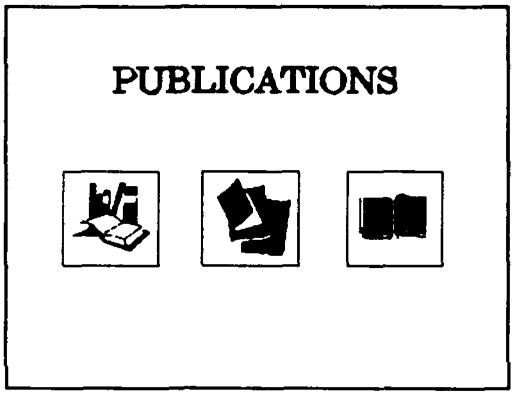
12. Preflight checklists



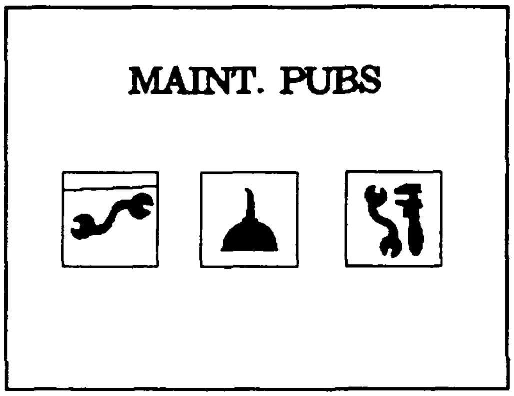
13. Backup messages to diskette



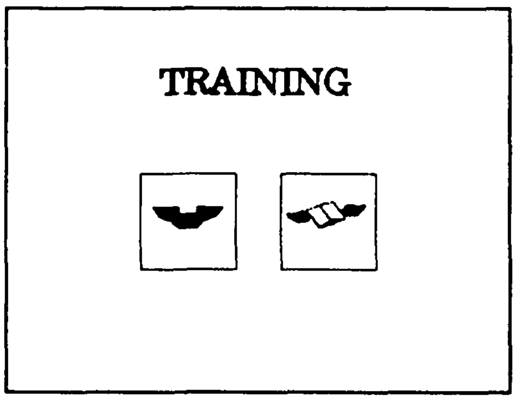
14. Abbreviations and acronyms



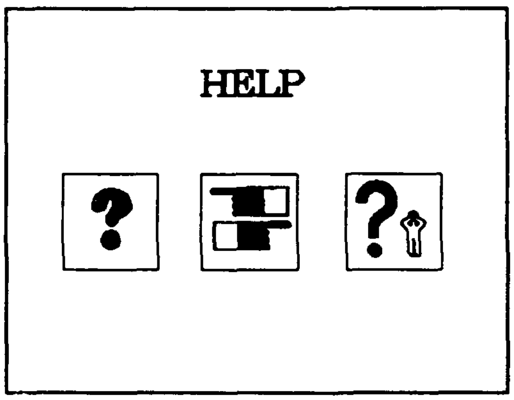
15. Publications library



16. Maintenance manuals



17. Training and qualifications



18. Help and information

APPENDIX D.2

TACAMO ICON SET REVISIONS

1. **Transmit a message.** Original ideas were abundant for this icon, from a picture of the drogue at the end of the transmitting wire to a telegram symbol. The arrow bolting downward from the silhouette of a TACAMO E-6A aircraft was chosen to signify the transmission of a message from the TACAMO aircraft. The arrow was used as a common attribute in icons used to depict message movement in this icon set.

2. **Queue of outgoing messages.** A capital "Q" was the clearest representation available to represent this abstract icon, which will be used to check the flow of outgoing messages. Various fonts were considered, but a DrawPerfect's *WP Century Schoolbook* font gave the "Q" its distinctive tail.

3. **Create a message.** The scroll and quill design was borrowed from the Navy's enlisted journalist's rating badge. Pens, inks, and even word processor's were considered, but the rating badge drew high approval marks from Navy personnel.

4. **Display message files.** The old TMPS terminology for this icon would be "display message catalog." Drawings and ideas were rather weak on this task description, so an office metaphor of a group of file folders was chosen over a picture of a file cabinet.

5. **Print a message.** This icon show a printer with paper feeding out of the top of it. This version may have drawn high support because it closely resembles the teletype printer currently used aboard the TACAMO aircraft.

6. **Punch a teletype tape.** A spool of teletype tape was drawn for this icon. It was reversed on the y-axis to prevent confusion with the question mark used for the help icon.

7. **Save and retrieve message.** These icons also employ arrows. Save signifying a message being stored in a computer's fixed hard drive. Retrieve signifying a message being retrieved from computer memory. Arrow directions were modified between the save, retrieve, and backup icons to reduce confusion from similar arrow types.

8. **Spellcheck a message.** This task description was described by most as the toughest to represent pictorially. The checkmark seemed natural, but glasses were added to represent additional focus.

9. **Cut a block of a message.** The scissors cutting into a block depicts a common text editing function.

10. **Status of aircraft/equipment.** The thumbs up and thumbs down with question marks for uncertainty was chosen for this icon. The thumbs were chosen to replace arrows to lessen confusion with arrows representing message movement.

11. **Configure Comm Central.** This icon shows three plugged-in patch panel connections, similar to communication patches made aboard the TACAMO aircraft.

12. **Preflight checklists.** The aviator's three-ring checklist with a large check through it was a natural for this icon.

13. **Backup message to diskette.** The arrow shows a message being stored to a 3.5" diskette, the size of diskette anticipated for use with the improved MMPS.

14. **Abbreviations and acronyms.** A book with "ABC" and an abbreviation for the Dictionary of Naval Abbreviations was considered for this icon which was later dropped from the study.

15. **Publications library.** A set of books is shown for this pictorially-based icon drawn from Modley's (1976) book of pictorial symbols.

16. **Maintenance manuals.** A separate icon for use by the flight engineers is designed to give direct access to the aircraft's maintenance and equipment manuals. The wrench inside a large book neatly combines both ideas.

17. **Training and qualifications.** An open book signifying studying is laid across a set of aircrew wings for this icon.

18. **Help and Information.** The question mark, a universal symbol for help and information, was a clear selection for this icon.

APPENDIX D.3

DISCRIMINABILITY INDICES

Icon	X1	X2	25-Z	Z	DI
HELP	18	0	23	2	2.25
TRANSMIT	19	16	20	5	2.30
SAVE	19	16	20	5	2.30
RETRIEVE	19	16	20	5	2.30
BACKUP	19	16	20	5	2.30
PREFLIGHT	18	17	20	5	2.30
QUEUE	19	0	24	1	2.70
FILES	19	0	24	1	2.70
TAPE	19	0	24	1	2.70
CONFIGURE	19	0	24	1	2.70
CALENDAR	19	0	24	1	2.70
BASES	19	0	24	1	2.70
CREATE	19	17	21	4	2.75
PRINT	19	17	21	4	2.75
PUBS	19	17	21	4	2.75
MAINT	19	17	21	4	2.75
TRAINING	19	17	21	4	2.75
CUT BLOCK	19	18	22	3	3.20
SPELLCHECK	19	18	22	3	3.20
STATUS	19	18	22	3	3.20

c = 20 where DI = 0.07[X1+X2+(25-Z)] - 0.31Z.

REVISED DISCRIMINABILITY INDICES

Icon	X1	X2	23-Z	Z	DI
HELP	16	0	21	2	1.83
TRANSMIT	17	14	18	5	1.88
SAVE	17	14	18	5	1.88
RETRIEVE	17	14	18	5	1.88
BACKUP	17	14	18	5	1.88
PREFLIGHT	16	15	18	5	1.88
QUEUE	17	0	22	1	2.28
FILES	17	0	22	1	2.28
TAPE	17	0	22	1	2.28
CONFIGURE	17	0	22	1	2.28
CREATE	17	15	19	4	2.33
PRINT	17	15	19	4	2.33
PUBS	17	15	19	4	2.33
MAINT	17	15	19	4	2.33
TRAINING	17	15	19	4	2.33
CUT BLOCK	17	16	20	3	2.78
SPELLCHECK	17	16	20	3	2.78
STATUS	17	16	20	3	2.78

c = 18 where DI = 0.07[X1+X2+(23-Z)] - 0.31Z.

APPENDIX D.4

CONFUSIBILITY MATRIX

Response (subject selection)

Actual Stimulus	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Other
1	100																				0
2		95																			5
3			100																		0
4				86																	14
5	5				76						10			5							5
6		5				95															0
7				5			95														0
8								100													0
9									100												0
10										100											0
11				5	10		5				81										0
12												100									0
13													86						14		0
14														90							10
15															100						0
16																100					0
17																	100				0
18													14					86			0
19																			100		0
20																				100	0

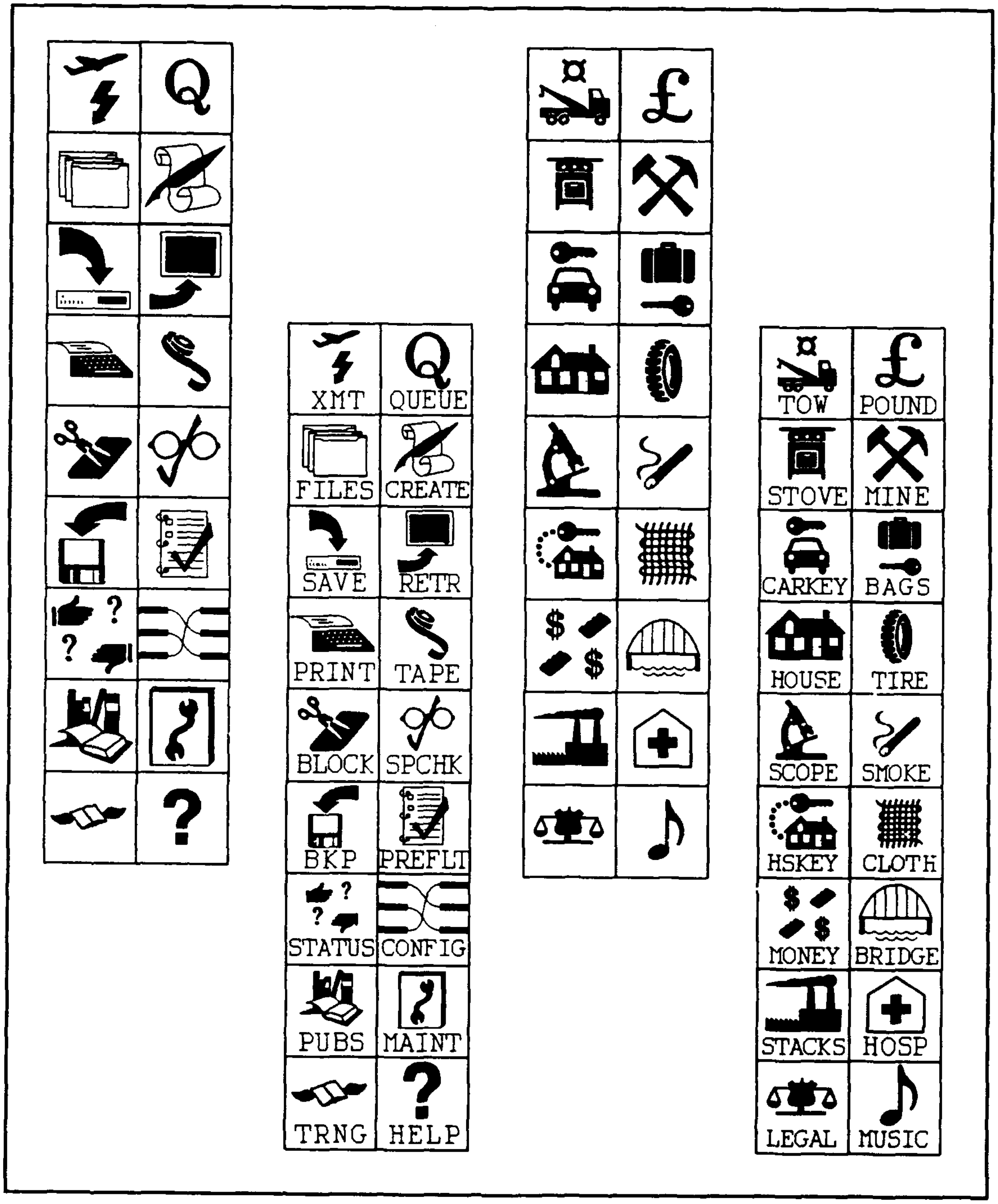
This matrix represents the actual stimuli as rows and the responses of the subjects as columns. Each number represents a percentage of the subjects' responses. Entries along the main diagonal represent *recognition* and off-diagonal entries represent *confusion*.

APPENDIX E

ICON DESIGN FORMAT EXPERIMENT

APPENDIX E.1

TACAMO AND DISTRACTOR ICONS FOR FINAL TESTING



APPENDIX E.2

TIMESTAMP PROGRAM

STAMP.C

```
#include <dos.h>
#include <stdio.h>

void main(int argc, char **argv)
{
 struct  time t,s;
 FILE *fp;

 if((fp = fopen("datafile", "at"))== NULL){
   printf("FILE did not open correctly.  Check memory management");
   exit(1);
 }
 if(argc != 2){
   printf("Wrong number of parameters were passed");
   exit(1);
 }

 gettime(&t);
 fprintf(fp, "%02d:%02d.%02d\t%s\n",
        t.ti_min, t.ti_sec, t.ti_hund,
        argv[1]);

 fclose(fp);
}
```

Disclaimer: The reader is cautioned that this program may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that it is free of computational and logic errors, it cannot be considered validated. Any application of this program without additional verification is at the risk of the user.

APPENDIX E.3

INSTRUCTIONS FOR ICON DESIGN FORMAT EXPERIMENT

Background. The Naval Air Development Center is supporting thesis research from the Naval Postgraduate School for the development of future TACAMO communications upgrades. This experiment is the final testing stage for an icon set developed for use aboard the TACAMO airborne communications platform. The experiment consists of five phases conducted on a personal computer:

1. Initial Icon Training
2. Review Training
3. Baseline Testing
4. Additional Review Training
5. Icon Recognition Testing

Your participation will indicate how well each of the developed icons is associated with its intended purpose.

Purpose. This experiment will be used to measure the effectiveness of the icon set to increase performance while reducing errors.

Icon Training. The initial icon training phase wil present eighteen icons with task descriptions. All training is self-paced and typically advances with the pressing of the spacebar. Review training presents the icons again with abbreviated task descriptions.

Baseline Testing. Baseline testing uses the numeric keypad keys one through nine with a simple search for a black block in the 3×3 matrix. The index finger/forefinger of the right hand will start at a specified point beneath the numeric keypad and should return to that point before continuing.

Primary Task. In the main icon recognition test, a text-only screen asks you to select the icon which best represents an abbreviated task description. When you are ready to continue, pressing the spacebar will present a 3×3 icon matrix. Press the key of the numeric keypad which corresponds to the described icon and return your finger to the starting point. In addition to the eighteen TACAMO icons, eighteen arbitrary icons have been randomly included in the search matrices. You are asked to work as accurately and quickly as possible. If you have any questions, please ask them at this time.

APPENDIX E.4

TACAMO ICON RECOGNITION EXPERIMENT QUESTIONNAIRE

Age: _____ **Sex:** M F **Primary hand:** L R

Education:

High School/GED

Some College Courses

Associate's Degree ____________________

College Degree ________________________

Postgraduate __________________________

Computer experience (circle as many as applicable):

IBM PCs	Macintosh	Mainframe terminals
Amiga	Commodore	Other __________

APPENDIX E.5

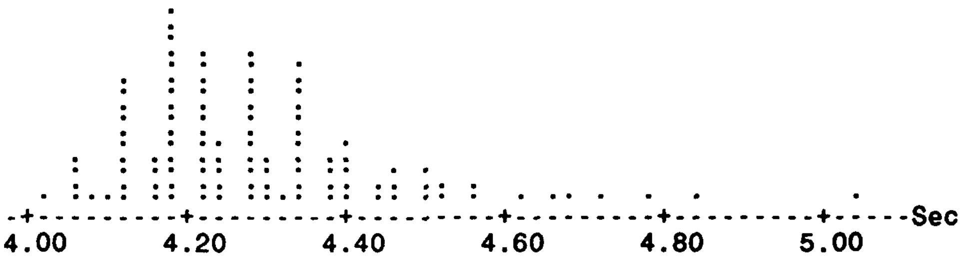
ICON TASK DESCRIPTIONS

1. Transmit a message.
2. Queue of outgoing messages.
3. Display message files.
4. Create a message.
5. Save message to computer storage.
6. Retrieve message to display monitor.
7. Print a message.
8. Punch a teletype tape.
9. Cut a block of a message.
10. Spellcheck a message
11. Back up a message to diskette.
12. Preflight checklists.
13. Status of aircraft/equipment.
14. Configure patch panel.
15. Publications library.
16. Maintenance manual.
17. Training and qualifications.
18. Help.

APPENDIX E.6

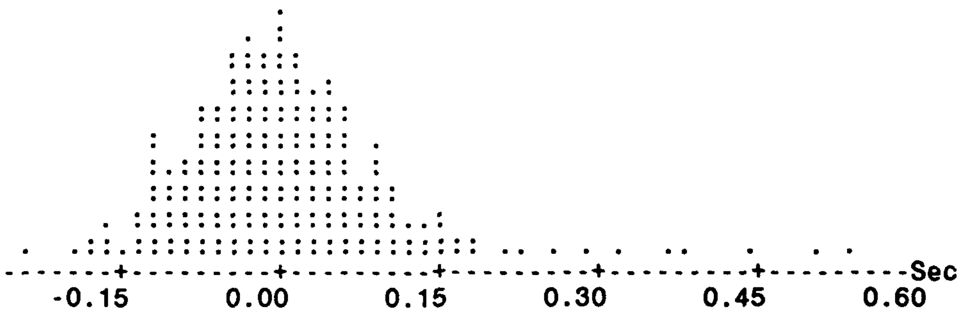
EFFECTS OF BASELINE SUBTRACTION

E.6.A. BASELINE REACTION TIME DATA BEFORE SUBTRACTION OF AVERAGE REACTION TIME



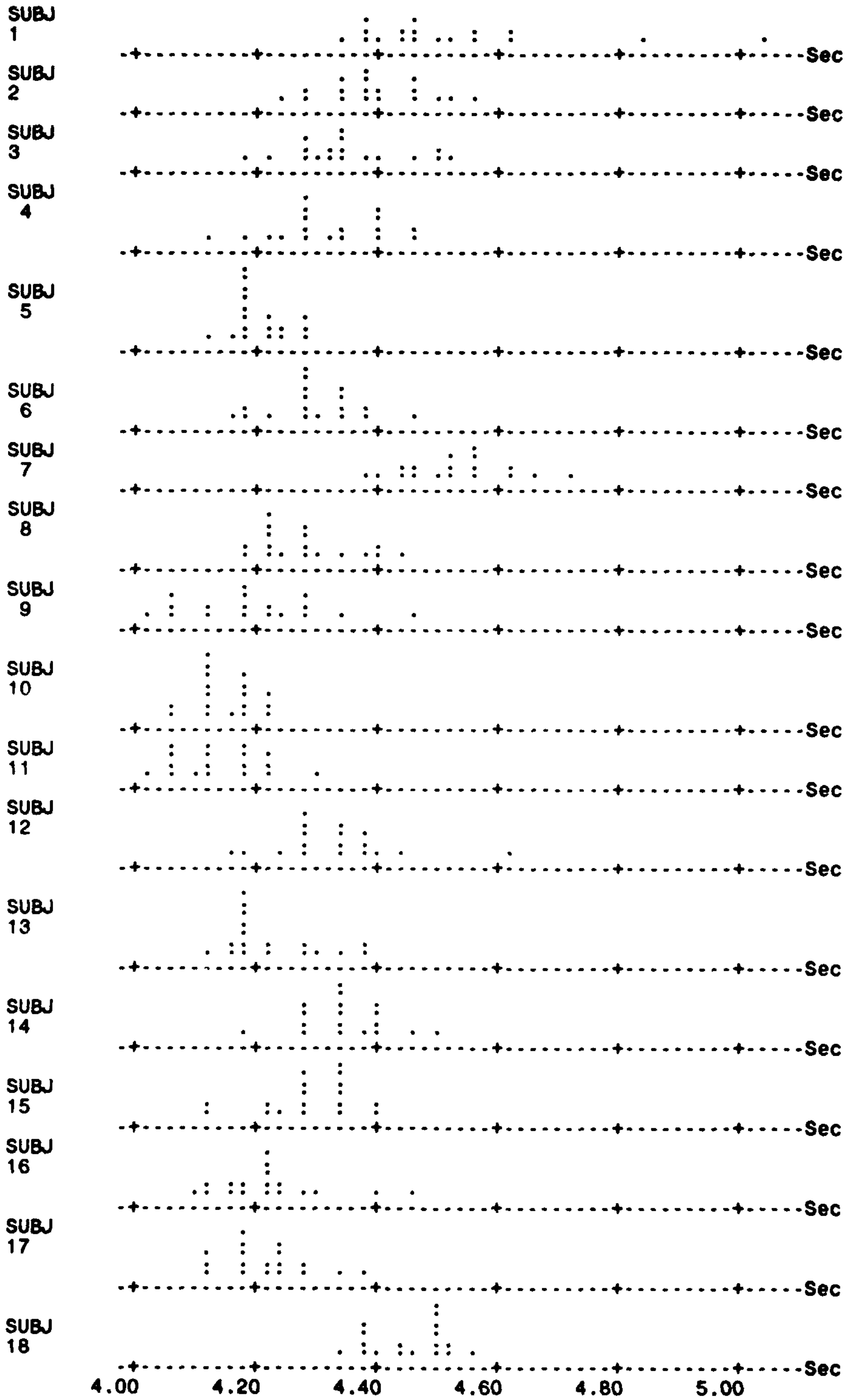
Each dot represents 7 data points.

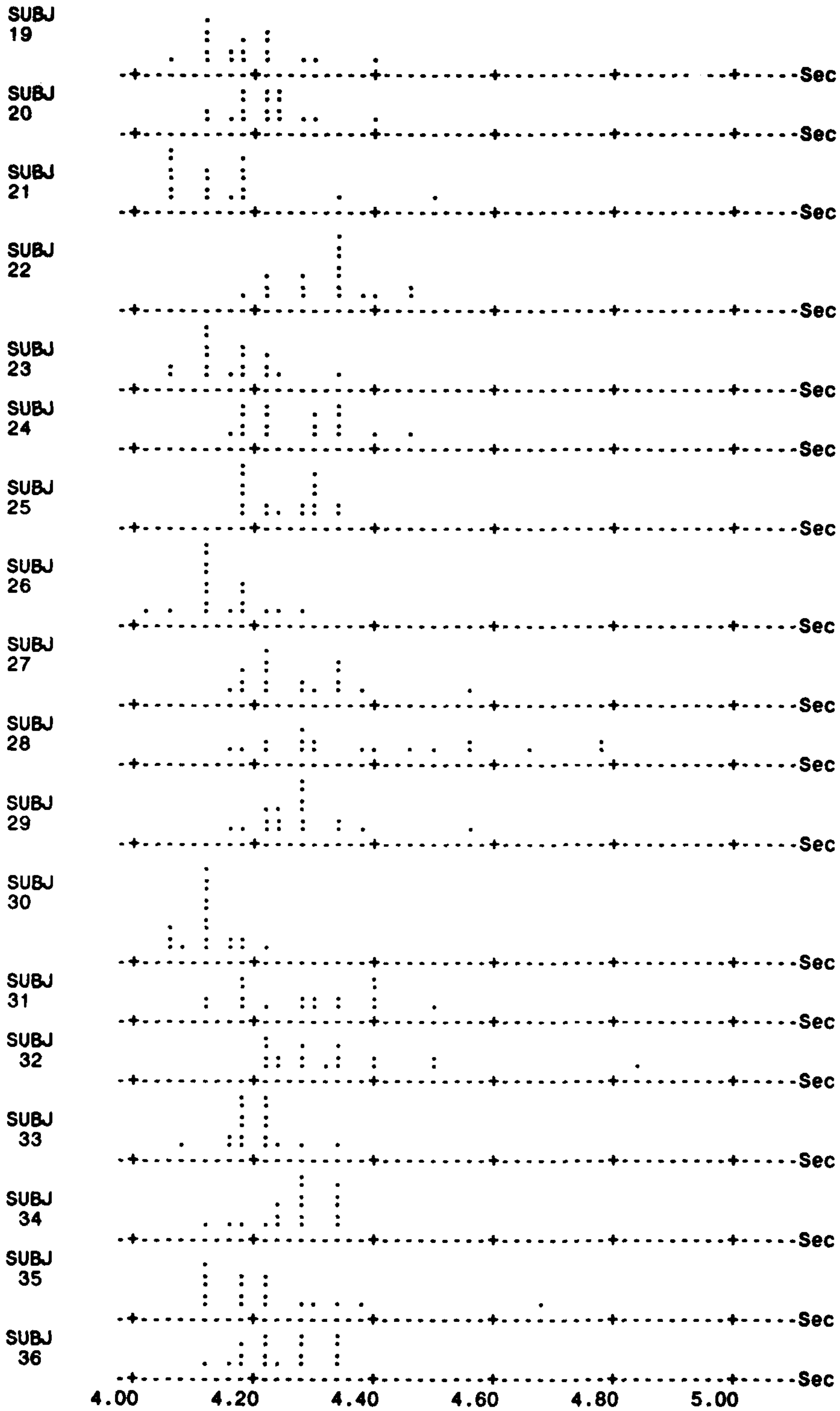
E.6.B. BASELINE REACTION TIME DATA AFTER SUBTRACTION OF AVERAGE REACTION TIME



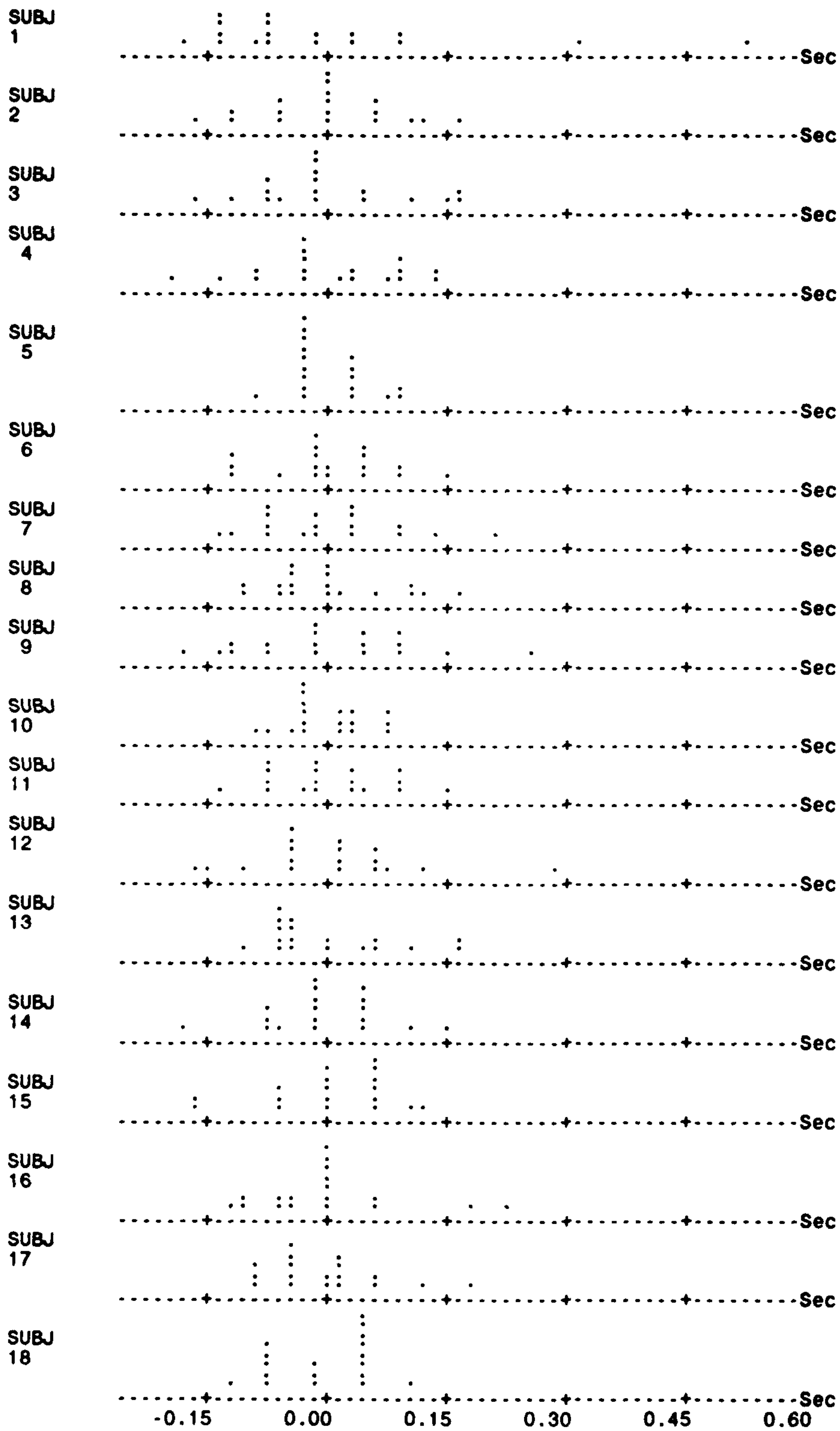
Each dot represents 3 data points.

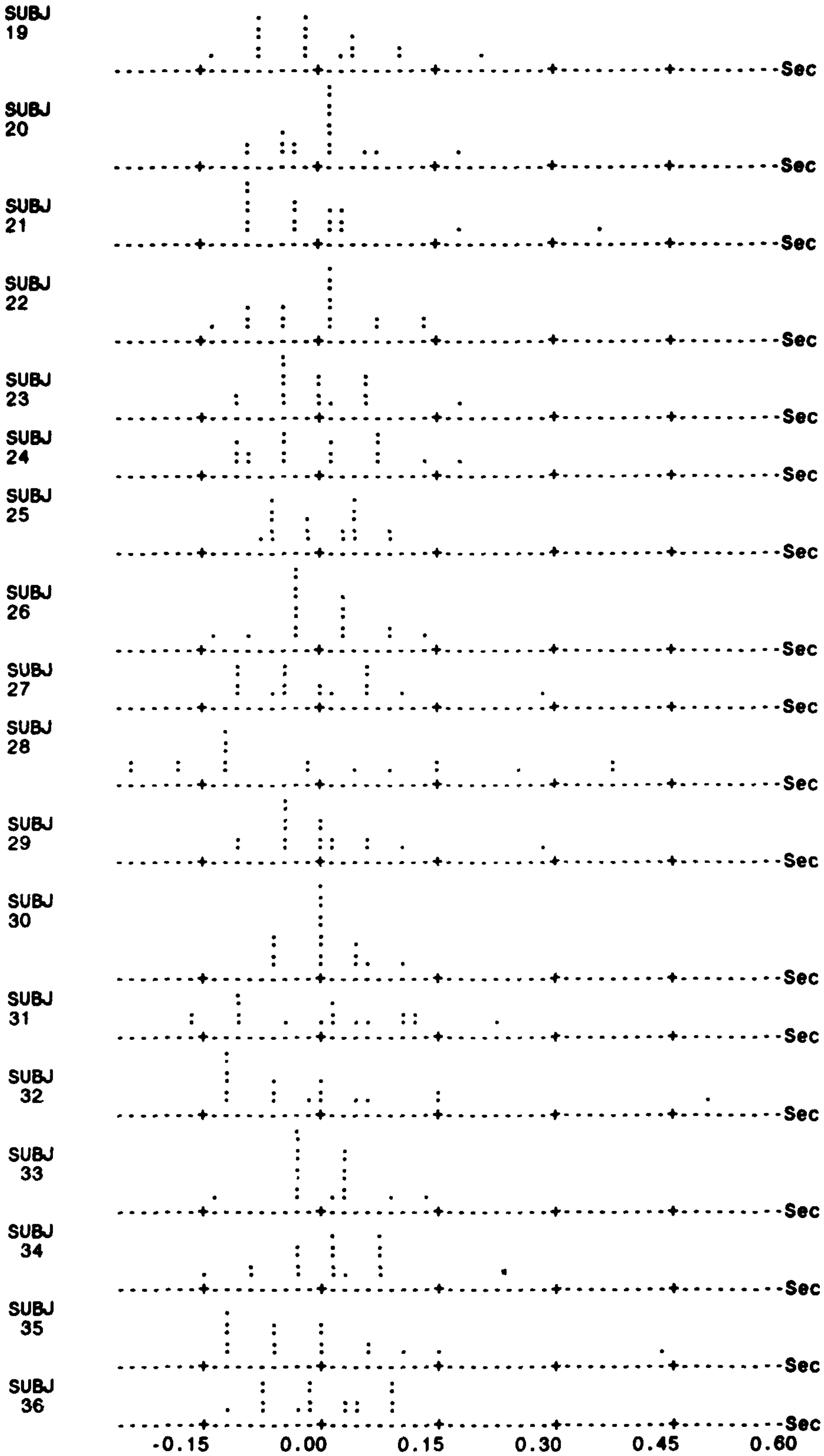
E.6.C. DOTPLOTS OF SUBJECTS' BASELINE REACTION TIME BEFORE SUBTRACTING AVERAGE REACTION TIME




SUBJ 19
SUBJ 20
SUBJ 21
SUBJ 22
SUBJ 23
SUBJ 24
SUBJ 25
SUBJ 26
SUBJ 27
SUBJ 28
SUBJ 29
SUBJ 30
SUBJ 31
SUBJ 32
SUBJ 33
SUBJ 34
SUBJ 35
SUBJ 36
Sec
4.00
4.20
4.40
4.60
4.80
5.00

E.6.D. DOTPLOTS OF SUBJECTS' BASELINE REACTION TIME AFTER SUBTRACTING AVERAGE REACTIOM TIME




SUBJ 19
SUBJ 20
SUBJ 21
SUBJ 22
SUBJ 23
SUBJ 24
SUBJ 25
SUBJ 26
SUBJ 27
SUBJ 28
SUBJ 29
SUBJ 30
SUBJ 31
SUBJ 32
SUBJ 33
SUBJ 34
SUBJ 35
SUBJ 36
Sec
-0.15
0.00
0.15
0.30
0.45
0.60

APPENDIX E.7

95% SIGN CONFIDENCE INTERVALS FOR IDENTIFICATION TIME

E.7.A. LABELED AND UNLABELED TACAMO ICONS COMBINED

```
Icon      95% Confidence Interval

              ----
1            -I+ I---**                                    0
              ----
            ----
2          -I+ I--  *  0
            ----
               ------------------
3           ---I  +             I------------------------
               ------------------
               --------
4         -----I  +   I---------
               --------
              ------
5          ---I +  I------
              ------
              ----
6           --I+ I---   *   0
              ----
               -----
7           ---I+  I--- **     0
               -----
               -----
8           ---I+  I-----
               -----
              ------
9            -I  + I--    *
              ------
              ---
10          --I+I---   0
              ---
               -----
11           --I + I-------
               -----
              -----
12         ---I+  I----  *
              -----
             ------
13         --I  + I------        *
             ------
            ----
14         -I +I----
            ----
                -----
15         -----I + I--    *  *
                -----
               -----
16          ---I + I------ *  *   0
               -----
              ------
17          --I  + I------          0
              ------
            ---
18         -I+I-- *
            ---
+---------+---------+---------+---------+---------+------Sec
         0.0       2.5       5.0       7.5      10.0      12.5
```

E.7.B. UNLABELED TACAMO ICONS

```
Icon      95% Confidence Interval

              ---
 1P           I+I-   *                                           O
              ---

            ---
 2P        -I+I---
            ---

               --------------------
 3P         ---I+                  I--------------------
               --------------------

               -------
 4P        ----I  +  I----------*
               -------

              ------
 5P         --I  +  I--
              ------

             ----
 6P         -I  +I-
             ----

               -----
 7P         ---I+  I---   *
               -----

               -----
 8P           --I + I-----
               -----

              -----
 9P           -I + I--
              -----

              --
10P         --+I-       O
              --

              ------
11P           -I  +  I--
              ------
              ---
12P        ---I+I-- *
              ---

              ------
13P        ---I  +  I-----        *
              ------

             ----
14P        --I+ I---
             ----

                -----
15P           ---I + I--    *
                -----

               ----
16P           --I +I      *
               ----          *

              ------
17P         --I+   I--                O
              ------

            ---
18P        -I+I-
            ---
         +----------+----------+----------+----------+----------+------C6
        0.0        2.5        5.0        7.5       10.0       12.5
```

E.7.C. LABELED TACAMO ICONS

```
Icon    95% Confidence Interval

            -----
1L         -I+ I----
            -----
          ----
2L       -I +I--  *  *
          ----
             ----------------
3L        ---I     +        I-------------------  *   *
             ----------------
            ---------
4L      ----I   +   I----
            ---------
            ------
5L       ---I  + I------
            ------
            -----
6L        --I + I--   *   *
            -----
              ----
7L        ----I+ I-----      O
              ----
             ----
8L        ---I+ I-----*
             ----
             -----
9L          -I + I--    *
             -----
            ---
10L        -I+I---
            ---
               ----
11L        ----I+ I-    *
               ----
            -------
12L      ---I  + I-----
            -------
           ------
13L      --I  + I-----
           ------
          ----
14L      -I +I-
          ----
             ------
15L      ----I   +I-         *
             ------
             --------
16L       ---I +    I--------    *
             --------
             -----
17L        --I + I-----*
             -----
           ---
18L       -I+I- *
           ---
        +---------+---------+---------+---------+---------+---------+------C9
       0.0       2.5       5.0       7.5      10.0      12.5
```

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