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The Part Task Trainer for Airborne Weapons Systems: Human Factors Evaluation of the User Interface

September 1990

Michele Terranova
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Engineering Physics and Mathematics Division

The Part Task Trainer for Airborne Weapons Systems: Human Factors Evaluation of the User Interface

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LIST OF ACRONYMS AND ABBREVIATIONS

ACU	Armament Control Unit
B/N	Bombardier/Navigator
CATM	Captive Air Training Missiles
IMP	Integrated Missile Panel
NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
PMTC	Pacific Missile Test Center
PTT	Part-Task Trainers
S/WIP	Systems/Weapons Integration Program

ABSTRACT

This research examined and evaluated the human factors aspects of a part-task trainer's user interface. Questionnaires, interviews, and observational techniques were used. A number of established human factors attributes were investigated such as user control and trainer fidelity. Recommendations were given for a variety of issues such as screen design (e.g., design log-on process and procedures for user identification to be as simple as possible); text display (e.g., avoid sentences exceeding 20 words); and training for cognitive skills (e.g., train time-sharing skills for dealing with high workload environments). The results and recommendations for future enhancements were reported. An installation process was documented and comments regarding its effectiveness were included.

The Part Task Trainer for Airborne Weapons Systems: Human Factors Evaluation of the User Interface

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BACKGROUND

Interactive computer systems continue to take an increasing role in training the armed forces, and as such, military preparedness has become dependent upon effective human-computer interaction. Jones, Hennessy, & Duetsch (1985) claim that the availability of minicomputers and microcomputers has greatly facilitated the development of part-task simulators. Part-task trainers (PTTs) can be designed to perform only those functions necessary for a specific purpose. These devices are much more cost effective for training a limited set of tasks or procedures than complex full-scale simulators. In addition to cost savings, Knerr, Morrison, Mumaw, Stein, Sticha, Hoffman, Buede, & Holding (1986) cite another advantage of PTTs. They found that procedural trainers are very effective at sustaining procedural skills that are otherwise susceptible to forgetting over periods of no practice.

The Naval Air (NAVAIR) Systems Command and the Pacific Missile Test Center (PMTC) have designed a part-task trainer for airborne weapons based on a PTT developed for the Systems/Weapons Integration Program (S/WIP) for the A-6E aircraft. It is a desk-sized system with partial simulation capability, consisting of three computers and two touch-screen monitors. The designers' intentions for the system are: to maintain a simultaneous delivery of the weapons and training; to provide missile and operational procedures familiarization as well as proficiency training in launch and control techniques; to adapt the system to weapon changes in a timely manner; to provide a

portable trainer for shipboard refresher training; to provide flexibility in scenario creation; to provide the ability to save multiple scenarios; to be "user friendly"; and to be expandable.

The PTT is being developed in response to a need for training operators of weapons deployed on Navy aircraft. These operators are experienced pilots or bombardier/navigators whose aircraft are being equipped with new weapons or new interfaces to existing weapons. Because the users are already expert aviators, they have no delusions about the complexity of their environment and should be able to accept a trainer that covers only tasks new to total system operation.

One aspect contributing to overall training effectiveness of a computer-based trainer is the user interface. The objective of this effort was to evaluate the user interface of the PTT and to recommend changes that would enhance the usability of the system. The importance of interface evaluation stems from its identification of both system acceptance and system usability by the users.

This evaluation was not meant to criticize either the trainer or its development process, but to provide information that might enhance the acceptance and usability of the trainer. The authors assume that system acceptance and usability contribute to the effectiveness of the training system. This is based in part on the fact that in order for a trainer to be minimally effective it must be utilized, and a system that provides a user interface that is easy to learn and motivating to use, is more likely to be used, and to be used more often. Some of the recommendations offered in this report are straight forward enhancements that are related to areas such as screen design, and other ergonomic concerns. Other suggestions are directed at more complex psychological issues, such as the training of decision-making skills. These suggestions require more research and development. Some of the recommendations made by the authors have already been incorporated into the PTT, and are included here in the event that they may be useful to other training systems.

USER INTERFACE EVALUATION APPROACH

For the most part, this report includes user input from the Attach 75 squadron at NAS Oceana and from the Attack Squadrons 128, 145, and 165 at NAS Whidbey Island, although other squadrons participated to various degrees. This human factors analysis consisted of the authors' professional interface evaluation, of interviews and questionnaires with the Navy users, and observational studies of navy aviators and subject matter experts using the PTT. Formal and informal evaluation methods were developed by the authors to answer behavioral questions concerning the trainer. These questions involved issues related to whether the PTT contained attributes of an effective product; whether personnel were able to utilize the system without excessive difficulty aided by the resources available (such as the operators manual and help functions); and ways that the PTT might be improved.

System Attributes Evaluated

The research reported here is an evaluation of the attributes of the user interface of the PTT. It should be emphasized that the objective was not measurement of training effectiveness, although the ultimate objective of this evaluation was to provide recommendations for enhancements to the user interface to support the effectiveness of the training. These attributes were selected based on the assumption that certain hardware and software design characteristics would have positive effects on operator performance and other characteristics would have negative effects. The attributes evaluated were pre-selected from the areas of system introduction, screen design, user control, feedback messages, information display, user interaction, user expectations, error messages, system navigation, user help, fidelity, and cognitive issues (See Appendix A for a complete summary). These are general attributes, not system or training specific. The attributes and their desired characteristics were based on established human factors guidelines, including guidelines listed in MIL-STD 1472C, Smith and Mosier (1986), the Ordnance Training Systems Style Guide (Davis & Terranova, see Appendix B), guidelines from the nuclear industry, and various other sources to a lesser extent.

A seven-point rating scale was developed to measure users' impressions of the system as well as their satisfaction with it. In addition to the rating questionnaire, interviews were used to allow the authors to pursue specific issues. This direct contact often produced very specific concerns and constructive suggestions.

Demographic Information

In evaluating the interface, interviews were also conducted with a sample of the users. They consisted of both pilots and bombardier/navigators (B/Ns). The following background information was collected: the number of Captive Air Training Missiles flights, the amount of flight time, missile training experience, amount of experience with the PTT, PTT experience with missile attacks, HARPOON, and HARM, and S/WIP experience. This information is not yet available for analysis.

Performance Evaluation

The system was observed in use during acceptance tests with subject matter experts and walk-throughs with the Navy users. The performance was recorded and interpreted.
Installation Evaluation

Installation Evaluation

The installation of the PTT was evaluated by one of the authors as it was being installed on the U.S. Eisenhower. She observed PMTC installation team during the process of transferring the equipment from the trucks to the designated space on the ship. The process was documented and comments regarding its effectiveness were included in Appendix C.

EVALUATION DATA AND RECOMMENDATIONS

The responses to the questionnaires, the interviews, and the observational studies were analyzed. The results, discussion, and recommendations were reported for each attribute evaluated.

System Introduction

Acceptance of the system is partially dependent upon the users' first interaction with it, which, in this case, is the system set-up. Because of the need to secure classified information contained within the PTT, the software must be removed from the system at the end of use and then set-up every time it is used. The type of person setting-up the system varied among the squadrons between the intelligence officer (INTEL), one or more specifically designated PTT persons, or random users who felt comfortable enough to set-up the system before its use. Users generally followed the guidance of a person who had previously set up the system, rather than reference to the User's Manual.

The set-up of the PTT was cause for some concern. It entailed many steps and the feedback information on the screens was confusing. Users from one squadron expressed confusion about the exact set-up procedures that were required. They had been working with the PTT for several months, probably completing many set-ups successfully, however, they were still confused about the specifics of the set-up. They expressed the need for a list of the set-up of the screen and devices, with specific information given concerning requests for depressing buttons on the devices and touching the screens. Smith and Mosier (1986) advocate designing the log-on process and procedures for user identification to be as simple as possible consistent with protecting the data from unauthorized use.

The complexity of the set-up may have been instrumental in the users' apprehension to report actual hardware malfunctions. For example, one of the authors observed a squadron user unsuccessfully attempt to boot the system. Apparently the squadron had been having the same problem for several days but did not report it as a failure, assuming they were doing something incorrectly. In another situation,

a HARM set-up was switched to HARPOON. The users waited while the system remained hung-up for about 15 minutes. They had no idea that this was caused by an improper shutdown and took for granted that it was a quirk of the system.

Members of at least one squadron used their own ingenuity to write a one-page reference document for set-up and for troubleshooting. This was based either on their own experience, or on guidance from PMTC or Delex Systems, Inc., the PTT developers. At the time of this report a quick-reference guide for set-up procedures was delivered by PMTC to one of the shipboard trainers. The authors evaluated the quick-reference card on the ship and made recommendations to PMTC regarding clarification of actions required in the set-up.

Once set-up is completed a user's next interaction with the system is the introduction screen. This screen should be attention-getting and geared to the user. These evaluators felt that the introductory screen could use some refinement such as addressing the target audience and stating the purpose of the training.

Input Devices

The observation of the PTT user testing revealed some screen design problems. The question came up several times as to why there are graphics on the B/N side only. Also, both the pilots and B/Ns agreed that the B/N side is easier to read. This was a source of some frustration on the pilots' part since their training screen was obviously less readable and useful than the B/N's.

A second problem associated with screen design concerned the touchscreen. Several times the user touched the right answer but was given feedback indicating a wrong answer. Shneiderman considers imprecise pointing due to thick fingers (or "fat finger") to often cause a problem when using touchscreens. At least two of the Whidbey squadrons adapted a pencil eraser as a tool for use in touching the screen. Shneiderman (1987) states that most touchscreen implementations have a further problem: the software accepts the touch immediately, denying the user the opportunity to verify the correctness

of the selected spot. A two touch strategy or a touch-in-touch-out pattern may prove more accurate. A two touch strategy involves touching once to produce a highlighted spot and touching again to execute the operation. A touch-in-touch-out pattern allows the user's finger to break the infrared lightbeams above the screen to produce a cursor that is dragged on the screen, then when the finger is pulled out, the operation is executed. Smith & Mosier (1986) note that such strategies will provide a routine feedback that item selection has been accomplished and will provide a continuing reminder to the user of just what selection has been made.

The users also complained about the sensitivity of the touchscreen. Through comments and observations, it was noted that the screen had to be touched two or three times in order for an input to be accepted. This appeared to be a frustrating experience for the users. They sometimes would have to touch their response at a different part of the screen than was indicated. One user commented that it appeared to him that the buttons needed to be touched at the top in order for the system to respond. Users also commented that in the multiple choice questions it is not clear as to which part of the answer they should touch on the screen to input their response. These problems with the sensitivity, calibration, or consistency of the touchscreen were annoying users to the point that they were reacting negatively to the touchscreen as a whole. One user said he would prefer a keyboard for the tutorial, and a touchscreen only when simulation was required.

Other issues related to input devices concerned the slew stick and the IMP. During the practice session if a user fidgets with the slew stick it accepts the input as incorrect. The authors recommend that this be disabled during the practice and used only during the freeplay session. The simulation of the IMP on the trainer failed to provide the user any feedback. The result was the user did not know until after the entry was complete if the number combination he intended to enter was actually the number he entered. The IMP in the aircraft provides natural feedback (such as the feel of a depressed key) as to whether the input was accepted. Also, the aviator can make a mistake in the aircraft and still press more buttons to get the missile off the aircraft, in

other words he can go back and retry. The trainer should also allow this.

User Control

Initial interviews indicated that users were particularly disappointed in the trainer's inability to allow alternate paths to reach the same goal. In the operational aircraft the aviators are able to use different paths or methods to accomplish the same goal. For example, there are procedures with optional steps that allow two different ways of setting up a missile, either directly with the IMP or with the IMP and the ACU. It is correct either way and the Navy teaches both. In addition to the PTT's inflexibility in allowing alternate paths, it required the user to do it one way in one lesson and differently in the next. This situation added to the confusion of whether one way is equally good or better than the other in accomplishing the goal. Smith & Mosier (1986) encourage designers to ensure that the means of sequence control are compatible with user skill, permitting simple step-by-step actions by beginners, but permitting more complex command entry and/or alternate paths by experienced users.

The learning strategies students use when encountering learning tasks vary greatly. Accommodating these differences is of critical importance in instruction and improves learning (Roman, Pistone, & Stoddard, 1986). A student should be able to execute the exercises in any order and quickly change from one instructional pathway to another.

Accommodating to varying skill levels can be accomplished by including tests at the beginning of a course and then directing the student to a suitable lesson based on his test results. Allowing different pathways may accommodate for this. Other ways are to include dynamic monitoring of student performance in practice and simulation, comparison of student performance with specified criteria at key points, and diplomatic adjustment of the student's path when necessary. If the student does not perform well, he should not continue, but be branched to remedial instruction. Such branching should be based on the number of successive questions the students answers incorrectly

on the first try. A preset criterion may be used as the decision to remediate. Another method is through the use of an end-of-the-unit calculation of the proportion of problems the student answered correctly on the first try. If the proportion is below a preset criterion, remediate.

Allowing students some control of the learning process may improve achievement in terms of increasing motivation, decreasing anxiety, and improving attitude. The benefits will vary with the extent of control allowed and the ability of the target population to generate appropriate learning strategies in the given tasks.

Feedback Messages

According to Smith & Mosier (1986), a dialogue without feedback is disconcerting to the user, as when we talk to an unresponsive human listener. They encourage the designer to ensure that the computer will acknowledge completion of a data entry transaction with a confirmation message, if the data entry was successful, or else with an error message. Accurate use of feedback can be reinforcing. The function of reinforcement is motivational in nature. The timing, tone and appropriateness of feedback are all important issues. Specific advisory feedback provided only when errors occur in the practice may produce the best results.

Knerr et al. recommend designing feedback to meet the following goals:

1. Minimize interfering activity between action and feedback (e.g., do not require that the user perform all of the tasks before feedback; provide feedback at the end of a segment or activity).

2. Minimize interfering activity after feedback (e.g., provide feedback as to the quality of the user's performance at the end of the segment, then allow time for linking the previous performance with the information in the feedback).

3. Associate error directly with the incorrect/correct responses (e.g., provide explicit information about the action that was wrong).

A problem identified during observational studies concerned the lack of feedback for correct answers. When the user touched the correct answer, the PTT accepted that answer and immediately progressed to the next question with no pause. During observation of the squadron users, it was evident that some correct answers were obtained by guessing. When users guessed and got the correct answer they normally did not ask for additional input. The system does not indicate that they can get more information on the correct items. The authors recommended the trainer note that additional information is available.

The quality of feedback and remediation should provide the following. First, it should provide users with explicit feedback about their performance. Second, it should provide users with feedback on all subparts of the task, as well as at procedure endpoints or as a result of performance on tests. Third, the feedback should provide error diagnosis consistent with the user's mental model of the task. Finally, remediation should be tailored to the specific needs of the individual user when possible.

Information Display

In general, color coding was consistent and concise. According to Thorell & Smith (1990), optimal colors for rapid response for images on a dark background (black) are usually primary hues and bright colors like green, yellow, cyan. For text, the PTT uses cyan on a black background and, thus, is consistent with established guidelines.

The users commented on the monotony of reading the text. They indicated that reading paragraphs from the screen was no better, and perhaps worse, than reading the information out of a book. Smith and Mosier (1986) note that reading lengthy text on an electronic display may be 20-30 percent slower than reading it from a printed copy. They suggest providing lengthy textual material in printed form rather than requiring the user to read it on-line. The text was judged by the users as too wordy, they felt they had to dig through a whole page of text to

find one relevant piece of information. The paragraphs and the sentences were long. It is recommended that sentences not exceed 20 words. Condensing the information, with highlighting of the important missile facts, is recommended. Prioritizing of information was important to the users. They wanted indications of how important certain information was. One user summed this up by saying that the system should provide the important "need to know" facts and refer the users to their checklist for the rest.

With regard to user complaints of the screens containing too much information, Knerr (1986) acknowledges that the amount of blank space that is worked into the text plays an important role in how users perceive the material, and how easy they find it to work through. Shneiderman (1987) states that dense or cluttered displays can provoke anger. Crowded screens are more difficult to scan, especially for novice users. Frequent expert users can deal with more dense screens and may prefer them because they are familiar with the format and they must initiate fewer operations.

A third concern of these evaluators was that the details described in the body of the text were not highlighted on the accompanying graphics display. Highlighted details would focus the user's attention to the objective of the text. At one point during the observational study it was not clear to the users how the graphic was related to the text. When they found the heading at the top of the screen they understood the relevance. A comment made by one of the instructors who was present noted that "When a person has to put that much effort into reading a graphic, he won't use it." The key to the graphic in this case was the title. It needed to be highlighted. The title did not look important because it blended in with the graphic. Smith and Mosier (1986) state that when a user's attention must be directed to a portion of a graphic display showing critical or abnormal information, that feature should highlighted to emphasize or distinguish it. Smith and Mosier also suggest that when a user is performing an operation on some selected display item, that item should be highlighted. This practice will help avoid error especially if the user has misunderstood or perhaps forgotten which item was selected.

User Interactions

The number of screens on the PTT without user interactivity should be reduced. Smith & Mosier (1986) recommend user interactivity every two to three screens. Schneider's (1985) fifth rule for training high-performance skills encourages the designer to maintain active user participation throughout the training. He states that active participation is enhanced if subjects need to respond every few seconds.

The user should be spoken to directly. Currently the trainer refers to the user as both 'you' and 'operator'. Limiting the address of the user to the use of 'you' may be better.

User Expectations

The interview also investigated users' expectations of the system. Users commented that they were expecting a full-scale simulator with all the "bells and whistles." These authors felt that the designers' intent may not be appropriately transferred through the trainer. Users felt that there was an inconsistency between what they see and what they get. The perceived capabilities are due to the size of the PTT and the amount of hardware. We recommend that the designers report their intention to the users along with the potential advantages of a PTT over a full-scale simulator.

At one point of the PTT development, the "scroll up," "scroll down," "page up," and "page down," functions were confusing. The user thought they meant the opposite of what they actually performed. Smith & Mosier (1986) note that compatibility between user action and system response is an important concept in human engineering design. They state that interface designers should not assume that user expectations will match their own. They encourage the designer to ensure that the results of any control entry are compatible with user expectations so that a change in the state or value of a controlled element is displayed in an expected or natural form. Stated simply, command names should be chosen that are meaningful and that specifically describe the functions being implemented. Also, commands should be consistent with population stereotypes.

Error Messages

The PTT's use of error messages is consistent with human factors guidelines. For example, the messages should be neutral in their wording and displayed only after the user has completed an entry. Where feasible, error messages displayed in response to a wrong entry should indicate the correct alternative and permit the user to request a more detailed explanation of the error. However, it should be ensured that error messages contain additional explanatory information rather than merely rewording the answers.

System Navigation

An issue related to flexibility concerned navigation through the computer system. The system was designed so that only instructors or squadron leaders, identified as superusers, could navigate through the system and control the sequence. Although for many of the users the information was a review, the question and answer module requires 100% accuracy rather than allowing users to skip areas already mastered. To overcome this obstacle, all users were being identified as superusers to allow more flexibility in navigation through the trainer. Smith & Mosier (1986) recommend allowing experienced users to by-pass a series of menu selections and make an equivalent command entry directly. They note that multiple paths, such as command entry to by-pass a menu, or use of abbreviated rather than complete commands, can speed the performance of an experienced user. The interface designer, however, should take care that such shortcuts supplement rather than replace the standard, fully guided procedures provided for novice users.

Users were concerned about receiving additional information on items found in the text. When using a book to review information, they were able to thumb through and refer back to specific pages. They found this an impossible task on the PTT. The branching forced them to stay in the lesson. They would like a way to shift from point to point rather than have to scroll back through each screen. At one point a user mumbled, "Whatever that means?" and continued to read. Other

users asked the PMTC technical representative questions specific to the text in the lesson, such as a situation where a feature would be used. On a positive note in relation to the text information, users were very excited that the PTT contained a consolidation of missile information from multiple sources (printed or subject matter expert). It would be an enhancement that would probably facilitate learning, and increase curiosity, to provide them with the ability to scroll or search freely to get additional information, and then return to their position in the lesson. This option would allow navigation by text items or technical terms. The features of Hypertext could provide this.

User Help

At certain points during system navigation, users were also confused when a certain input was required for continuation of a lesson. For example, highlights to indicate the required user action was not consistent. The authors found one instance where the PRESS had no highlighting. Smith and Mosier (1986) advocate that whatever methods are used to highlight critical items in the data display be used to highlight the display of critical user guidance information. The designer has made arrangements to use highlighting as a means of indicating critical user guidance information.

One important aspect of user help is its ease and availability to the user. These evaluators feel the guidance provided by the trainer is sufficiently easy to obtain.

Fidelity

Fidelity of the training system refers to the extent that the trainer physically functions like the operational equipment (physical fidelity) or the extent that the trainer reproduces the behavioral look and feel of the actual equipment to the Navy users (psychological fidelity). It is not necessarily a valid assumption that trainers high in physical fidelity are higher in training effectiveness. Nor is it necessarily a valid assumption that trainers low in physical fidelity are lower in training effectiveness. Training effectiveness is more likely supported by the representation of the essential behavioral processes necessary to perform the job. The

main objective of the trainer should be to replicate the essential characteristics of the real world that are necessary to produce learning and transfer. A complaint often heard from the squadrons was that the PTT did not function like the actual aircraft. Although they realized it was a procedural trainer, they did not like the big leap that was required between training on the PTT and flying.

Two of Schneider's (1985) rules apply to fidelity issues. First, designers should vary aspects of the task that vary in the operational situation. When developing automatic components, the components must generalize to the entire class of situations to which they are appropriate. Second, the design should train time-sharing skills for dealing with high workload environments. That is, the training should be structured so that an expert can perform reliably even during those rare occasions when skills are pushed beyond reasonable limits.

Knerr et al. (1986) comment on decision-making and fidelity. They state that if the trainees will be required to make the decision under stress in the real world, then they must overlearn the decision-making skill during training. Decision-making behaviors must become automatic. That is, they must be able to make the correct decision, and they must be able to make the decision efficiently, accurately, and repeatedly in distracting surroundings. During the final stages of training, it is important to provide situations that closely duplicate the real world with respect to: amount of data, type of data, amount of time to complete the decision-making tasks, and amount of distraction and "noise" in the working environment.

The users from squadrons that were not A-6E S/WIP complete commented that there was not enough practice using the IMP. Without this practice, it would be difficult or impossible to use the IMP. They stated that they would continue to use the ACU alone. It seems that use of the IMP requires quick decision-making and that they did not have enough hands-on experience to complete the required tasks under stressful situations. Since they were not fully S/WIP they did not get this experience in the aircraft, therefore realistic training is essential. The PTT offers an excellent opportunity for IMP training with the appropriate simulations.

One of the common themes voiced by users during the interview was the need for freeplay. Without freeplay users were learning to operate a system without any simulation of the probable environment in which the system would be used. The training of independent tasks in a PTT, therefore, may not be realistic enough. Schneider's (1985) second rule for training high-performance skills states that the task should be designed to allow many trials of critical skills. Well-designed freeplay would adhere to this rule.

Cognitive Issues

Freeplay gives the opportunity to train a variety of cognitive skills, such as decision-making. Initial interviews indicated that some of the users felt the PTT is a "good procedural trainer." This may indicate that the behavioral requirements of task performance are taught. However, they felt it was weak in development of decision-making skills. For example, users commented that they would like a scenario where they were able to practice using the actual checklist from the aircraft. This scenario would allow them to practice free navigation, i.e., not "being led by the nose." Under circumstances of free navigation they felt that they would be required to think, and actual learning would take place, rather than the rote memorization of the required steps. They also felt it was necessary to evaluate their performance on this.

According to Knerr et al. (1986), in designing freeplay the trainer should provide the user with a wide variety of decision-making experiences. It should provide basic problems where there are only a few factors to consider and solutions to these problems should range from easy to hard. Furthermore, the design should provide complex problems which require the user to consider many factors. Again, the solutions should range from easy to hard. Once freeplay is in place, records of performance will enable evaluators to identify where the trainer is effective as well as where common errors lie. Such knowledge could be used in the redesign of the training.

Creating problem-solving contexts should facilitate learning for several reasons (Anderson, Boyle, Farrell, & Reiser, 1984). First, many

studies have shown that human memory is partially context dependent. If performance of a task requires a problem-solving activity, then instruction in the facts and theories of the task domain should take place in a problem-solving context. Additionally, many concepts are hard to understand when presented in the abstract. Teaching these concepts in a problem-solving context provides a concrete example of the concept and how it is used. Finally, there is the issue of the applicability of information. When facts are taught in the abstract, students may be perfectly capable of demonstrating that they know these facts (by tests of recall or recognition) but not recognize that the fact is relevant in a particular context. Students can access memory, but they do not know when to apply it. Teaching facts in a problem-solving context assists students in learning the "goal relevance" of the knowledge.

Hurlock and Montague (1982) reviewed the literature concerning which factors affect the initial acquisition and retention of complex cognitive skills. They cite three variables: structural organization of course content, quality of feedback, and testing methods used to evaluate user performance (Wetzel, Konoske, & Montague, 1983.) The structural organization of course content should do the following. First, it should provide a mental model of the task that emphasizes the relationship between facts, rules, procedures, principles, and concepts underlying the task. Second, it should enforce a coherency of the mental model to facilitate the recall of facts, rules, principles, and concepts. Third, the organization should teach, practice, and test each content area as a skill that supports the primary task. And fourth, the learning objects should require the user to perform the task skills, not recall or recognize verbal descriptions of the task.

At one point during the observational studies an expert on the missile system pointed out that the graphic depiction of one of the missile concepts was not correct. The concept was a particularly difficult one for the aviators to grasp. The use of an expert, such as a PMTC technical representative, would be an excellent source to provide input as the correct conceptualization that should be utilized and portrayed in the graphic. For example, one specific recommendation concerned color coding of a initial missile search area on a graphic that

would relay the correct conceptualization. Changes in the graphic may be able to enhance the ability of the aviators to understand difficult concepts. For facts that are difficult to conceptualize, the PTT can provide an excellent medium for training.

Schneider (1985) also suggests training under mild speed stress. The speed stressing of subjects may improve individual development rate. He also encourages the designer to train strategies that minimize operator workload.

Although the trainer provides feedback about performance on knowledge and procedural skills, little individual feedback is directed toward diagnosing and correcting repeated errors caused by conceptual misunderstandings. The procedural tests of knowledge do not presently require the users to demonstrate conceptual understanding of the material but, rather, to employ rote memorization techniques that may mask inadequate conceptual understanding of the task. The goal of this human factors evaluation was to evaluate the user interface. It was not aimed at determining whether or not the decision-making components of the tasks are being trained by the current system. There is a need for a cognitively-based task analysis that incorporates techniques from psychology, along with the current Instructional Systems Design task analysis, in order to determine the mental processes and skills that need to be supported by training.

Probst (1989) discusses a number of aspects involved in cognitive skills assessment. He states that a cognitive skills assessment is an evaluation of the job requirements in terms of the cognitive skills required in each cognitive level required for performance by the trainee. If the instruction given in a training program is not on the same cognitive level as that required by a specific job, and if the cognitive skills required by the job are not taught in the training program, the training program is likely
to fail.

Testing methods used to evaluate user performance should be appropriate to the type of performance required. Cognitively complex tasks should measure student progress in terms of the quality of

conceptual understanding of the relationship between facts, rules, principles, and concepts. The questions should be formatted as "paper and pencil" simulations that lead to revelations concerning the quality of the user's conceptual understanding, and promote post-test diagnosis of conceptual errors. Multiple-choice tests that require the user to recognize discrete facts should be avoided. Rather, a fill-in-the-blank or a short answer format should be used. The PTT uses a multiple-choice format to test learning.

Probst also identifies means of dealing with learning problems. He claims there are many learning problems that prevent each cognitive skill from being mastered. With computer-assisted instruction, an instructional program can be designed that can anticipate what learning problems a trainee may have in mastering each cognitive skill through the analysis of each incorrect responses. Each incorrect response identifies a specific learning problem. Thus, when a trainee makes an error, immediate feedback can be provided on the specific cause of a specific learning problem. Immediate feedback will prevent the learning problem from becoming a learning barrier. When a learning barrier develops, it can cause a learned helplessness state in the trainee that will prevent the trainee from ever becoming a successful learner. Through computer-assisted instruction a record can be kept of a trainee's learning problems, and once patterns develop, appropriate remedial instruction can be given so that the trainee does not lose motivation.

RECOMMENDATIONS FOR FUTURE ENHANCEMENTS

In addition to providing data on the system attributes investigated, the questionnaires, interviews, and observations revealed a number of other user interface issues that affect the usability and acceptability of the system. The PTT developer may wish to consider these issues in developing future enhancements of the system.

Motivation

Schneider's (1985) rules encourage designers to facilitate high motivation in the trainees throughout the training period. He states that the designer should provide extrinsic motivation but with limitations to a small portion of the training period (e.g., less than 5%). Roman, Pistone, & Stoddard (1986) also comment on motivation. They state that the function of reinforcement is motivational in nature. The timing of this reinforcement and its appropriateness is most important. Examples of means of motivation include: using the student's name; earning of a personal score, use of realistic video images, and specific advisory feedback when errors occur. Users commented that they had no motivation to practice on the PTT. The authors felt the training instructions failed to encourage curiosity and/or exploration on the user's part. One user felt that the practice session should be integrated as a regular part of their training program to provide the required motivation, currently they were completing it on their own time. On a positive note, some users felt that the ability to review lecture and textbook information was reinforcing to them.

Personality

Several researchers have investigated pilot personalities (Siem, 1988; Retzlaff & Gibertini, 1987; Gawron & Porges,1981). Retzlaff & Gibertini state that although pilots are careful conformists who can follow rules meticulously, they have a need for novelty and stimulation. For many pilots, this need is extremely salient and tends to be gratified by the danger and thrills of flying. Gawron & Porges found pilots to be more emotional, impatient, and active. Siem found graduates of Air Force pilot training to demonstrate higher self-confidence and values flexibility (self-acceptance of aggression, non-dogmatism) than non-graduates.

A variety of aspects of the trainer may need to be altered due to these unique personality characteristics common to military pilots. First, the trainer's lack of interactivity and rigid paths toward goal accomplishment inhibit the need for novelty, stimulation, and activity. Incorporating more interactivity, including freeplay throughout the trainer, may enhance the trainer in this area. Second, along with high

self confidence, pilots are oftentimes stereotyped as having "big egos". Unfortunately, while performing the questions and answers on the trainer, the users will sometimes respond correctly, and yet, they are not credited for it. This incorrect, negative feedback makes a bad impression on the users and as a result, they may be less likely to use it in the future. Finally, with regard to the pilots' tendency toward meticulous rule following and impatience, many users complained that the trainer did not clearly identify the important tasks on which they needed to focus. Many said they liked the idea of tests because they seemed to indicate what is important. Based on this perception, it is essential that all the important information be reiterated during the question and answer period. The PTT offers an excellent opportunity to have users attend to important information. We also recommend that a prioritized list of learning objectives be presented to the user early in the training sequence and continue to be emphasized throughout the sessions.

Team Training

The pilots and B/Ns using this PTT are trained individually. However, while actually performing the task, they act as a team. The lack of team training could result in less transfer of learning to the actual situation.

Several recommendations have been made for military teams (Dyer, 1984). First, team training should be preceded by individual training because individual proficiency is necessary for team training to be successful. Meister (1985) reported that individual reinforcement during early team training overcomes the characteristic decrement in proficiency that occurs during the transfer from individual to team training. However, this reinforcement does not reduce the amount of team practice required.

Dyer's second recommendation is that team training should be sequenced in terms of increasing complexity and degrees of teamwork. Third, military teams should be trained in conditions that approximate those situations in which they will be expected to perform. If a team is expected to perform under stress, members must train under stress. If

a team is expected to work as a coordinated unit, members must be trained under conditions that force teamwork.

A fourth recommendation suggests interdependencies among team members be clarified. Members of teams cannot and should not act independently of each other. Lack of coordination can often lead to serious errors. The ways in which one member's actions affect other team members or the team as a whole, need to be illustrated and stressed. Dyer's final recommendation states that team training should include training individuals to analyze their own errors, to sense when the team or team members are overloaded, and to adjust their behavior when overloads occur.

To some extent the nature of the PTT forces team interactions. For example, a first time PTT user was observed with an experienced user. The experienced aviator led the novice through the system. The inexperienced user felt that the system would benefit him more if he used it alone. He felt that it would eliminate the problem with different learning rates. On the other hand, using the trainer in a team context encouraged users to bring up scenarios and discussions concerning what they might do in a certain situation. The PTT offers an excellent opportunity for team and individual training. The designers should take advantage of this opportunity by structuring team-building tasks into the training.

Voice Input and Output

The designers are generating ideas for voice input and output. Voice driven commands may alleviate some of the monotony of the interaction with the touch screen. Also, voice narration may reduce the monotony of reading the text. However the assumption that a voice narrator would enable the trainer to communicate through the unused auditory modality and thus enhance training is unsubstantiated (Taylor, 1988). Taylor states that adding a voice output, regardless of its quality or nature, may really be adding still another confusion factor to an already overloaded situation. Furthermore, requiring a voice input from the user may be further shredding the cognitive processing that underlies the performance of all tasks.

Smith & Mosier (1986) comment that when considering speech output for user guidance, one should remember that people other than the user might hear those spoken messages. Since the PTT is stored within the squadron's quarters, speech output may prove distracting to the other people working nearby, or noises in the environment may prevent the user from hearing the message. Also, a spoken message may embarrass the user whose error has been announced. In group environments, Smith and Mosier suggest allowing users to disable the auditory signal.

The squadron's populated environment also presents a problem for the use of voice input. The voice recognition device may be likely to react to voices in the room other than that of the PTT user. Alternative input devices should be made available to the user training in a noisy environment.

If audio input and output is instituted in the future, headsets, earphones, and microphones will make the acoustic more private. In the addition, the following Smith & Mosier (1986) guidelines would be applicable. First, a variety of signals could be made available to employ distinctive sounds to code items requiring special user guidance. Such signals may include sirens, bells, buzzers, and tones of different frequencies. Second, for auditory displays with voice output, consider using different voices to distinguish different categories of data. When using computer generated speech to provide messages, ensure that those messages are short and simple. Smith and Mosier comment that if a user does not understand a written message, he or she can reread it. That is not the case with spoken messages. Though a REPEAT function might be provided, a better solution is to restrict use of speech outputs for short simple messages. Finally, if computer speech is used to provide warnings as well as other forms of user guidance, it should be ensured that spoken warnings are easily distinguishable from routine messages.

Smith & Mosier (1986) also provide guidelines useful for instituting voice input. First, the designer should structure the vocabulary used for spoken data entry so that only a few options are needed for any

transaction. Second, the designer should ensure that the spoken entries needed for any transaction are phonetically distinct from one another. Next, the designer should consider providing feedback and simple error correction procedures for speech input, so that when a spoken entry has not been correctly recognized by the computer, the user can cancel that entry and speak again. Finally, if the system cannot recognize an entry after repeated attempts, the designer should incorporate an alternative entry device to be substituted for the speech input.

Training Performance Measurement

Military training is measured in troop readiness, and, short of an all-out war, researchers can do nothing more than approximate the success of training (Grossman, 1988). Captive Air Training Missiles (CATMs) may not always provide a realistic scenario for measuring performance. This dilemma results from not having a platform on which to conduct experiments rather than the inability to do so. However, the capability to measure performance in some way is one of the critical features in the design of any good training system. One must be able to specify the skill level at the beginning, with regard to some behavior that can be measured either directly or indirectly, and then what is to be the minimum acceptable skill level at the end. One must also specify what learning experiences are necessary in order to change these behaviors. There may be a need to measure progress, diagnose incorrect behavior, and introduce diversions to remediate incorrect behavior.

According to Berliner, Angell, & Shearer (1964) when material on proficiency measurement is included in the basic design parameters of simulated systems, the system may provide the following benefits:

* Establishment of objective training criteria
* Development of behavioral norms
* Accurate prediction of performance in real circumstances

Evaluation of equipment designs through behavioral usage. These benefits are valuable because performance cannot be measured until

the aircrew has the rare opportunity to launch the actual missile. Data keeping is one form of material on proficiency measurement which can be used for monitoring the learner and evaluating the instruction. One useful form is the number of tries the student takes to answer a given question correctly. A count indicating the number of tries the learner takes to understand could indicate the need for instructional feedback, and/or that the questions need revision (Roman, Pristone, & Stoddard, 1986).

Training/Instructional Design

According to Knerr et al. (1986), training guidance assumes some general human learning principles. Inform the learner of the objectives; students meet objectives better when they understand what they are expected to learn. Provide active practice (students learn better when they actively practice the new skills. That is, practice on performance assists in learning faster, improving during learning, and retaining what is learned. Provide feedback; the student needs to have feedback about his performance for the practice to be effective. The feedback tells the students what they are doing wrong, what they are doing right, and how they can improve their performance. Students usually benefit from cues, demonstrations, and prompts. Cues or prompts before performance help the students perform correctly without wasting time in trial-and-error learning. Guidance during early performance helps the student relate new learning to past learning and focus on specific cues to watch for during the task.

Probst (1989) identified nine steps to insure a training program will be successful.

1. Assess cognitive skills - Determine what cognitive level must be mastered in order to perform a job or pass an examination. The objectives required to demonstrate mastery of cognitive skills for a job, or to pass a test, will be called a terminal objective.

2. Write learning objectives - For each terminal objective found by the cognitive skills assessment, write prerequisite learning objectives.

3. Determine prerequisite objectives - For most learning objectives it will be necessary to write prerequisite objectives. Through an analysis of each terminal objective, prerequisite learning objectives are developed. The prerequisite learning objectives are the objectives found in a learning hierarchy.

4. Determine entry level objectives - For some training programs, it will be necessary to develop prerequisite entry level learning objectives. It may be impractical to develop all of the entry level prerequisite skills required for some training programs.

5. Write test questions - Test questions should be constructed that measure the cognitive skills on the proper cognitive level.

6. Develop course content - Information should be presented to trainees that will permit the trainee to master the required cognitive skills.

7. Develop practice material - Material should be developed that gives the trainee practice using the cognitive skills required by each learning objective.

8. Construct selection test - A screening test should be constructed that will determine if the trainees selected for a training program have the prerequisite learning skills required to master the cognitive skills to be learned in the training program.

9. Develop a pre-training program - A pre-training program can be initiated that will develop the required cognitive skill in trainees who fail to pass the selection test.

Summary of Recommendations

The objective of this human factors evaluation was to contribute to the overall effectiveness of the user interface of the PTT. The PTT has to be both accepted and usable by the intended military users. It is anticipated that the increased effectiveness of the user interface will be instrumental in the overall training effectiveness of the PTT. The

recommendations generated by this effort will enhance the user acceptance and usability of the system. These recommendations are summarized in Table 1.

TABLE 1

Summary of Recommendations

1. Design log-on process and procedures for user identification to be as simple as possible.
2. Design the introduction screen to be attention getting and to directly address the target audience.
3. Display only the necessary information avoiding extraneous information.
4. Use a two touch strategy or a touch-in-touch-out pattern to avoid "fat finger" problems.
5. Disable the slew stick during the practice sessions.
6. Ensure that the means of sequence control is compatible with user skill.
7. Accommodate to varying user skill levels.
8. Acknowledge completion of a data entry transaction.
9. Minimize interfering activity between action and feedback.

10. Associate error messages directly with the incorrect/correct responses.
11. Provide users with explicit feedback about their performance.
12. Note that additional information or help is available.
13. Provide lengthy textual material in printed form rather than requiring the user to read it on-line.
14. Avoid sentences exceeding 20 words.
15. Highlight featured items to emphasize or distinguish them.
16. Highlight the item on which a user is performing an operation.
17. Ensure user interactivity every two to three screens.
18. Speak to the user directly.
19. Report the designer's intentions to the users along with the potential advantages of a PTT.
20. Command names should be chosen that are meaningful and that specifically describe the functions being implemented.
21. Allow experienced users to by-pass a series of menu selections.
22. Provide users with the ability to scroll or search freely to get additional information.
23. Vary aspects of the task that vary in the operational situation.

24. Train time-sharing skills for dealing with high workload environments.

25. Allow many trials of critical skills.
26. Use a fill-in-the-blank or a short answer format, rather than multiple choice.
27. Reiterate all the important information during the question and answer period.
28. Provide a prioritized list of learning objectives.
29. Regard voice input and output with caution.
30. Precede team training by individual training.
31. Structure team-building tasks into the training.

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APPENDIX A

Evaluatee Items

The format for the following items was a seven point rating scales with anchors from strongly disagree to strongly agree.

1. The introduction screen is attention getting.
2. Abbreviations are available for use to minimize the amount of input requirement.
3. The system (text, etc.) speaks to me directly.
4. Messages are affirmative not negative in wording.
5. Warning and caution messages are informative and explicit.
6. All of information displayed is necessary.
7. All necessary information is displayed.
8. Screens are self-explanatory (i.e., instructions on what to do next or information on what will happen next is on every screen).
9. Guidance or help is easy to obtain.
10. The system notifies me if at any time the terminal becomes disabled.
11. Transaction status is indicated to me whenever the complete response to a user entry is delayed.
12. When the computer detects an entry error, an error message is displayed to me stating what is wrong and what can be done about it.
13. Hardcopy documentation is available.
14. Error messages are specific and brief, yet informative.
15. The content of error messages is oriented towards the task.
16. Error messages displayed in response to a wrong entry indicate the correct alternative.
17. Error messages are neutral in their wording (i.e., they do not imply blame or attempt to make a message humorous).
18. Experienced users are provided with the means to by-pass a series of menu selections and make an equivalent command entry directly.
19. Forward and backward navigation through the trainer is simple.
20. Experienced users are able to key in a series of commands at one time.
21. I am able to obtain further on-line guidance by requesting HELP.
22. A simple standard action is provided to request HELP.
24. The response to a HELP request is tailored to the current transaction and its content.

25. When an initial HELP display provides only summary information, more detailed explanations are provided in response to repeated user requests for HELP.
26. I am informed of any records kept of individual performance.
27. I am able to request a displayed record of past transactions in order to review prior actions.
28. Training objectives/goals are clearly defined.
29. Training instructions are clear.
30. Training instructions encourage curiosity/exploration.
31. Training tasks are structured to hold my interest.
32. Training material supports transition from novice to expert.
33. Material is within my memory limitations.
34. The material is written at my ability level.
35. I have control over how learning progresses on this trainer.
36. The reinforcement offered to me is motivating.
37. The trainer resembles the actual physical operational environment.
38. The critical decision-making skills required by the operational task are taught by this trainer.
39. The trainer gives a thorough abstract view of the operational task.
41. My experiences with the trainer are consistent with what my expectations were.
42. This trainer is effective.

APPENDIX B

Ordnance Training Systems Style Guide

ORDNANCE TRAINING SYSTEMS STYLE GUIDE

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1.0 SCREEN DESIGN

1.1 Log-On

1.1.1 Log-on procedure should be separate from operational options.

1.1.2 Log-on response time should be from 1 to 30 seconds with immediate interim acknowledgement.

1.1.3 System status (information on current data processing) should be provided to users at all times (e.g., System is down for maintenance until 0900), either automatically or by request.

1.1.4 Appropriate prompts for log-on procedures should be automatically displayed at user's terminal (e.g., Enter SSN).

1.2 User-Impact Opening

1.2.1 Introduction screen should be provided that is attention-getting and geared to user group, while identifying training systems family and/or producer of training (e.g., PMA205-11).

1.3 Format

1.3.1 Information presented to user should adopt a consistent organization for the location of various display features, such as user guidance, from one display to another.

1.3.2 Format for user guidance should be distinguishable from displayed area in terms of location and/or intensity, color.

1.3.3 Data fields should be formatted consistently and distinctively, thus providing cues for entry.

1.4 Labels

1.4.1 Control labels should be clearly labelled (e.g., CANCEL, PAUSE, REVIEW) to indicate their function.

1.4.2 Data labels should clearly label all displayed data (e.g., NAME, ADDRESS, TELEPHONE NUMBER).

1.5 Highlighting

1.5.1 Critical user guidance information should be highlighted.

1.5.2 Technique used to highlight data and control labels should be easily distinguished from that used to highlight critical user guidance information.

1.5.3 No more than 10% of the display should be highlighted at one time.

1.6 Intensity

1.6.1 No more than two levels of intensity should be used.

1.6.2 High brightness levels should be used to signify information of primary importance and lower levels to signify information of secondary interest.

1.7 Screens

1.7.1 When possible, all data related to one task should be displayed on a single screen.

1.7.2 Information density should be appropriate (i.e., the amount of information-bearing activated screen area should not exceed 25% of the total screen area).

1.7.3 Screens should be installed to minimize or eliminate reflected glare.

1.7.4 Screen luminance and contrast should be adjustable by user.

1.7.5 Screens should be self-explanatory (i.e., instructions on what to do next or information on what will happen next should be on every screen).

1.7.6 Screens should be symmetrically balanced.

1.7.7 There should be no more than 3 to 4 consecutive screens without interactivity.

1.8 Coding Conventions

1.8.1 Coding conventions (e.g., symbols, color) should be consistent from one display to another.

1.8.2 Coding conventions (e.g., abbreviations) should be familiar, conform to conventional usage and user expectations, but should not be specific to learning task (i.e., new material should not introduce new abbreviations).

1.8.3 Abbreviations should be available for user input whenever possible to minimize input requirements.

1.8.4 Abbreviations should not include punctuation (e.g., USA).

1.9 Color Coding

1.9.1 Display colors should be easy on the eyes (e.g., white text on black background).

1.9.2 Color code should provide redundant information (e.g., to enhance symbol visibility or to convey relative information quickly).

1.9.3 Color code should be logically related to operator's task.

1.9.4 Color code should appear with minimal user effort.

1.9.5 Color code should be consistent (e.g., all error messages should be in one color).

1.9.6 In alphanumeric displays, color should be used conservatively (i.e., no more that 4 per screen and 7 per program).

1.9.7 Color in graphic displays should be used for greater information density by separating items into several color categories where symbols can be assigned to task-related groups.

1.9.8 When used for coding, number of colors should not exceed 11.

1.9.9 Color changes should indicate status changes (e.g., SAVING, PRINTING).

1.9.10 Meaning assigned to a particular color should remain consistent and be narrowly defined (e.g., red means danger and yellow means caution).

1.9.11 Similar colors should have the same or similar meanings across display set. They should never have contradictory meanings.

1.9.12 Colors selected for coding should contrast well with the background on which they appear (e.g., white on blue).

1.9.13 Colors that need to be discriminated quickly should be as far apart in hue and lightness as possible, but near in saturation.

1.10 <u>Graphics</u>

1.10.1 Graphics quality should be good.

1.10.2 Simple graphics should be used to represent concepts.

1.10.3 Full screen graphics should be used to provide information.

2.0 TEXT READABILITY

2.1 Type Style

2.1.1 Type style should be simple and consistent.

2.1.2 All text materials should be written in a combination of upper- and lowercase letters.

2.1.3 Menu items, labels, error messages, and user guidance messages should be written in uppercase.

2.1.4 A maximum of four different letter sizes should be used.

2.1.5 A maximum of three different fonts should be used.

2.2 Sentences/Paragraphs

2.2.1 Sentences should contain less than 20 words.

2.2.2 Use of hyphenation should be minimized.

2.2.3 Paragraphs should be single spaced with double spacing between them and are not indented.

2.2.4 Paragraphs, in general, should be less than eight lines in length.

2.3 Justification

2.3.1 Justification of text should be consistent, whether right justified or not.

2.3.2 Numeric data should be left justified, with all decimal points lined up.

3.0 SYSTEM MESSAGES

3.1 Messages

3.1.1 Users should be directly spoken to.

3.1.2 User guidance messages should be affirmative not negative in wording.

3.1.3 User guidance messages should be active rather than passive in voice.

3.1.4 User guidance messages should follow the same sequence when describing a sequence of steps (e.g., CLEAR THE SCREEN, ENTER DATA, etc.).

3.1.5 Warning and caution messages should be explicit.

3.1.6 All information displayed should be necessary.

3.1.7 Individual input words which must be typed should not exceed 7 characters.

3.1.8 Wording should be consistent for similar or identical functions in different transaction sequences (e.g., UPDATE, MODIFY, EDIT).

3.1.9 Task-oriented wording should be used for labels, prompts, and user guidance messages (e.g., COPY, ERASE).

3.1.10 Wording for user guidance should be consistent with control entry (e.g., DELETE).

3.1.11 Grammatical structure should be consistent when wording user guidance, (e.g., ERASE, SELECT, WRITE).

3.1.12 User guidance should be flexible enough to permit an experienced user to by-pass standard guidance procedures.

3.1.13 Guidance should be easy to obtain (e.g., PRESS F3 FOR GUIDANCE ON HOW TO CONTINUE).

3.1.14 User should be notified if at any time the terminal becomes disabled.

3.2 Routine Feedback

3.2.1 Feedback should be consistent (i.e., every user input will produce some output from the computer).

3.2.2 Display screen should never be blank when the terminal is in use.

3.2.3 Computer response to user entries should be rapid, with consistent timing as appropriate for different types of transactions, i.e., within a transaction, 4 to 6 seconds; after completing a transaction, up to 15 seconds.

3.2.4 Transaction status should be indicated whenever the complete response to a user entry is delayed (e.g., SYSTEM IS PROCESSING REQUEST, PLEASE WAIT).

3.2.5 User should be informed when processing is completed and appropriate guidance for further user actions should be provided.

3.2.6 A unique identification (e.g., label) should be provided for each display in a consistent location at the top of the display frame.

3.2.7 User should be informed when the display is continued on multiple frames.

3.2.8 When data are contained on multiple pages, each page should display both a page number and the total number of pages.

3.2.9 Current operational mode should be indicated (e.g., DELETE MODE).

3.2.10 Available options, such as CANCEL, SAVE, PRINT, should be indicated either automatically or on user request.

3.2.11 A selected item should be highlighted on the display.

3.2.12 Following user interrupt of data processing, an advisory message should be displayed assuring the user that the system has returned to its previous status.

3.3 Error Feedback

3.3.1 When the computer detects an entry error, an error message should be displayed to user stating what is wrong and what can be done about it.

3.3.2 Error messages should be specific and brief yet informative.

3.3.3 Error messages should be task-oriented (NUMBER ENTERED IS OUT OF RANGE, 0-10).

3.3.4 Where feasible, error messages displayed in response to a wrong entry should indicate the correct alternatives.

3.3.5 Error messages should be neutral in their wording (i.e., they do not imply blame to the user, or personalize the computer, or attempt to make a message humorous).

3.3.6 Simple error messages should permit user to request a more detailed explanation of the error.

3.3.7 User should be notified when multiple errors are detected in a combined user entry (i.e., when a user enters two or more commands at the same time, e.g., save and print).

3.3.8 Error message displayed should be different if user repeats an entry error.

3.3.9 Error message should be displayed only after user has completed an entry.

3.3.10 Error message should be displayed approximately 2-4 seconds after the user entry in which the error is detected.

3.3.11 As a supplement to on-line guidance, a listing and explanation of all error messages should be included in the system documentation.

3.3.12 In addition to providing an error message, the location of a detected error should be marked by positioning the cursor at that point on the display.

3.3.13 When an error entry has been detected, the erroneous entry should continue to be displayed, as well as an error message, until corrections are made.

3.3.14 Following error detection, the user should be required to re-enter only that portion of a data/command entry which is not correct.

3.3.15 Displayed error message should be removed after the error has been corrected.

3.3.16 Error identification number should precede each error message.

3.4 Prompts

3.4.1 Advisory messages and other prompts should be provided to guide users in entering required data.

3.4.2 Prompts for data/command entry should be displayed in a standard location.

3.4.3 Format for prompts should use consistent phrasing and punctuation.

3.4.4 Prompts should use concise wording.

3.4.5 A standard symbol for prompts should be used and reserved only for that purpose (e.g., :>).

3.4.6 Prompting as an optional guidance feature should be provided.

4.0 DIALOGUE INTERACTION

4.1 Function Keys

4.1.1 Function keys should have standardized functions (e.g., F1 should always mean HELP).

4.2 Cursor Control

4.2.1 Cursor should be distinguishable from other displayed items.

4.2.2 Cursor should be automatically positioned so that it appears in a consistent display location for each type of transaction.

4.2.3 Cursor control should be obtained by using "up", "down", "right" and "left" arrow keys.

4.2.4 Cursor keys should be located to the right of the alpha keys in a cross or inverted T-shape layout.

4.3 Navigational/Menu Control

4.3.1 A general list (menu) of control options should always be available to serve as a "home base".

4.3.2 Menu options should be displayed in logical groups (e.g., by importance or frequency).

4.3.3 Numbers should be used as designators when listing selectable items.

4.3.4 When hierarchic menus are used, they should be organized and labelled to guide users within the structure.

4.3.5 Displayed menu should only include those actions which are appropriate at that particular step in a transaction sequence.

4.3.6 Experienced user should be provided with the means to by-pass a series of menu selections and make an equivalent command entry directly.

5.0 INPUT DEVICES

5.1 Keyboard

5.1.1 Only relevant keys should be displayed on keyboard.

5.1.2 Keyboard should have a standard QWERTY layout, with separate cursor control and programmable function keys.

5.2 Mouse

5.2.1 Mouse should be used for item selection, scrolling, data retrieval, and data entry.

5.2.2 Mouse should be easily movable in any direction without a change of hand grasp.

5.2.3 Mouse should be operable with either the left or right hand.

5.2.4 Complete excursion of the mouse from side to side of the maneuvering area should move the cursor from side to side on the display.

5.2.5 If the mouse can drive the cursor off the edge of the display, indicators should be provided to assist the user in bringing the cursor back onto the display.

5.3 Joystick

5.3.1 Joystick controls should be used for tasks that require precise or continuous control in two or more related dimensions.

5.3.2 Joystick should be a non-return-to-center position type. In other words, the stick should remain in any position in which it has been placed when the user's hand is removed.

5.4 Touch Screen

5.4.1 Touch screens should be used for item selection, scrolling, data retrieval, data entry, and/or manipulation of tasks.

5.4.2 The terminal should recognize the user's touch in approximately 100 ms.

5.4.3 The system should accept only one command at a time, indicate the command has been accepted and respond in a time commensurate with the activity.

5.4.4 The sensitive areas should be large enough to allow entry using fingers and allow for parallel due to CRT screen curvature.

6.0 USER GUIDANCE

6.1 HELP

6.1.1 Help menu should contain no more than 26 terms per menu.

6.1.2 In addition to explicit aids (labels, prompts) and implicit aids (cueing), user should be permitted to obtain further on-line guidance by requesting HELP.

6.1.3 A simple, standard action should be provided to request HELP that is always available (e.g., PRESS F1 FOR HELP).

6.1.4 The response to a HELP request should be tailored to task context and the current transaction.

6.1.5 When a request for HELP is ambiguous in context, the computer should initiate a dialogue in which the user can specify what data, message or command requires explanation.

6.1.6 When a user requests HELP on a particular topic, the computer should accept synonyms for standard system terminology (e.g., erase for delete).

6.1.7 When an initial HELP display provides only summary information, more detailed explanations should be provided in response to repeated user requests for HELP.

6.1.8 User should be permitted to browse through on-line HELP displays.

6.2 Error Prevention

6.2.1 When a data or command entry seems doubtful, in terms of defined validation logic (e.g., entering a letter instead of a numeral), a cautionary message should be displayed asking the user to confirm that entry.

6.2.2 User should be required to take some explicit action to confirm a potentially destructive data/command entry, such as deleting a file, before the computer will execute it.

6.3 Index

6.3.1 In applications where the user can choose what stored data to display, an on-line data index should be provided to guide user selection.

6.3.2 In applications where the user can employ command entry, an on-line command index should be provided to guide user selection and composition of commands (e.g., MERGE, SEARCH).

6.4 Job Aids

6.4.1 Specific user guidance information should be available for display at any point in a transaction sequence.

6.4.2 At every point in a transaction sequence, guidance should be provided telling the user how to continue.

6.4.3 If there are control options that are specifically appropriate to the current transaction, those options should be indicated on the display.

6.4.4 Forward and backward navigation should be simple.

6.4.5 Reference material describing system capabilities and procedures should be available to user for on-line display.

6.4.6 A complete dictionary of abbreviations used for data entry, data display, and command entry should be provided.

6.4.7 When codes are assigned special meaning in a particular display, a definition of those codes should be included in the display.

6.4.8 System should recognize common misspellings of a command and should execute the command as if it had been spelled correctly.

6.4.9 Experienced user should be able to key in a series of commands at one time (i.e., command stacking).

7.0 TRAINING

7.1 User Records

7.1.1 In applications where skilled user performance is critical to system operation, an automatic computer recording and assessment of appropriate user abilities should be provided.

7.1.2 Users should be informed of any records kept of individual performance.

7.1.3 User should be able to request a displayed record of past transactions in order to review prior actions.

7.2 Instructional Design

7.2.1 Training objectives/goals should be clearly defined.

7.2.2 Material should be sequentially organized for knowledge layering.

7.2.3 Target audience should be well defined.

7.2.4 Material should be written at an appropriate level for user.

7.2.5 Training instructions should be clear.

7.2.6 Training instructions should encourage curiosity/exploration.

7.2.7 Training tasks should be structured to hold user interest.

7.2.8 Training system should include a task analysis.

7.2.9 Training system should have documented objectives, instructional design, and scripts.

7.2.10 Material should support novice user.

7.2.11 Material should support expert user.

7.2.12 Material should support transition from novice to expert.

7.2.13 Material should be within human memory limitations.

7.2.14 Pre-test should be included in instruction.

7.2.15 Post-test should be included in instruction.

7.2.16 An appropriate time frame should be allotted for mastery.

7.2.17 Where appropriate, an on-line training capability should be provided to introduce new users to system capabilities and to permit simulated "hands-on" experience in data handling tasks.

7.2.18 Needs of different users should be anticipated and different levels of training for on-line job support should be offered.

8.0 ERGONOMICS

8.1 Screens

8.1.1 Resolution quality should be clear (i.e., for CRT's displaying alphanumeric text, a minimum of 20 resolution elements per inch is necessary and for CRT's with graphic detail, a minimum of 100 resolution elements per inch is required).

8.1.2 Luminance contrast should be appropriate (i.e., between light characters and dark screen 15:1 minimum, 20:1 preferred; between dark characters and light screen 1:15 minimum, 1:20 preferred).

8.1.3 Screen luminance should be appropriate (i.e., CRT's with light background, luminance = 23 ft.-Lamberts minimum and 46 ft.-L preferred; CRT's with light characters, character luminance = 23 ft.-L minimum and 46 ft.-L preferred).

8.1.4 User should be at least 19 inches from display.

8.1.5 User's viewing angle of display should be at least 45 degrees.

8.1.6 Regeneration rate should be between 50 and 60 Hz to avoid flicker.

8.2 Character Size

8.2.1 Character height should be appropriate (i.e., visual angle should be between 15 and 20 minutes).

8.8.2 Character width-to-height ratio should be between 3:5 and 1:1.

8.8.3 Stroke width-to-height ratio should be between 1:5 and 1:10.

8.3 Spacing

8.3.1 Minimum spacing between characters should be one stroke width.

8.3.2 Minimum spacing between words should be one character width.

8.3.3 Spacing between lines should be between 50 and 150% of the character height.

8.4 Keyboard

8.4.1 Keyboard should give a positive indication when a key is hit (e.g., click, snap, or feel) with resistance between 1 oz. and 5.3 oz.

8.4.2 Slope of keyboard should be 15 - 25 degrees from horizontal.

8.4.3 Keycaps should be no smaller than 10 mm by 10 mm and should be of 19 mm centers (except for function keys which may be spaced further apart).

8.5 Mouse

8.5.1 Mouse should have physical dimensions of 1 1/2 to 3 in. width, 3 to 5 in. length, and 1 to 2 in. thickness.

8.6 Joystick

8.6.1 Joysticks should be 1/4 to 5/8 inch in diameter and 3 to 6 inches long.

9.0 MISCELLANEOUS

9.0.1 Interaction between user and computer should be user paced.

9.0.2 Display rate should be appropriate or should be user paced.

9.0.3 Access time should be appropriate.

9.0.4 Minimum effort should be required to master the system.

9.0.5 Where audio components exist, sound should be crisp and clear.

9.0.6 If audio components exist, it should be under user control.

9.0.7 Hardcopy documentation should be available for support purposes.

9.0.8 Quick reference cue cards should be available for support purposes.

9.0.9 Update rates should not exceed 3 seconds.

9.0.10 Information should be presented in a directly usable form (i.e., no computing, translations or interpolations are necessary).

9.0.11 Data should be keyed without dimensional units necessary (e.g., $, mph).

9.0.12 Key entry of leading zeros should not be required.

9.0.13 Current default values should be displayed.

9.0.14 Acceptance of a default value should be easily accomplished.

9.0.15 System should be able to stand alone with no manual needed to operate it.

APPENDIX C

EVALUATION OF THE INSTALLATION OF THE PTT

EVALUATION OF THE INSTALLATION OF THE PTT:
Human Factors report from PTT onload to USS Eisenhower
(6-7 March, 1990)

Below are the major tasks for the PTT onload to the USS Eisenhower. Not all tasks were done sequentially, some were overlapping.

Task 1: Obtaining access to the ship

0805 The installation team - J. Watson (PMTC), T. Lyons (PMTC), M. Terranova (ORNL), Leanne (NAC), and M. Rayone (Delex) - arrived at the ship to meet LCDR Tim Quitter, our POC. We could not obtain passes on the quarterdeck. While John waited on the pier with the truck, the rest of the PMTC installation team left the pier to get ship passes.

Task 2: Unloading the containers from the truck onto the pier

Task 3: Moving the containers from the pier to the hanger bay

0850 With the ship working party, John moved boxes off the truck to the pier. The rest of the installation team joined him and waited by ship with the containers for a crane to pick up the containers. There was another huge crane by the flight deck that would have been more convenient, but was not available for our use. We waited while various supplies were loaded for the deployment. The area was noisy and confusing. A bunch of pallets showed up and the team loaded the containers on the pallets. The load on each pallet was balanced by four chains, one on each side. The load was lifted to the hanger bay.

Task 4: Determining the optimal route from the pier to the installation area

Once the containers were loaded, the installation team looked for the easiest way to the flight deck.

0905 We met our containers on the hanger bay. The installation team and the working party moved the containers manually to the elevator.

Task 5: Preparing the installation area

The installation team went up three flights to check out the CAG administration space for the PTT. The space was about 7 feet x 14 feet.

0930 While waiting on the elevator, the installation team began to set up the space in the CAG Administration room. The chief wanted the PTT installed against a different wall than from where it was being installed. John pointed out that this would interfere with the ability to open the door to the room.

While these activities continued, the truck needed to be moved off the pier. The rest of the team waited for the elevator to bring the containers to the flight deck.

Task 6: Moving the containers off the elevator

1010 The elevator arrived on the flight deck. The working party was no where to be found. The team members moved the containers off the elevator and then asked the forklift operator to move the containers to the opposite end of the flight deck.

Task 7: Moving the PTT equipment to the installation area

1035 The team began to open up the containers and unload the equipment. This was necessary for two reasons. First, the ladder was relatively narrow with respect to the size of the containers, and, second, the weight of a full container would make carrying it dangerous, if not impossible. The weight and/or awkwardness of the individual pieces made it necessary for 2 strong individuals to carry each piece (the heaviest piece was about 240 pounds). Some of the pieces were handed over the side of the deck. The equipment had to be moved down two

exterior ladders (with a railing that made things pretty tight), over 18 knee-knockers, up 2 sets of stairs with 3 steps each, and through one door that had to be opened each time the installation team came in with a piece of equipment. Wires were hanging off the equipment.

Task 8: Installing the PTT

1100 At this point it was necessary to leave some of the equipment on the flight deck and begin to assemble the cabinets in order to accommodate the equipment in the space of the ready room, this was also a good time for a break. It became quite hot and uncomfortable in the CAG administration room.

1130 The team broke for lunch upon invitation from LCDR Quitter to join him in the ship's dining room.

1215 Linda Childs joined the group and brought the software for installation. A fuse for one of the fluorescent bulbs was removed from the light directly above the PTT. This reduced the direct glare on the screen considerably. John worked on the electrical set-up and Tim worked on the equipment set-up.

1350 The PTT was pushed into place against the wall by three of the men on the installation team and the installation was complete. The software had to be authorized for receipt by someone from the CAG.

Task 9: Removing the containers from the ship

1400 We waited on the flight deck for the elevator in order to take the empty containers down to the quarterdeck.

The installation was made smoother by:

* Having team members such as Mark and Tim who had spent time on the Eisenhower, and John who was familiar with carriers in general. They were able to map out the most direct routes from the

flight deck to the CAG Administration room. They were also able to anticipate the type of traffic that would be encountered on various alternate paths.

* CDR Quitter paving the way to make it a smooth installation, as well as inviting us to lunch on the ship.
* The smooth working of the installation team; they had good team interactions, and a sense of humor.
* Good weather, it was sunny, dry, low humidity, and sea states were calm.

The installation could have been improved by:

* A dedicated Navy working party.
* Modifications to the containers and/or equipment, to made it less awkward to move.
* Predictability of the elevator schedule.
  Containers appropriately labeled by contents

Recommendations:

Since the containers are too large to carry to the point of installation, modifications should be made both to the PTT equipment and the containers to provide easier handling. The installation team (eg. John Watson, Tim Lyons of PMTC) should have suggestions for this. For example, handles bolted on the sides of the larger pieces would alleviate some of the awkwardness. The size is potentially dangerous to workers and equipment alike.

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