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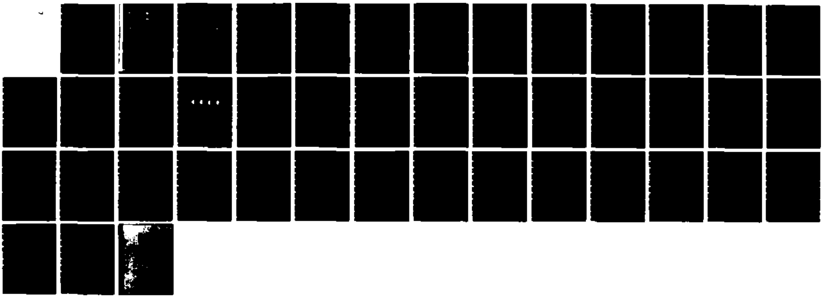

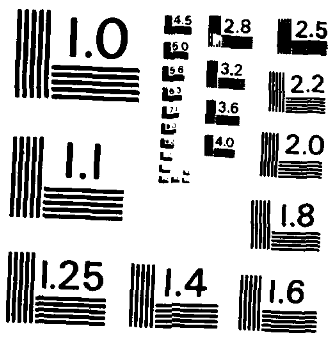

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GUIDELINES FOR MAN/DISPLAY INTERFACES WITH RELEVANCE TO MILITARY ENVIRONMENTS

by

B. Ford

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 84-3

Canada

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ABSTRACT

The report presents guidelines for developing a man/display interface. Military environment requirements are addressed. The guidelines include: methods of highlighting the displays; techniques for minimizing operator confusion and error; methods for system prompt, and user reply; choice of hardware control devices; and consideration of display and system peripheral ergonomics.

RÉSUMÉ

Ce rapport énonce certains principes utiles au développement de systèmes utilisant un écran pour communiquer avec l'usager; une attention est portée aux exigences d'un environnement militaire. Plus particulièrement, on traite de méthodes d'accentuation de l'écran; de techniques pour minimiser la confusion et les erreurs de l'usager; de méthodes d'interrogation pour le système; de méthodes de réponse pour l'usager; du choix du hardware pour les éléments de contrôle; et de l'ergonomique de l'écran et des éléments périphériques du système.

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1. Introduction:

1.1 Overview:

In any man/display interface it is desirable to allow the user, or operator, to view the display, assimilate the contents, make a decision, and present his request, or order, to the system as quickly, efficiently, and accurately as possible. A useful display system informs the operator about what the computer knows and assumes about the system and the operator; and informs the operator about what it intends to do. The other half of the effective display system interface expects the operator to keep the system informed of his intentions. To do this competently appropriate peripherals are mandatory, as well as an efficient man/display interface.

An effective man/display interface design begins with an understanding of the operator's role in the overall system performance. The design should consider what the operator needs from the system and the display, and what the display can present and the system provide. The interface should be as comfortable for the operator to use as possible because this promotes the operator's trust in the system. There are times when quick interface to the system by experienced users may be accomplished through acronyms, symbols or abbreviations; but to avoid unnecessary trauma and improve the interface, the interface should be as natural-language-like as possible.[1] Operators can sometimes compensate for poor interface designs but this requires extra effort and may lead to unnecessary confusion and wasted time. The system should build in safeguards to avoid or reduce the impact of unpredictable human error.[2] Designers of large complex, high-risk-of-failure systems would often prefer to automate human operators out of their systems; but operators are required to plan, monitor and step in when systems fail.

A very difficult problem in man/display interfaces is necessarily the determination of the visual display requirements. The display must present to the operator crucial information at all times, and less crucial information at times when the operator has a need for it. If too much information is on the display the operator may actually notice and retain less than is necessary. Proper placing of information attracts operator attention to the correct information, and proper highlighting of the information attracts operator attention at the correct time. Currently display formatting is an intuitive art and guidelines are needed to allow interface development to be more standard and less of an art.

A likely source of difficulty in designing the man/display interface is a mismatch in the mental models of those who design the interface and those who operate it. This report is aimed at the designer of the interface system, offering points to keep in mind about the operator involved in the interface, and the display interface itself. The purpose of this report is to make human factors information for display environments easily accessible, easily assimilated and directly usable by military associated personnel. The recommendations are given as succinctly and clearly as possible without elaborate documentation or qualification. Often the qualification is intuitive, and sometimes reasons for the recommendations have been outlined in the references. The design guidelines are based on opinion, judgement and accumulated experience rather that on quantitative performance measures. The guidelines do not indicate the consequences of not being implemented. In the past, and likely a continuing source of guidance regarding the design of man/display interfaces, is the intuitive beliefs of experienced operators.

The areas associated with guidelines for an effective man/display interface presented in this report are as follows:

i) The method of presenting the display: what to highlight, how to highlight it, whether to use graphs (and what type of graph), whether to use icons (pictorial symbols) (and what type of icon).

ii) General techniques for minimizing operator confusion and error.

iii) How to prompt the operator and how to expect the operator to reply. How to make it clear to the operator, at all times, what he should do next, in order to avoid delay.

iv) What response times should be tolerated.

v) Optimization of the choice of hardware control devices to ease operator input.

vi) Consideration of display and system peripheral ergonomics.

1.2 Military Environment Considerations:

Many of the guidelines presented in the report may pertain to civilian applications; but many are especially relevant to military applications.

Computer systems help guide planes, ships and submarines, direct missiles, track targets, guard shorelines, and plan battle strategies. Man/display requirements exist in all these areas. In the past the military used large arrays of meters and gauges or large situation boards and control panels or maps to display information.[2] The current developments in hardware and display technology are pushing human factors engineers to devise better ways of formatting and presenting large collections of information to facilitate interpretation and reliable decisions by operators. Current displays encountered in military environments are typically information intensive: dense, and cluttered. The amount of information the operator must assimilate is considerable and extensive. Usually some information must be maintained in constant view at all times.

The display for a military scenario may be used by command personnel who need an overview of the situation but those that use the displays most often and most extensively are the operators themselves. These military operators are frequently highly trained, dedicated and experienced; however they are usually not computer programmers. Many man-machine interfaces involve simple, carefully described, step-by-step interaction; but this extensive description may not be necessary with the trained military operators. However the interface should still be as straightforward as possible since errors in most military situations can be very critical. The trained operator can be taught to concentrate on crucial areas or features of the display without excluding the less urgent areas. The trained military operator is also familiar and comfortable with many acronyms and symbols. These acronyms and symbols would be very confusing to those not familiar with them but can be save space and reduce screen clutter when used for those who can accept them.

Many of the military operating environments are not optimum. Some situations require little interaction for a long period of time which may lead to boredom and a serious decrease in alertness; and then suddenly the operator is expected to observe events on the display and make critical judgements. Consider the amount of time needed for the operator to reacquire comprehension and orientation to make proper diagnosis and take over control.

Other military situations require sustained mental workloads for long durations. Man is very adaptable but if the interface is not the most effective or efficient under high workload conditions the operator may no longer work as co-operatively with the system as may be necessary. Due to the critical nature of many military situations there is a strong requirement to minimize error under the demanding workload. In many military scenarios the operator must act quickly so there is strong requirement to minimize the need for unnecessary or redundant moves and inputs by the operator. If the computer performs as many of the tedious functions as possible, the operator is more readily available for other demanding functions. The military environment also presents stressful situations when, for example, the command and control centre is under fire. Under stress ones attention narrows, one's concentration is on more central aspects, and habitual behaviour takes precedence over new or novel behaviour.[2] This indicates the necessity of a straight forward interface to avoid complication if panic or temporary memory lapse should occur.

The ergonomics of many military environments could stand improvement. It is not uncommon for operators to use displays in restricted vehicle space. This may subject the operator to very short eye-to-display distances. This can be very fatiguing for those situations requiring sitting and staring at the screen for long periods of time. Currently the military job environment designs are equipment oriented rather than user oriented, and there has been minimal consideration given to user requirements.[3] It should be kept in mind that the user is an integral part of the system and determines its effectiveness.

The user is in contact with the scenario through the display, which interfaces the system, and which is integrated with external sources of information, for example, radar. Using this information source the display situation is constantly changing as the surrounding theater changes. In order to keep the display current there is the need for real time rates of processing and display. The appropriate balance of user and system functions should be implemented. For example consider target tracking: man can integrate effectively over space to determine which targets in the area present the most threat; the system can most effectively track the suggested targets.[4]

The following guidelines do not always indicate explicitly why they are needed to improve the military environments but if all of them were implemented, where possible, the man/display interface in the military theaters would be as efficient as possible. This would minimize errors, confusion, and stress; all of which are damaging in the urgent situations that would be encountered. Not all the guidelines can be implemented for all situations but those that are most applicable and most important should be considered.

2. Ergonomics of the Display
(How to Present Display Information)

2.1 Highlighting Display Items

Whenever a user interacts with a display system there is the requirement to have the user notice certain key points of information. There are many techniques to attract the user's attention. In military environments it is often imperative to concentrate the user's attention in vital areas quickly and accurately, so the attraction technique should be considered carefully. The human eye scans a picture and key points are scanned frequently. The eye keeps coming back to the areas of interest.[5] Highlighting techniques can bias this natural scanning tendency to view the important areas of the picture or display. The following are the most frequently used methods of highlighting display items.

2.1.1 Underlining

Underlining the portion of the display that requires notice is effective for key words or phrases, but is not applicable to graphs, pictures or entire display areas that require highlighting.

2.1.2 Pointing

An arrow, or other appropriate shape, may direct the user's attention to an area of the screen. It can point to words, phrases, graphs or entire segments of the display so pointing is more versatile than underlining.

The disadvantage of the pointing technique is that space must be reserved for the arrow or other shape. This may add clutter to an already dense display.

2.1.3 Marking

A circle or box around an area of the display may be used to attract attention. This is an easy way to indicate the area of interest for any size group of information.

2.1.4 Size

The attention of the operator may be attracted by the size of an item on the display; as the size increases so does the degree of importance.

This attraction technique takes up precious display space since some space must be reserved to allow for size increases.

Too many choices of size to associate with an item may be confusing. For rapid and error-free reaction a maximum of three different sizes is recommended. If a small degree of error may be tolerated the recommended maximum can be increased to 5 sizes.[6]

Location time using size as the distinguishing feature is longer than using colours or shapes.

2.1.5 Flash

Turning an item off and on about two to three times per second (2-3 Hz) is the most effective way of attracting attention to a particular item but it should be used with discretion since flashing is very tiring for the eyes. The flash should have a duty cycle of 50%. Flash rates higher than 5 Hz should not be used as they tend to induce fatigue and nausea.

2.1.6 Intensity

Attracting the user attention by varying the degree of intensity or brightness may be effective. However the effect may be lost if the screen has poor contrast.

Four levels of intensity can be used, but for rapid and error-free identification this might be reduced to two.

2.1.7 Texture

Texture can be varied in many ways depending on where it is applied. The variation may involve changing the fill pattern, varying width of line, or using solid or broken line patterns.

Using texture to attract attention can be confusing to the operator. It is certainly more confusing to decide what pattern is what than what colour is what, so not too many varieties of pattern should be used. The recommended maximum number of textures is five for rapid and error-free reaction.

2.1.8 Colour

Colour is a very powerful indicator; it is very appealing and is valuable for highlighting. Colour helps reduce apparent clutter and this is important in dense military displays. Item location time is short using colour for attraction. Studies of eye fixations on areas of interest have shown the largest percentage of eye fixations were on objects of a correctly chosen colour.[7] Colour coding should be consistent with conventional associations with particular colours. Red is very effective for attracting attention, and since red is usually the first colour to be noticed it is used to indicate danger or critical situations. Similarly orange or yellow are most readily associated with cautionary events. Since blue items appear dimmer than others and are more difficult to focus, blue should not be used for critical data.[8]

The number of different colours to be used should be held to a minimum to avoid complication and reduce the amount of training required to learn the meanings of various colours and avoid errors of interpretation under conditions of stress. For rapid error-free reaction, using colour as the distinguishing factor, 6 is the recommended maximum. Highly trained operators can effectively use 11 colours. Colour should not be used for aesthetic purposes as these aesthetic colours might detract from those used for more critical purposes.

Care must be taken about adjacent colours. Colours should not be next to other colours that change their effect.[9] For example, cyan surrounded by green looks bluish; but surrounded by blue look greenish. If this cyan is a critical colour it may be costly if it is not readily recognized as cyan. To be safe adjacent colours should be substantially different in hue: if the field is yellow then orange or green are not recommended as the distinguishing colour; if the field is green then yellow or white are not recommended as the distinguishing colour; if the field is white then green or cyan are not recommended as the distinguishing colour; if the field is red then magenta (blue-red) is not recommended as the distinguishing colour.[10]

Care should be taken to regulate colour saturation since heavy saturation causes eye fatigue.

Colour is very effective for attracting attention in dense displays without requiring extra space.

2.1.9 Auditory Cues

Bells or buzzers may be used to attract the user attention. Although a bell does not pin point the source of error or area requiring attention, an auditory cue is unique from the other types of display cues and therefore easily recognized. After an auditory cue the user would look carefully for the source of the cue.

In a noisy environment, such as some existing in military environments, the auditory cues may be less effective and more confusing. Too many bells and buzzers can be annoying to the operator.

2.2 Presenting Alphanumeric Data

Alphanumerics are necessary for presenting information on the display. Sometimes the information is in the form of text; sometimes it is columns of numbers. Whatever the reason for the alphanumeric data there are some guidelines to consider that should enhance information integration.

The height-to-width ratio of displayed alphanumerics should be between 7:5 and 3:2. Stroke width should be in the range of 1:6 and 1:10 character height. Character separation should be between 25 percent and 63 percent of symbol height. [11]

When presenting text, sentences should contain just a single thought. No hyphenation should be used, so keep complete words on one line. Text output should not have more than 30 to 40 characters per line. If the display handles more than 80 characters per line then the text should be broken into columns. Columns of size 30 to 40 characters, like newspaper columns, are easier to assimilate with minimal eye movement. Text strings should be presented to the user using upper and lower case. Text of entirely upper case is harder to read than the standard use of both cases. Each separate topic should be on a new line.

The use of punctuation in abbreviations should be avoided. For example DREO should be used instead of D.R.E.O.. It is also important to adhere to recognized abbreviations. For example the abbreviation of mega should be M.

When presenting information the existing accepted formats should be adhered to. The military has standards for information presentation that should be used. For example the time is 1400h not 2 o'clock. Data display types should be kept consistent. For example, if the date is presented in the YYMMDD format in one place it should always be used in that format.

Characters representing words are advantageous as long as they are familiar. For example it is easier to use "<" than "less than".

Data should be broken into columns of meaningful data.

Short alphanumeric strings are easier to assimilate than long ones. If long strings are required they should be broken into shorter segments. For example a SIN number is easier to recognize as 123-456-789 than 123456789.[12]

In dense tables with many rows of data, a blank line (or some other delineating feature) should be inserted after every fifth row to aid horizontal scanning.

Items to be numbered on the display should begin with number 1, not 0.

Lists of decimal numbers should be aligned vertically by the decimal. For example:

```
167.09
  4.667
   .3214
 90.523
```

Vertical lists of integers should be right justified. For example:

```
  890
   45
36721
```

General alphanumeric lists should be aligned vertically with left justification. For example:

```
Size
Colour
Weight
```

2.3 The Use of Graphs and Icons

Carefully chosen and properly used graphs, icons and other forms of pictures can enhance the legibility of the display. Entire scenarios with associated information can be viewed quickly and easily when in picture format.

2.3.1 Graphs

Graphs can be more effective for presenting data than lists. Data trends are much more obvious when graphed. Interpretation is easier and faster, with less error.

A choice of circular or cartesian coordinates is available for graphs.

The axes of the graph should always be labelled.

Many factors may be considered when choosing an appropriate graph for the application. In some cases a line drawing is effective and in other cases a histogram. Within the graph, features can be emphasized using intensity, texture or colour.

2.3.2 Icons

Icons are pictorial symbols. The word icon comes from the Greek word eikon meaning image. Man has innate capabilities to abstract and process complicated visual information. Because of this ability to interpret a picture quickly, effectively and efficiently icons are useful in man/display interfaces. Pictures can be processed as complete units, not in some fixed sequence like a line of print.[13] This facilitates fast information integration.

Experiments have been done to test common recognition and comprehension of icons. Although a viewer can interpret pictures he has not seen before, once he has seen it the picture is easily remembered and reidentified correctly [14]. Other tests concluded that objects are recalled more frequently than pictures and pictures more frequently than words.[15]

With minimal military training relevant icons can easily be learned. The standard set of military NTDS symbols are an example of some simple icons. It is clear from this example that the use of these icons is more quickly, compactly and clearly presented than the equivalent phrase.

The NTDS symbols:[16]

Friendly Air

Friendly Surface

Friendly Subsurface

Enemy Air

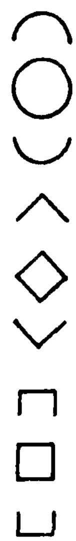
Enemy Surface

Enemy Subsurface

Unknown Air

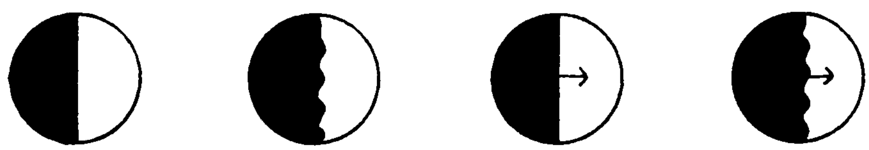
Unknown Surface

Unknown Subsurface



From the many papers written in favour of using icons it can be concluded that icons are effective for many reasons. Icons trigger responses more quickly and more accurately than a corresponding set of words. Instead of strings of sentences, one icon may suffice, so they reduce clutter. Where words clutter a display an icon remains simple, separate and clear. Icons are remembered more easily and longer than strings of words. Icons cross language barriers.

Developing the optimum set of icons must be done with care. If two or more icons are to be compared they should be highly discriminable. For example a circle and a square can be uniquely identified but a circle and an ellipse might be confused. Icons should be kept simple; with single component representations. The simpler the icon the better, because it is then easier to remember and identify, but the icon should not be so simple that it is ambiguous. A good example of steps taken to determine the proper icons (for the fill function) follows:[17]



The half filled circle is the initial attempt at indicating fill but it may be confused with other meanings. The second circle is clearer in that a wave of fill is indicated. However it is still ambiguous. The third circle clarifies the process and direction of fill. The fourth circle adds the improvement of the fill wave again. The wave helps indicate the motion of filling. The fourth circle is therefore the clearest to the user and it is still simple enough to remember clearly.

2.4 Minimizing Operator Confusion and Error

There are five psychological causes of error:[1]

i) **Boredom**:

Boredom is a consequence of improper pacing. There may be long periods when the system has no data to act on, so the operator must also wait. Or on a less serious level the operator may be awaiting system response. Boredom may also be a result of lack of motivation.

The solution to boredom is a complicated subject. While no new data arrives at the system operator boredom may be minimized if the operator is involved in other related functions. On the less critical level, boredom can be reduced if system response times are adequate.

ii) Panic:

Serious panic may be a result of a military attack, or panic may simply result from the operator not knowing the reason for a system delay.

The solution to the serious level of panic is psychological and improves with operator training. The solution to the simple level of panic is proper system feedback.

iii) Frustration:

Frustration is a consequence of the inability of the operator to convey his intentions to the system. This frustration may result in or be a result of typing mistakes.

The solution to this frustration is meaningful prompting by the system and comprehensive error messages.

iv) Discomfort:

Discomfort is a consequence of providing an inappropriate physical environment. This could include improper display brightness, or improper choice of input peripherals, or cramped working quarters.

The solution of this discomfort is to consider the physical ergonomics.

v) Confusion:

Confusion is briefly a result of the perceived display being overwhelming in detail, or the system providing inadequate instructions to the operator.

The solution is complex but involves reducing unnecessary detail and highlighting critical detail.

Human error in man/display systems could be minimized if the human was more alert, attentive or conscientious, or the human was better trained, or the system interface was better designed. There are two types of general errors: error by doing something that should not be done (error of commission); and error by not doing something that should be done (error of omission) [2]. Humans make errors that lead to others once they are flustered or confused. Humans under stress of emergency tend more often to err. However humans can detect their errors and correct them.

Errors as a result of frustration are addressed in the following section on system prompt and user reply.

Errors as a consequence of discomfort are addressed in the section on system ergonomics. Errors mainly as a result of confusion are addressed in this section. Guidelines for minimizing these errors resulting from operator confusion, and minimizing the confusion itself, are presented.

An obvious method to reduce error due to confusion is to have the system do as much as possible. This would reduce the input workload and ease a military heavy workload problem.

Confusion is reduced if the operator has only one display to view at all times. The use of only one display reduces the question of where to look for information when it is required. With only one display it becomes very important to optimize the content of that display.

Size of display is also an important question. If the display is small it must still be legible. The display must be readable by all personnel that must view it. If the display is large, care should be taken to not display too much information at one time, since the operator can only assimilate a certain amount of information without confusion.

Whether the amount of information on the display is considerable or not it must be structured carefully to minimize confusion and error.

Specific areas of the screen should be reserved for specific types of information so the operator always knows the area of the display to refer to for the information he needs.

The operator should be limited to accessing only areas of interest to him. This limitation strips extraneous and potentially misleading information from the operating environment.

It must be obvious to the operator how the display is structured.

Specific areas of the display should be separated by spaces or lines for easy delineation.

Keep the number of specific areas or windows to a minimum so the operator will not be overwhelmed. With training, operators are comfortable with more windows.

Some applications may be conducive to dividing the displayed information into many windows. The operator may even be able to choose which of the windows he wishes to have displayed at a given time. This flexibility is useful for the trained and knowledgeable operator, however the less experienced operator may neglect to display certain necessary windows. A solution to this problem is system control of displaying the mandatory windows.

If possible the system should allow the user to request less information on the display format if he finds the display confusing, or to request more (in any specified area) if he can handle more or needs more related to any area. The trained military operator will know what he is looking for and how much associated information he requires and is comfortable with.

When a display output contains too much data for presentation in a single screen, the data should be partitioned into separately displayable screen "pages" with obvious relation to other pages. The screen pages must keep the layout of like items consistent in substance and location from one page to the next. There should be a convenient way of changing pages and the operator should always be kept informed of which page he is on, using informative titles and sometimes numbering.

If data is relevant on more than one page it should be displayed on all the relevant pages. The operator should not be required to remember data from non-visible screens.

A single screen page may have overlays. These can be useful in tactical situation displays. If the operator finds the situation confusing he can remove one or more overlays; and if he needs more information he can request the pertinent overlay. The use of overlays results in flexible displays.

Ideally all information necessary at a given time, and only relevant information for that time, should be on the display.

Another useful technique is the use of zoom to view detailed areas of the display. An overall tactical situation can be viewed when necessary; and specific areas can be viewed in detail when necessary.

Man/display interaction should be designed so that the operator stays in one mode of input as long as possible. This minimizes frequent changes.

The user should be able to freeze the display (stop inputs and changes) if careful examination is required. The user should be warned if some critical information is frozen out. There should be an indicator when the display is in frozen mode. When frozen mode is no longer required the system should resume at the current real time point unless otherwise specified by the user.

The user should have access to a dictionary of abbreviations, acronyms and icons.

Information must be presented to the operator in a directly usable form, with no need for transposing, interpolating, or converting into other units. Information presented to the user should not be reams of raw data: rather the data should be presented in processed form providing important information is not lost.

If the operator is presented a list of items to choose from then the list should be in decreasing order of probability of choice or reference.

Directions to the operator must precede the list of choices. Seven is the recommended maximum of choices for ease of recognition and ability to remember.

Labels may be used to help draw user attention to pertinent areas of the display. The labels may be numbered for easy reference.

The screen should be cleaned up periodically; data no longer required should be removed.

If the operator gets confused or lost, it should be easy for him to ask for help or clarification from the system.

3. System Prompt and User Reply

3.1 System Prompt

An important part in making a man/display interface optimal is the informative prompts to the operator by the system. In order for the operating environment to be optimal it should be clear to the operator at all times what he should do next; he must be clear as to his choices of action to input. A delay to stop and ponder is costly. The system should echo to the operator what function he is requesting so he can confirm it is the one he wants performed. This verification is useful and necessary in the precise military environment. The operator must also always be made aware of how much time he has to make his decision and act on it. There must always be adequate feedback to inform the operator when he is in error; and clearly inform him of the steps to be taken to clear the error. There must also be adequate feedback from the system so the operator is confident that the system is accepting his input and is acting upon this input; or if no input is required the operator should be so informed.

Prompt messages should be kept factual and informative. The prompts should not attempt humour since that would waste time.[1]

System explanations should be brief and to the point.

Only information that is relevant and essential to the decision should be supplied to the user to avoid complication.

System instructions to the operator should stand out.

Prompts should be on a standard area of the screen so the user is aware of them when they appear.

The military user with several screen choices must always be aware of which type of screen he is on and what are his interactive options. It has already been discussed that interaction should be consistent from one screen to the next but where they differ there should be sufficient clarification.

The prompts should make it clear to the user what is necessary input: all parameters required should be requested. This is especially important under military stress situations where haste may result in the user forgeting to enter a required parameter and causing succeeding information to be inaccurate.

In order for a prompt for user input to be very clear, delimiters and field labels should be used where possible. A 'form-filling' approach involving delimiters and field labels assists the user in knowing what and where to input.

An example of the use of delimiters is as follows:

___/___/___

where / is the delimiter.

An example of the use of field labels is as follows:

DATE: _________

or

DAY: __ MONTH: __ YEAR: __

Field label punctuation (for example the colon) should indicate where data should be input.

Field labels should be formated (for example using capitals) to distinguish them from input.

Data fields and associated labels should be separated by at least one space.

If the display is crowded field prompt labels should be highlighted in some way to facilitate locating them.

Field delineation cues should be supplied where possible. In the above examples the underscores indicate the delineation. This delineation indicates to the user the length of input required. If the input is of variable length the field delineation cues must be indicated in another way. For example fixed length input may be indicated by the correct number of underscores: _____ and variable length input may be indicated by three dots: ...

The system should supply the units of measure where applicable. For example the operator should not have to input "mph" or "$".

When prompting using keywords or technical words they should be familiar to the user, not just the programmer.

When values are to be input by the operator the default values should be displayed where applicable.

The user should be able to request prompts if he needs them.

As the user becomes proficient he may not require as much information from the system prompts. A welcome feature is the capability to bypass some of the explanation levels of the prompts that was required by the less experienced user.

Menus are often effective for prompting techniques. The operator would choose from a list of possibilities what course of action he may take. The menu may be presented as a list of sentences or words, or may be a series of boxes of phrases or icons. The menu can be on the display, keyboard, and/or the digital tablet.

It is important that prompt menu sequences be flexible enough to allow each person to proceed at a pace with which he is comfortable. They should be designed with branching so the familiar user can follow abbreviated paths.[4] Menus can aggravate experienced users if they cannot bypass the verbiage. Menus do not require operators to remember code.[8] Menus with icons are an effective combination.[17]

Each menu display should require just one selection by the user.

Menu choices should be indicated with a standard preset indicator. For example the +:

+ page-1

+ page-2

Menus are usually ordered in an hierarchical manner with easy movement up and down through the hierarchy.

Menu options should be ordered by frequency of use and should include only and all those applicable at the time.

There should be sufficient comprehensive prompting to minimize the operator's requirement to refer to manuals. Manuals can be cryptic, and information retrieval is slow.

System error messages should be informative, specific, concise, and non-blaming.

Error messages should be layered in such a way that if the operator needs further information about the error message he should have access to it.

An indication of user input syntax error should be given as soon after the input error as possible.

A welcome convenience for the user under stressful situations, who might incorrectly input portions of a response, would be to change only the portions of the input string that do not pass the syntax check.

The cursor is an important part of prompts and inputs. The cursor points to the place of input succeeding a prompt. The cursor should be obvious and distinctive from other characters on the screen; should not obscure other characters; and should have fine resolution and accurate positioning.

If the user places the cursor it should normally stay where it was placed until moved again by the user.

A standard home position for the cursor may be useful for cases when the user cannot find the cursor and requests it return home so he can locate it.

Areas of the display not used by the operator should not be accessible by him with the cursor. This saves wasted cursor movement. Required movement of the cursor should be minimized.

The cursor should skip over field labels.

When the system is expecting a reply from the user the cursor should be positioned by the system where the input is expected. The user should not have to waste his time relocating the cursor.

3.2 User Reply

The ways the system expects user replies is an important area to consider. The optimum man/display interface involves the right combinations of speed and accuracy of user input. The system should expect user replies in as easy, straightforward and fast a manner as possible.

Data entry should be paced by the user, not the computer system. This is less stressful and error prone.

The user should not have to enter the same data twice. This wastes time and allows more chance for error. The computer system should be able to access associated information and therefore use previously entered data. Redundant data input may be required in military environments only for security checks.

The user should have some means of identifying default entries and these should remain until the user changes them. The context in which the user is working should remain the same until he changes it.

If data is to be changed the system should display old and new values to prevent inadvertent changes. The user should be warned of potential data loss and asked to confirm his intentions.

Functions requested by the user should be indicated so the user can check the correctness of his request.

The shorter the input string required from the user the better. He may not have time to type in long strings.

If possible, keep individual input word requirements to less than 7 characters since the longer the word the more chance of error during input.

Replies using abbreviations help minimize typing errors but the abbreviations should be done consistently. Truncation is a common, straightforward method of abbreviation. Usually truncation is to 3 characters.

Abbreviations should be of a fixed length.

If the user wishes to type the whole word the system should recognize it as well as the abbreviation.

If blanks are required for input there should be no distinction between single and multiple blanks so the user does not have to count blanks.

Systems should not be designed to require input of leading zeros unless conventional military practice demands.

If the user must delimit, spaces are preferred to special characters. However if a special character is insisted upon, it should be consistent.

Input data should be all one case if possible; to avoid repeating shift keying.

The user should be able to interrupt, defer, or abort the current transaction sequence. In military settings it is not uncommon for an event of higher priority to replace the current function.

The operator should have access to a record of his prior entries.

The user should be required to acknowledge any system alarms.

The user input should always be reflected somewhere on the display.

The user should not have to switch between modes of entry too frequently. For example switching from keyboard to joystick to digital tablet to keyboard is not advisable.

The area in which an item is selectable (for example, with a light pen) should be as large as possible. If the area is too small (the resolution is too fine) then there is more chance for an incorrect selection. If the equipment environment involves random movement, selections may be difficult to pin point.

The position for user input should be evident. This includes the cross hairs for screen area selection and the blinking cursor for alphanumeric input.

Further user input should be flexible in cases where an input error has been made. The user should be able to cancel a transaction, backup a number of steps, restart, or end, depending on his application. Minor edits should be accomplished by backspacing and rekeying the input before entering it.

User input can be facilitated by use of function keys. These special function keys are usually part of the keyboard. The special function keys allow the user to initiate functions with the press of a single key. This minimizes typing which can cause errors and time wasted.

The keys pertinent to the current activity should be illuminated. Only these pertinent keys should be illuminated.

Too many special function keys can be confusing so only the most important and most frequently used functions should have special keys.

Function keys should be clearly labeled.

If a function key is to be used for more than one function there should be an indication of what is the current function.

If a function is done by a certain key that type of function should consistently be done by that key.

Unneeded function keys should be (temporarily) disabled.

Function keys should be grouped together in common and distinctive locations.

Function key layout should be consistent with frequency of use.

The ENTER key is clearer to the operator than the implied CR or RETURN.

4. Response Times

Response times fall into two categories: those of the users, and those of the system. If the display ergonomics are right, the prompting is clear, and the operator is trained and experienced, as he would be in a military scenario, then the user response time should be as inconsequential as possible.

However, the time required for the system to process user input must still be considered. If the interaction is to be optimum the user should not be kept waiting for system replies for many seconds. System response delays can cause the user to lose concentration or grow impatient. As well, the user's short term memory capabilities should be considered.[6] The short term memory retains information for only a brief time. For longer retention there must be deliberate reinforcement. The short term memory is in danger of having its contents overwritten as new thoughts intervene. For this reason the operator must not be given idle time to let his mind wander to less crucial matters. The average short term memory will hold about 7 unrelated items. If the system response requires a number of consecutive input phrases the most familiar ones should be required last since they can be remembered longer by the operator.

The ideal system response time is obviously less than 1 second for interactive inquiry processing. However depending on how complex the request, there are system processing speed limitations. The user is willing to wait varying lengths of time for system response depending on the type of his request. A response as simple as echoing a typed character should be done within 0.2 seconds. For more complex requests users are comfortable waiting 2 seconds. However, if the system reply takes more than 10 seconds the system has likely allowed the user to break his continuity of thought.

If the system is loaded and cannot respond in the expected time, some indication of load should be given so the user knows what length of delay to expect.

Frequently for military applications fast processing power would be purchased since operator inputs must be processed quickly to assist in critical situations. It is doubly important that the operator not be kept waiting for system replies in critical situations or he may have cause to panic.

5. Hardware Control Devices for User Interaction With Displays

There are many different methods of interacting with the display system. This section presents many of the hardware control options that can be used by the operator to implement the interaction. The following options with their advantages and disadvantages should be considered and the optimum devices for suitable interaction chosen. These peripherals should be limited to as few as possible to, once again, decrease the chance of operator confusion and to decrease the number of switches from one device to another.

The optimal devices allow:

- accurate positioning.
- fast movement (1/2 second from one point of reference to another).
- easy reach by the user.
- stability of the cursor once placed.

Military environments often involve random movement which must be considered in peripheral selection. The peripheral must not move easily, the hand must be able to position the cursor accurately, and once positioned, the cursor must remain fixed so inaccurate, or unexpected input will not result.

5.1 Keyboard

The keyboard has alphanumeric keys and often special function keys.

Advantages:

The keyboard can be used for text editing as well as display picking (selection of displayed entity).

The keyboard is fast for simple picking.

The special function keys are a fast, accurate method of user input.

The palms can rest while using the keyboard so there is minimal arm fatigue.

Disadvantages:

The keyboard is only good for rough cursor positioning.

The resolution is not as good as the display; all points on the display cannot be addressed directly from the keyboard. A special locator program can be written to allow addressing of any point but this process is slower and less obvious.

Keyboard typing errors are common.

5.2 Light Pen

The light pen is a wand with a light detecting tip used to determine the specific point on a display it touches. It is attached to the display by a cord. It frequently has a push button at one end which is pressed to indicate that a response is required.

Advantages:

The light pen is fast for simple picking and so it is efficient for tracking moving items or making multiple inputs.

Minimal time is required to point to a target so it is suitable for military environments demanding speed of selection.

The light pen has a low error rate.

No time is wasted scanning the screen to locate the cursor.

No screen space is required for position reference.

The light pen is effective for drawing applications.

Disadvantages:

The light pen lacks precision due to its aperture, distance from the screen surface, and viewing angle.

The resolution is not fine since a large activate area around the pick choices is required.

Interaction with the system may be assumed but may not have occurred.

If a button press is required to indicate position selection then slippage may occur and inaccuracy result. If no button press is required then accidental input may result.

Mode mixing, for example using keyboard and light pen alternately, can significantly disrupt performance since the light pen must always be picked up and replaced.

The cord attached to the display may get in the way. This cord placement makes the light pen awkward for left handed users.

Since one must raise an arm to touch the pen to the display, arm fatigue results.

The hand holding the pen obstructs a portion of the screen when in use.

5.3 Position Indicating Device, or Touch Panel

Screen attachments are available which allow the user to use a finger to touch the screen to indicate a position. The system determines the position using intersecting light beams, or a touch sensitive device overlaying the screen.

Advantages:

The touch panel feels natural.

There is no need to lift or position a device.

Simple picking is fast and easy, so it is efficient for tracking moving items or making multiple inputs.

No time is wasted scanning the screen to locate the cursor.

No space is required for position reference.

Minimal times is required to point to the target and this is advantageous in military environments demanding speed of selection.

The touch panel is convenient for left handed users.

There is no cord to get in the way.

Disadvantages:

The touch panel has very coarse resolution; it lacks precision, so there must be large activate areas around pick choices.

The arm raised to display level is fatiguing.

The hand obstructs a portion of the screen.

5.4 Digital Tablet

The digital tablet is also called a digital pad, a digitizer, and a graphical input tablet.

It is a flat surface on which a stylus or crosshair button cursor indicates relevant positioning. The digital tablet should be at least screen size so there is at least a 1:1 mapping from tablet to screen.

Advantages:

The digital tablet can have a "special key" area, or an explicit overlay, for fast interaction.

It can be used for drawing applications.

The digital tablet is versatile in that it is effective for many applications.

There is no associated arm fatigue since it is on a horizontal surface.

It allows convenient 1:1 mapping with the display.

The tablet has good resolution; it is capable of fairly high pointing accuracy.

Use of the tablet leaves the screen unobscured.

Disadvantages:

The digital tablet requires a significant amount of physical space in the work area.

Switching from looking at the tablet to looking at the relevant area on the display may be confusing and time consuming. This disadvantage is similar to that of having two displays.

Items cannot be erased from the tablet like they can from the screen, so a tablet with many function areas and screen reference areas can be cluttered and confusing. The tablet layout remains fixed even when portions of the layout are no longer required.

5.5 Mouse

The mouse is a palm sized device with two potentiometers at right angles used to indicate x and y directions. Displacement from start position indicates cursor position. The mouse is rolled by hand across any hard, flat surface. Buttons on top of the mouse can be used to note input.

Advantages:

The mouse is accurate, with high resolution.

Use of the mouse causes minimal arm fatigue.

Use of the mouse leaves the screen unobscured.

The mouse allows easy movement in any x,y direction.

The mouse allows easy rotation of the cursor.

If desired, the change in cursor coordinates can vary exponentially according to the speed of movement of the mouse.

Since the movement of the mouse does not depend on a position on a tablet of any kind, the user is free to watch the cursor on the display at all times.

Disadvantages:

An operator may lose his sense of screen orientation since the mouse has no virtual address space.

The screen must be scanned to locate the cursor.

The mouse rolls easily so the cursor may not stay stable.

The mouse must be used on a sufficiently large, flat, uncluttered area which may not be practical in some military environments.

A few seconds must be taken to position the cursor.

5.6 Trackball

The trackball involves a ball mounted on x,y direction potentiometers. The ball is partially exposed but rests in a fixed base. The movement of the ball translates to the position of the cursor.

Advantages:

The trackball is accurate with high resolution.

The trackball is effective for cursor movement in any x,y direction and it can be used for 3 dimensional cursor positioning.

The trackball has momentum which can be used in positioning the cursor.

If desired, the change in cursor coordinates can vary exponentially according to the speed of trackball movement.

Use of the trackball results in minimal arm fatigue.

Use of the trackball leaves the screen unobscured.

The trackball is stable which is important in military environments involving random movement.

The trackball takes up little space.

Disadvantages:

The screen must be scanned to locate the cursor.

A few seconds must be taken to position the cursor.

5.7 Joystick

The joystick is a vertical stick that is a compact two dimensional hand control.

Advantages:

The joystick is accurate, with high resolution.

Use of the joystick results in minimal arm fatigue.

Use of the joystick leaves the screen unobscured.

The joystick allows easy cursor movement in any x,y direction.

If desired, the change in cursor coordinates can vary exponentially the further from centre the user moves the stick.

The joystick is stable.

It takes up minimal space.

The joystick returns to a firm centre of stick position.

Disadvantages:

Scanning of the screen is required for cursor location unless the cursor returns to centre.

A few seconds must be taken to position the cursor.

5.8 Thumbwheels

The thumbwheels consist of two wheels, frequently mounted in the keyboard. One wheel designates the x direction of the cursor and the other wheel designates the y direction.

Advantages:

The thumbwheels have high resolution and allow accurate positioning of the cursor.

Use of the thumbwheels results in minimal arm fatigue.

Use of the thumbwheels leaves the screen unobscured.

The thumbwheels are stable.

They take up minimal space.

Disadvantages:

The thumbwheels only allow movement in one of x or y direction at a time so a slower seek time results. The thumbwheels are not convenient for tracking moving objects or drawing applications.

Scanning of the screen for the cursor is required.

A few seconds must be taken to position the cursor.

5.9 Automated Speech Recognition

Automated speech recognition involves a hardware and software system interactive set up that recognizes voice commands from the user. This device is likely to be used for applications quite different from those associated with the above devices.

Advantages:

Input for automated speech recognition is natural and requires little effort by the operator.

The operator can interact with the system and sit in comfort.

The operator's hands are free and so are available for other input functions.

Automated speech recognition is fast for simple picking.

The screen is not obscured.

Disadvantages:

Automated speech recognition is still in the development stages, so there is significant chance for system error.

Currently most speech recognition systems only recognize one operator's voice patterns. This is restrictive and may cause serious problems if the operator is not available.

There is no capability for fine resolution or fine cursor positioning since the input is reliant on keywords.

Use of automated speech recognition is limited to relatively simple input tasks.

If there is a noisy background (common in military environments) this random noise may interfere with voice input, causing errors.

Only one operator can be talking in the area at the time. This precludes rows of operators each operating separate equipment.

6. System Ergonomics

Many aspects must be considered to make the working environment involving the equipment as comfortable and non-fatiguing for the operator as possible.[18] Eye-strain, back-strain, and tired arms are among the problems to minimize. There are two main categories for ergonomic consideration in a display environment: the display itself; and the system equipment with associated peripherals.

6.1 The Display:

i) The minimum resolution of raster displays should be at least 70 pixels per inch. [19] The display should maintain the illusion of a continuous image; the viewer should not have to resolve scan lines or matrix spots.

ii) Flicker is the rapid blinking that occurs if the screen is not refreshed often enough. For raster displays 60 Hz refresh rate results in a steady picture. Some display systems will refresh at 30 Hz interlaced. This is effective except for horizontal lines one pixel high which are in effect refreshed at only 30 Hz and therefore the human eye can perceive the flicker. Flicker is extremely hard on the eyes and since military environments frequently involve looking at displays for long periods of time it is mandatory to minimize flicker.

Some displays use longer persistence phosphors to reduce the flicker effect but the result of this is trailing images (or shadows) appearing on the screen as the picture changes. If a picture involves a number of changes, the shadowing can be very distracting. The longer persistence phosphors can be effective on slow moving displays such as radar screens.

Vector refresh display systems are refreshed as quickly as the display list can be processed. This is often 60 Hz. The display list should not be so long as to reduce this refresh rate.

iii) There should be sufficient contrast. German ergonomic guidelines call for contrast between 3:1 and 15:1. At low contrast levels symbols begin to blur, causing action of the lens as it attempts to focus the image on the retina. This leads to eyestrain, headache, and fatigue. Displays should allow for adjustment capability by the operator for varying ambient light and personal preferences.

iv) Glare from the screen should be minimized since it is distracting and fatiguing. The display should be positioned away from windows and shielded from overhead lights. Many manufacturers now supply non-glare screens or partial hoods.

v) If the display is monochrome studies have suggested using green or amber phosphors as they are the least strenuous for the eyes. Green gives the best results in strong light; amber gives the best results in low light.

vi) The display pictures should not change too quickly before the user can easily assimilate the information, since this could result in frustration and the missing of vital information.

vii) The degree of horizontal and vertical field of view should be considered when placing the display with respect to the users. Greatest detail will be seen in the small area directly in front of the eyes. The preferred visual area of the display is approximately 15 degrees below horizontal, the normal line of sight of the operator.

viii) The operator should be a good viewing distance from the display: approximately 20 inches is considered fatigue free to operators 25 to 40 years of age.[20] Military environments might not allow this viewing distance. Aircraft are designed for 28 to 30 inches eye-to-console distance. Underwater applications involve cramped quarters so the eye-to-console distance is currently sometimes as little as 10 inches.

ix) If possible the system should only include one display since the display is the main focus for information retrieval and it is exhausting to be continually refocusing attention on an alternate display to scan for additional information. The alternate display may also be somewhat ignored, resulting in information being overlooked.

6.2 System and Peripherals

i) It is important to have seating with sufficient support, particularly for the lumbar and thoracic regions of the back. It is best that system and peripherals are positioned in such a way that they can be viewed or manipulated while the operator remains seated. The operator would get needlessly tired and interrupted if he had to constantly stand up and sit down.

ii) The posture of the operator should be considered: screen and peripheral placement should allow for posture shifts after long periods of sitting.

iii) All controls needed for system interactions should be within an arc described by a bent arm. This allows for minimal chair movement.

iv) All peripherals that require viewing concentration such as the screen, keyboard and digital tablet, should be equidistant from the eyes of the operator to minimize constant refocusing requirements.

v) There should be as few peripherals as possible that require arm raising for long periods.

vi) The output of fans for cooling equipment should be directed away from the operator.

vii) Ambient noise levels should not exceed 65 dB in order to avoid operator distraction, stress, and headache.

viii) If the keys on the keyboard are any higher than 1 1/4 inches from the surface on which the keyboard rests, then palm rests should be provided.

ix) A keyboard tilt of 7 to 15 degrees is considered optimum.

x) The keyboard should group keys according to usage. The letters should be grouped together; the numbers should be grouped together; and the special function keys should be together. There is a standard, accepted grouping for lettered and numbered keys. The special function keys may be placed according to importance, with those most frequently used being the most accessible.

7. Future Plans

This report has discussed the man/display guidelines to consider for military environments. Many of the guidelines and their methods of application are still in need of experimental verification. Plans are being made to apply combinations of these guidelines to specific scenarios generated by a programmable signal simulator and to study the effects on test personnel.

Specific scenarios with missiles, aircraft, ships and/or land vehicles operating in standard ways will be output from the simulator. Tactical display studies may be conducted:

- to examine the various modes of highlighting displays.

- to determine effectiveness of colour and the optimum number of colours to use.

- to determine display cutoff density, where operators become saturated.

- to investigate the use of multiple windows.

- to determine effectiveness of overlays.

- to determine effects of using multiple screens.

- to determine applicability of icons; and an optimum choice of icons.

8. Conclusion

The report has stated guidelines for developing a man/display interaction environment for military applications. Most of the report can apply to civilian applications as well but those most important for the military have been stressed. Many of the suggestions are intuitively obvious but it is best to have them conveniently compiled to use as a double check that standard ergonomics have not been overlooked. Not all suggestions can be applied equally to all situations so the systems engineer will still have to decide which of the guidelines should be given priority. Comparative cost of the proposed ergonomics were not mentioned and it is once again up to the system engineer to decide if a feature or technique is cost effective.

Ongoing research at DREO in tactical display technology will, in time, provide more quantitative information on the advantages and disadvantages of various techniques enumerated in this report.

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13. ABSTRACT

The report presents guidelines for developing a man/display interface. Military environment requirements are addressed. The guidelines include: methods of highlighting the displays; techniques for minimizing operator confusion and error; methods for system prompt and user reply; choice of hardware control devices; and consideration of display and system peripheral ergonomics.

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