Chapter 4
DOCUMENTATION DESIGN AID DEVELOPMENT

C. G. Drury, A. Sarac and D. M. Driscoll
Department of Industrial Engineering
State University of New York at Buffalo
and
USAir Inc.
Pittsburgh International Airport

4.1 INTRODUCTION

Studies of human error in reading and interpreting documents such as workcards have shown that substantial improvements are possible by incorporating human factors guidelines into document design. Error reduction through information design was addressed in this study by developing a design aid for documentation producers. With an airline partner, a focus group generated issues in the existing process for generating, testing and issuing of Engineering Orders (EOs). Parallel aspects of the project considered the physical design of the document and the organizational aspects of the procedures. A Documentation Design Aid (DDA) was developed using the technical literature on human performance in information transfer tasks. The DDA is available as a paper procedure document and as a Visual Basic (tm) computer program. User tests of the DDA gave positive results. The partner airline is acting to incorporate parts of the DDA into its electronic documentation systems and to revise its procedures for designing, prototyping, and using Engineering Orders (EOs).

4.2 BACKGROUND: DESIGN OF JOB INSTRUCTIONS

For a number of years the airline industry has been seeking ways to reduce errors, particularly human errors, in its operations and maintenance activities. During this time the Federal Aviation Administration/Office of Aviation Medicine (FAA/AAM) has been funding research and development to address human error. The 1995 Safety Summit declared human error to be a major concern, and reemphasized the importance of aircraft maintenance errors on the list of priorities. One error-prone area chosen for study early in the FAA/AAM program was the information environment of the people performing inspection and maintenance activities.[1] In particular, on-site data collection found that much of the paperwork used to control the hangar floor activities did not follow good human factors practice.[2]

Studies aimed specifically at paperwork improvement were undertaken with one airline partner. The first study[3] took existing work control cards (workcards) and determined their specific problems from task observation, interviews with AMTs and inspectors, and survey data. These findings provided the structure needed to develop guidelines for workcard design, compiled from the human factors research literature. Based on those guidelines, new workcards were designed and tested on inspectors performing C-check wing inspections of a DC-9-30. The new workcards were a significant improvement in terms of readability and usability.

Following this demonstration of the improvements possible in workcards from following human factors guidelines, the next logical step of producing computer-based workcards was taken.[4] These workcards incorporated all of the guidelines used for improved paper-based workcards, while adding specific recommendations on human interface guidelines for computers. Again, the new workcards were compared with existing workcards, this time using a nose landing gear inspection task on DC-9-30. In this study, however, there were three versions to compare: the existing workcard, the improved paper-based workcard, and the new computer-based workcard. The results showed that the computer-based system was a significant improvement over the existing paper-based workcards. However, an important finding was that about 80% of the total improvement was seen with the improved paper-based workcard. Clearly, getting the information correctly designed, sequenced, and presented is of utmost importance in improving paperwork.

These improvements can result in lower rates of paperwork errors. Drury[2] was able to collect airline data which showed a high error rate (2.5%) on workcard items which did not meet the Patel, Drury and Lofgren[3] guidelines, compared with a zero error rate for items which met the guidelines. If each item on a workcard of 28 items has an error rate of 2.5%, then 50% of the workcards would have at least one error, clearly an unacceptable outcome in airline operations or maintenance. Workcards are used by people regularly under nonoptimal environmental conditions, often with time stress, so that any physical means of reducing errors, such as better workcard design, is particularly cost-effective.

Other recent work on the information system/Aviation Maintenance Technician (AMT) interface has included:

- studies of paperwork errors in the engine overhaul facility of one airline partner[5]
- evaluation of Simplified English in workcards at a number of airlines[6]
- design of shift change logs at another airline partner[7]
- redesign of a logbook by the AMTs at another airline

4.3 PROJECT OBJECTIVES

Now that we have demonstrated the use of human factors guidelines to redesign work documentation for higher usability and less errors, these techniques need to be made available to the industry in a form which encourages their regular use. The current project was undertaken to compile a comprehensive and valid set of documentation guidelines, and design convenient interfaces to these guidelines for potential users. Also included in the project was a test of the usability and effectiveness of the guidelines.

An airline partner agreed to provide resources for carrying out this study. In return, they are able to use the study as part of a larger investigation and change process focused on one particular type of documentation -- Engineering Order (EO). Because the airline partner, like many in the mid-1990s, had an ongoing human factors program, this project could make use of their current human factors methodology, for example in the use of multifunctional teams to investigate, recommend and implement changes.

Thus, the project as undertaken had two complementary objectives:

1. To provide the FAA and the airlines with a developed and tested job aid to improve documentation design.

2. To provide the airline partner with model application of human factors to the process of design, production and use of documentation.

The project was structured so that the two objectives could be pursued in parallel, with successive refinements in the job aids being accompanied by progress through the change process at the partner airline.

4.4 METHODOLOGY

Because of the parallel objectives for the FAA and the airline partner, there were two closely interleaved aspects of the methodology, one primarily technical and one primarily behavioral.

The technological methodology consisted of accessing the research literature on document design, reviewing it critically, and incorporating these findings into the successive versions of the Documentation Design Aid (DDA). Because most of the research findings would be applicable to all documentation, the refinements to DDA were aimed at emphasizing the specific requirements of aircraft maintenance documentation.

For example, Tinker[8] showed that using black ink on white paper improved reading speed by 10.5% and reading comprehension by 8.6%. However, almost all aircraft maintenance documentation is already in "black ink on white page" format so that this issue rarely arises in practice. In contrast, the finding that use of upper case font (all capitals) reduces reading speed by 14%[8] is of great relevance as capitals are often used where emphasis is desired in work instructions.[3] In terms of DDA design, the finding on ink color should receive less emphasis than the finding on use of upper case font.

This project is not the first to bring together human factors research findings and good practice into codified guidelines. Simpson and Casey's[9] *Developing Effective User Documentation* come from the nuclear power industry, while Wright's[10] *Information Design* was based on requirements for design of forms and documents for use by the general public. There has even been software written, e.g., the Communication Research Institute of Australia's[11] *Forms Designer*, to help users design effective forms. A monthly newsletter (*Procedures Review*) is devoted entirely to design of work control documentation. As a final example, the guidelines of Patel, et al.,[3] and Patel, Prabhu and Drury (1992)[13] on paper and computer information design, respectively, were most closely adapted to the aircraft maintenance environment. Section 4.9.1 provides a bibliography of the major sources used to develop the DDA, and is a useful secondary source for further document design information.

The second aspect of the methodology was behavioral. This was comprised of all the work with the partner airline to tailor the documentation design aid to practical airline needs. Thus, while the compilation of the literature was ongoing, maintenance management of the partner airline met with SUNY Buffalo and internal human factors representatives to provide support and direction for the project. They approved the use of a team (or focus group) to investigate documentation issues within the airline, and to recommend specific actions to reduce human error and its impact in the documentation process. This management group suggested the idea of the DDA as a "workcard for workcard," i.e., a design aid arranged in steps with sign-offs after each step, whose use would ensure that each document was well designed. Such a product reemphasized the need to develop both paper-based and computer-based versions of any job aid produced in this project.

A team was formed with the SUNY Buffalo and airline human factors personnel and included representatives of each of the following stakeholder groups:

1. Producers of Documentation
    - Engineers and technical writers who control the technical content of work instructions and who control the process of transforming the content into a work instruction document.
2. Users of Documentation
    - Mechanics (AMTs), inspectors and first line supervisors who must use the documentation to perform the work to ensure compliance with all necessary standards.
    - Maintenance records operators who must check the completed documentation for completeness and accuracy.
3. Managers
    - Those responsible for the processes of ensuring that correct documentation is available, that the work is performed correctly, and that correct records are maintained.

This focus group acted as the main forum for interchange of ideas throughout the project. At the management meeting a suggestion was made to focus on the process for developing and using Engineering Orders (EOs) and Campaign Directions (CDs) to provide a sensible scope of work. This suggestion was taken up by the focus group, and in fact Engineering Orders became the true focus of the project. EOs are special work control cards used where a new aircraft modification is required on some or all of the aircraft in a particular fleet. Often they arise from regulatory directions based on recently discovered problems, or from manufacturer-initiated upgrades to aircraft. In format, EOs have great similarities to CDs and workcards. CDs are used to control new and often unique inspection and maintenance processes. The more repetitive tasks are covered by workcards. Because of this, EOs represent the initial designs produced by engineering and technical writers, often under severe regulatory time pressure. The tasks they detail may also be subject to the same time pressures. Time pressure is a well documented stressor in human factors, leading to altered task strategies and increased error rates as well as to operator stress.14 Thus improvement of EOs should give immediate payback under conditions where errors are *a priori* more likely to occur. Also, any design aid must be designed to be usable by engineers and technical writers under these same time pressures, ensuring a stringent test of its usability.

The focus group helped identify issues beyond the physical design of documents (such as EOs) which could be affecting usability and error rates. These included the design process, how EOs are field tested, control of the revision process, and specific confusions about the sign-off process. In any project on EOs such issues need to be tackled in parallel with development of the DDA to ensure that changes are made and implemented throughout the system.

The outcome of the initial meetings with management and the focus group was a better defined project: produce paper-based and computer-based design aids which help ensure that human factors guidelines are followed to reduce errors in the design, development, and use of Engineering Orders. We have used the term "Human Factors Good Practice" to connote recommended good procedures, whether they arose from standards, guidelines, or the research literature.

4.5 RESULTS

4.5.1 DDA Development: Content and Structure

During the compilation of literature on document design, a number of points emerged. First, while there was often agreement among the sources about recommendations, in some instances there were differences. Where we found differences, we chose the recommendation which was most closely related to aviation maintenance. For example, Tinker[8] showed that 60.5% of higher level readers preferred a double column layout text format. In contrast to this, Hartley[9] showed that using double column layout or single column layout does not make a large difference for higher level readers in terms of reading comprehension and reading speed while it makes a difference for lower level readers. However, as almost all aircraft maintenance documentation is already in a single column layout, we defined the guideline to favor single column layout. Second, in a few particular cases the research findings contradicted the practices codified for aviation maintenance in the ATA-100 document.[3] In ATA-100 standards, it is suggested to use all capital letters in caution sections, but this contradicts the findings presented by Tinker[8] about lower case vs. capitals. When this occurred, ATA-100 recommendations were replaced by those supported by research findings. Third, the SUNY team and the focus group thought it was important to go beyond just stating recommended good practice to include both examples and the reasons why the recommendation was made. With these additional aspects incorporated, the final DDA could be used both as a rapid design checklist and as a learning tool. The aim was to move beyond what Rasmussen[15] has termed "rule-based performance" to the higher level of understanding characterized by "knowledge-based performance."

To turn the final set of documentation design findings into a usable design tool required a number of iterations, each with feedback from the task force at the partner airline. The initial DDA structure followed, which was developed for workcards by Patel, et al.[3] This structure was expanded to include our newly discovered findings. In successive stages, this set was edited and its structure changed to conform to expected use by documentation designers. Table 4.1 shows the final structure, which starts with overall considerations of information content; i.e., what needs to be in a document and how it should be organized into a logical sequence. Next come considerations of readability, with the more mechanical aspects such as typeface, page layout and how to provide emphasis. Writing considerations come next, i.e. how to turn the document content into sentences and paragraphs which can be read and understood easily. Finally, the section on other organizational issues covers a recommended process for ensuring early and continuing user input into the document design. The final aspect of our design of the DDA was to insure that its form indeed meets our standards. Thus, the human factors best practice defined in the guidelines was applied to the DDA itself. During this iterative design process, the paper version of the DDA passed through many forms. This ensured that by the time coding of the computer-based version was begun, the DDA content was designed with the user in mind.

Table 4.1 Classification Scheme for DDA

1.0	**Information Content**
1.1	User-Centered Design
1.2	Logical Content
1.3	Task Sequencing
1.4	Headings and Levels
1.5	Notes/Warnings
2.0	**Information Readability**
2.1	Typographical Layout
2.1.1	Page Size
2.1.2	Page Layout
2.1.3	Justification
2.1.4	Paragraphs and Indentations
2.1.5	Spacing
2.1.5.1	Vertical Spacing
2.1.5.2	Horizontal Spacing
2.1.6	Typeface
2.1.7	Type size
2.1.8	Emphasis
2.1.9	Responses
2.1.10	Color
2.2	Pagination
2.3	Letters, Words, Numbers
2.3.1	Letters and Numbers
2.3.2	Words
2.3.3	Abbreviations
2.4	Writing Well
2.4.1	General Writing Consideration
2.4.2	Sentences
2.4.3	Lists and Tables
2.5	Graphic Information
2.6	Printing and Copying Quality
3.0	**Other Organization Issues**

4.5.2 DDA Development: Computer Considerations

In moving to a computer-based design aid, two considerations were important: the structure of the DDA interface and the choice of hardware/operating system combination. First, presentation of information need not be restricted to the linear mode forced by a paper-based system. As noted in Patel, et al.,3 for workcards themselves, information can be given in a hierarchical manner, where the user starts at a high level of abstraction and by successive menu choices reaches the required information as one particular branch of the tree structure. Alternatively, the user can move between branches directly, if the branches are constructed as interconnected nodes and a suitable program written for node-to-node movement. This branching structure is the basis for hypertext documentation systems, familiar to users in "Help" facilities on a PC, or as browsers on the World Wide Web. Patel, Drury and Shalin (1997 in press)16 showed how to take advantage of the cognitive structuring of a domain by expert users to help novices reach required hypertext information more rapidly. When there are enough expert users of DDA, this may become a useful option. A final way to access computer-based information is through a keyword index, such as those used under "search for Help on:" in Windows(tm) Help systems. The final version of the DDA supports all of these modes of use.

The second consideration is the issue of the appropriate hardware platform and operating system. Because of widespread industry use and FAA project requirements, the decision was made to write for Intel micro processors (X486 and above), running MSWindows (3.1 or above) with mouse support. Programming was in MS Visual Basic for consistency with other applications produced by SUNY Buffalo and Galaxy Scientific Corporation for FAA/AAM. With Visual Basic and Windows, it is possible to have the DDA reside in one window while working on a document in another window. In fact, the structure of the final DDA was made simple enough that users could produce equivalent code for themselves in other operating systems such as MAC-OS or UNIX.

4.5.3 Interface and Functionality of the Computer-based DDA

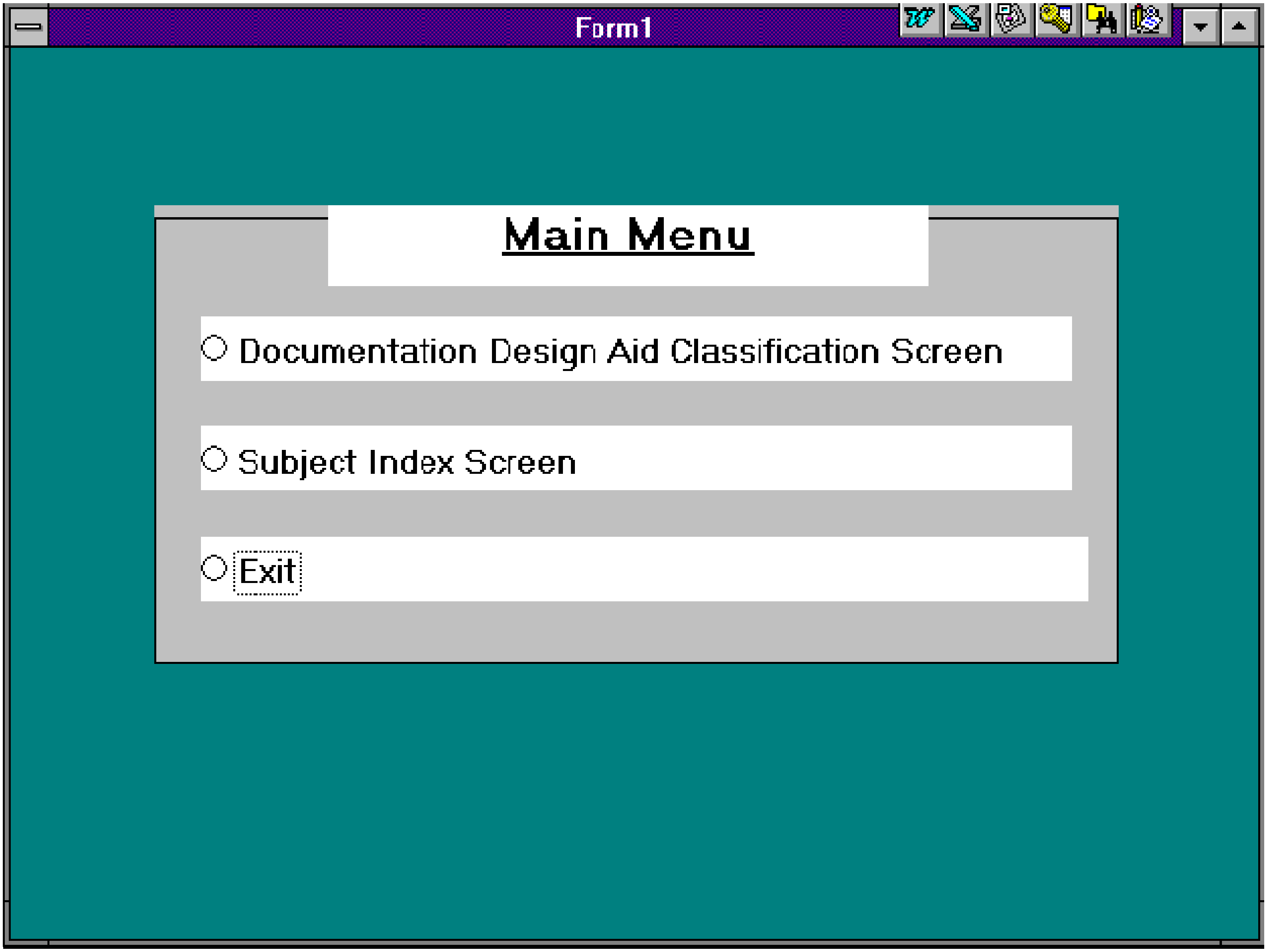


Figure 4.1 The Main Menu Screen of the Final DDA Program

The final DDA program is shown as a set of figures (Figures 4.1- 4.7). The user is first given the Main Menu screen (Figure 4.1) where a choice is made between the two major user modes: classification and index. The classification system (Figure 4.2) is a hierarchical table of contents matching the major and minor headings of the hardcopy document (Table 4.1 and Section 4.9.2). The index system gives an alphabetical list of contents (Figure 4.3). An experienced user will probably use the classification system; however, if the structure of the DDA is not well known (or is forgotten), the index would be more appropriate. Note that selecting an item from the index leads to exactly the same "Human Factors Good Practice" screen as could be accessed from the classification system.

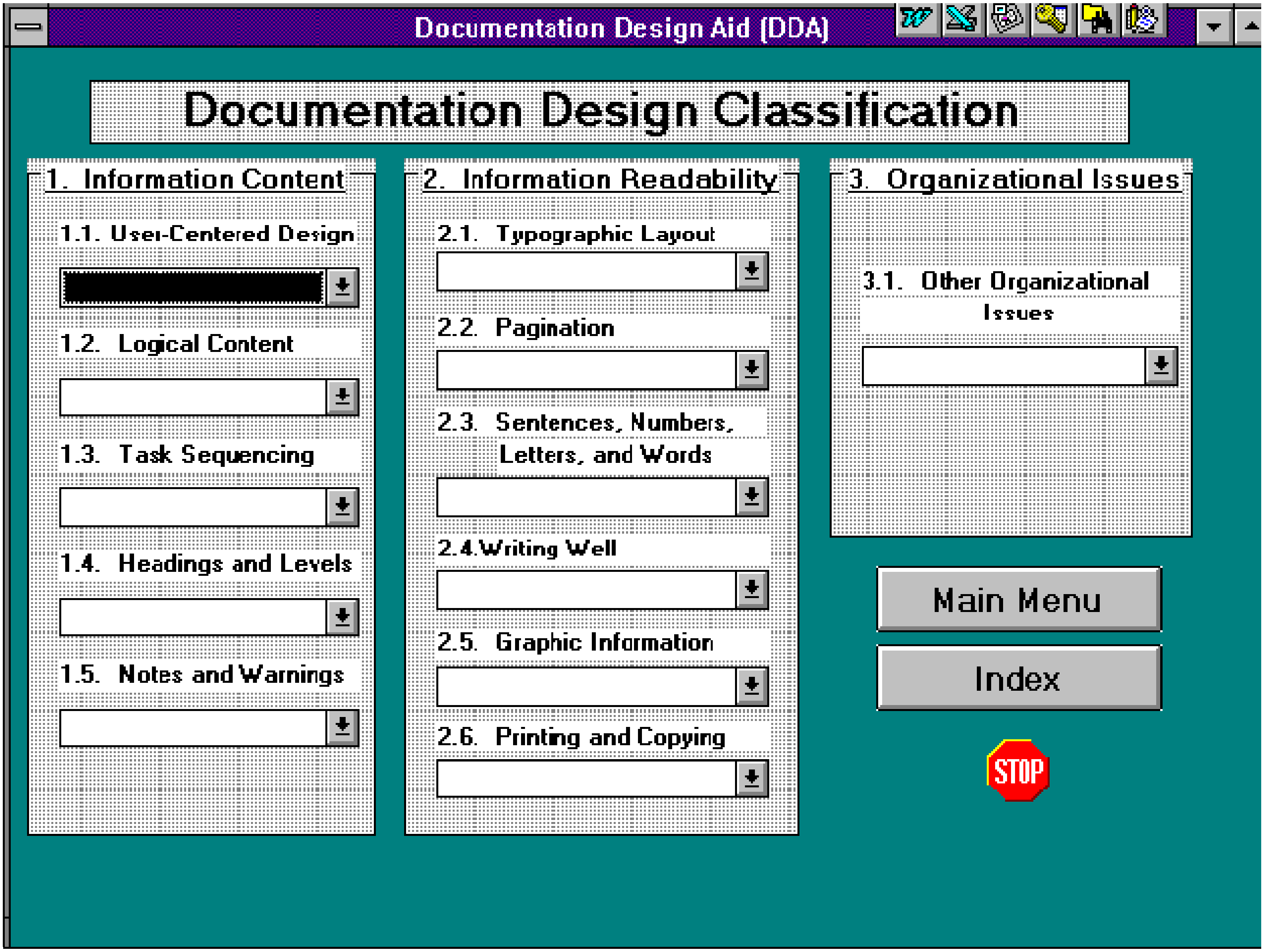


Figure 4.2 Documentation Design Aid Classification Screen

Selecting an item on the classification system, for example "2.1: Typographic Layout" on Figure 4.2, displays a pull-down menu of the end items under this heading (Figure 4.4). Selecting an end item, such as "Responses" on this pull-down menu, supplies the main screen of desired information -- the "Human Factors Good Practice" screen (Figure 4.5). This tells the user the basic rules for good practice, i.e., for designing low-error documents.

At this point, the user can select one of the buttons on the lower row to obtain more detail on each rule. In Figure 4.5 the rule on "Not Required" boxes has been selected. Pressing "Example" gives correct and incorrect examples (Figure 4.6). Canceling this box by selecting "OK" returns the user to the "Human Factors Good Practice" screen (Figure 4.5). Selecting the "Why?" button here brings up a box showing reasons from the literature supporting the practice. Figure 4.7 gives a reason for the margin recommendations under Page Layout as an example. As noted earlier, this facility helps the user understand that the guidelines are not arbitrary preferences, but the result of measurements of human characteristics.

The user can terminate the DDA program by using the "stop" button, or leave it active but reduced to an icon by clicking on the down-arrow button in the upper right corner of the DDA window, conforming to Windows stereotypes.

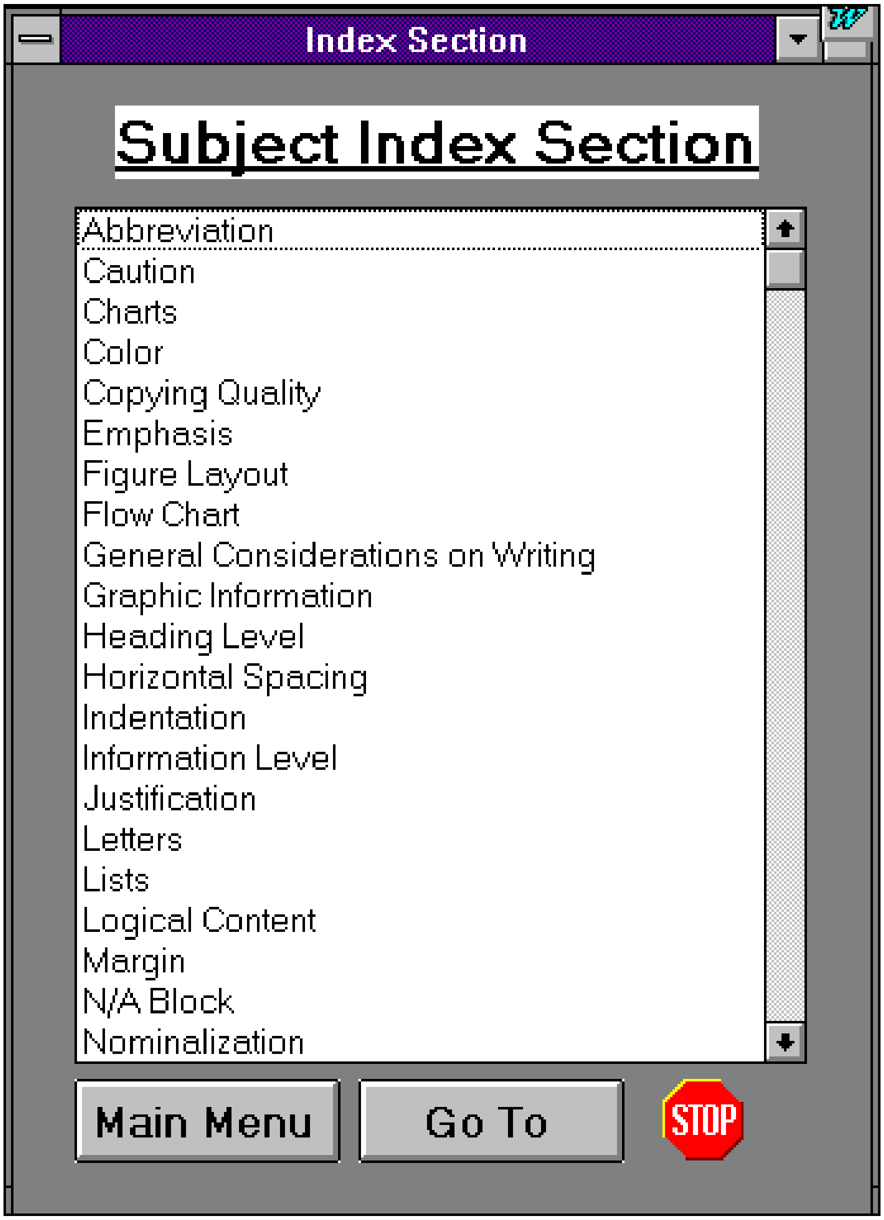


Figure 4.3 Subject Index Screen

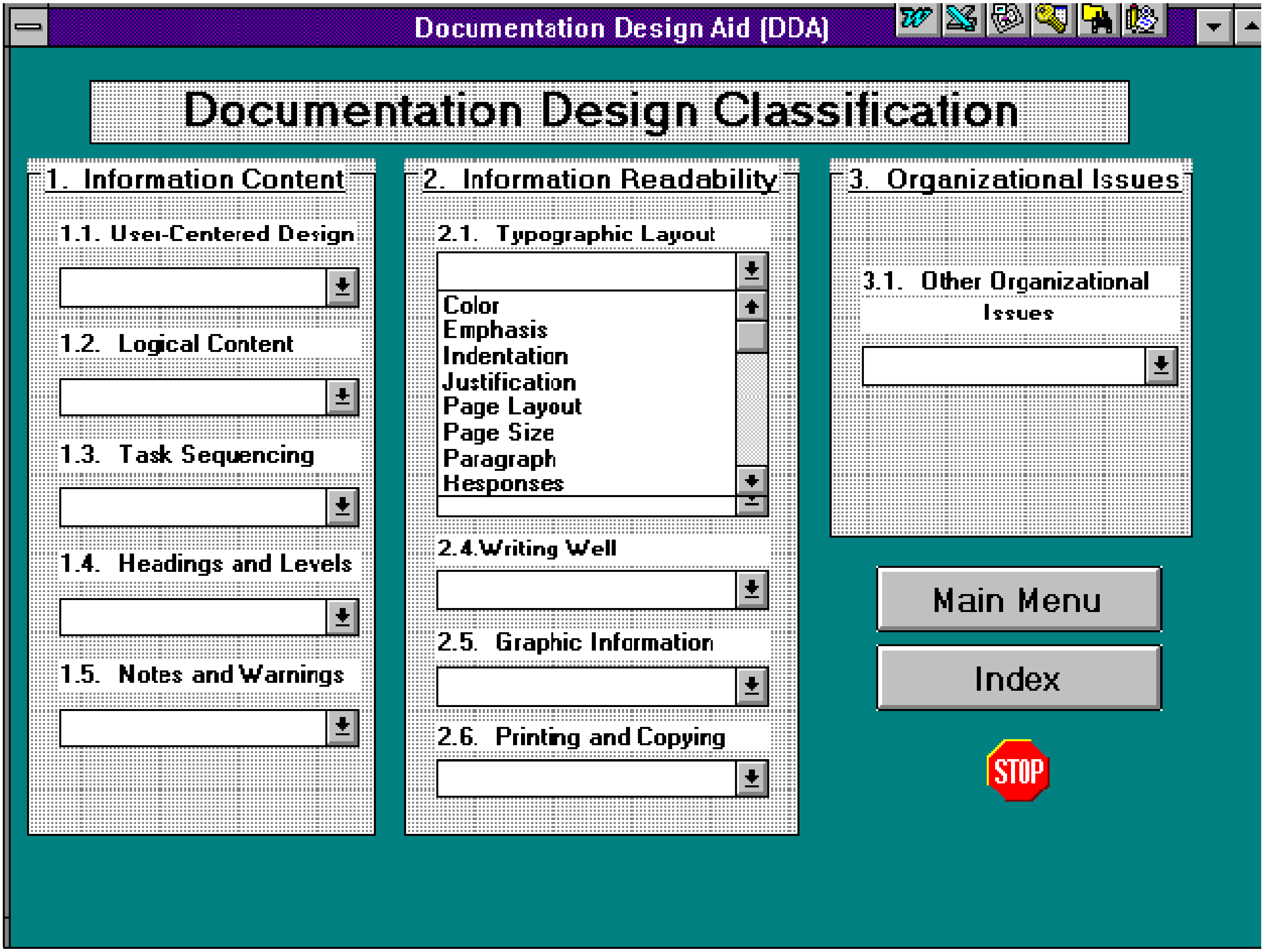


Figure 4.4 Pull-Down Menu for "2.1 Typographic Layout"

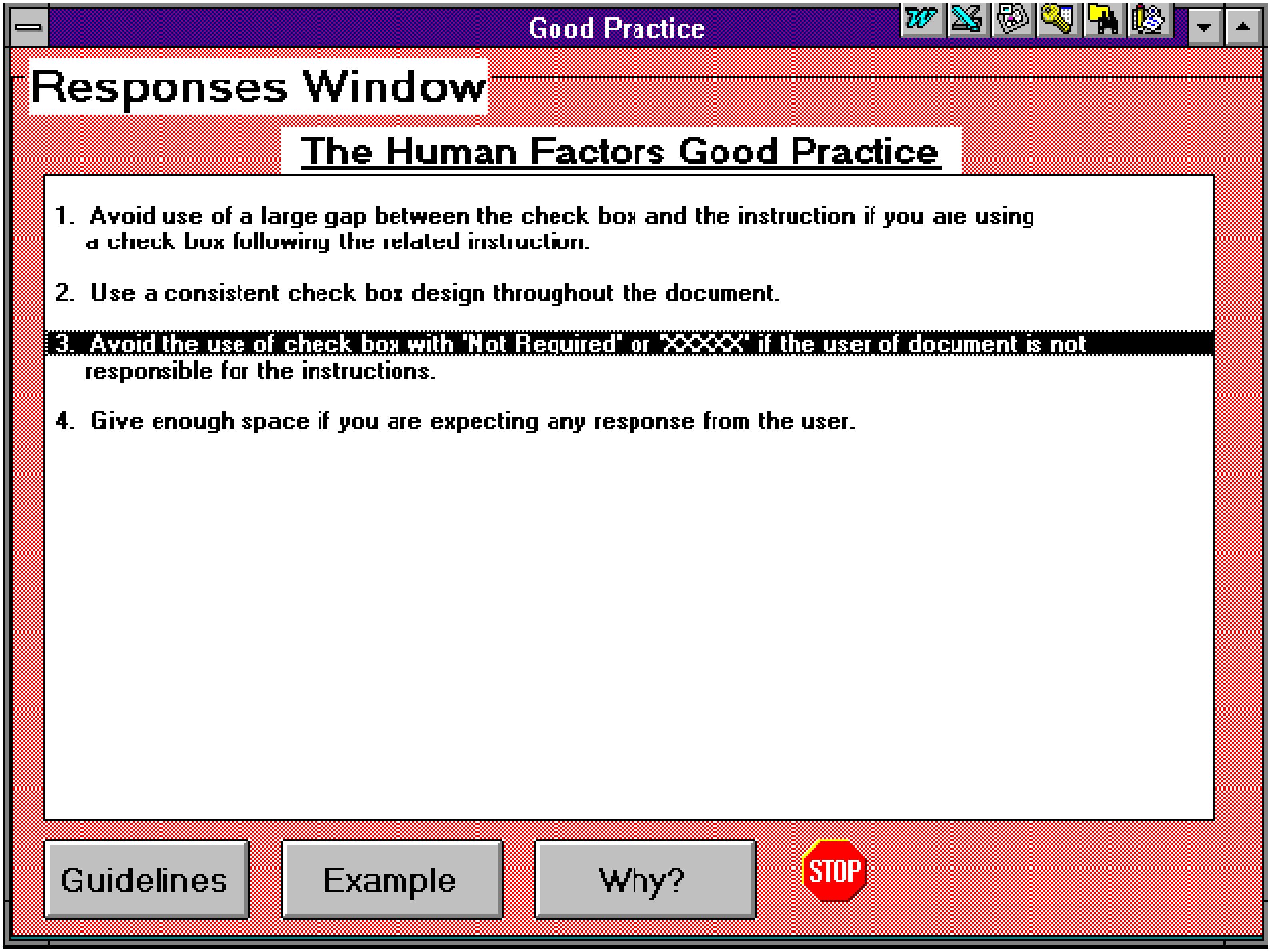


Figure 4.5 Human Factors Good Practice Screen for "Responses"

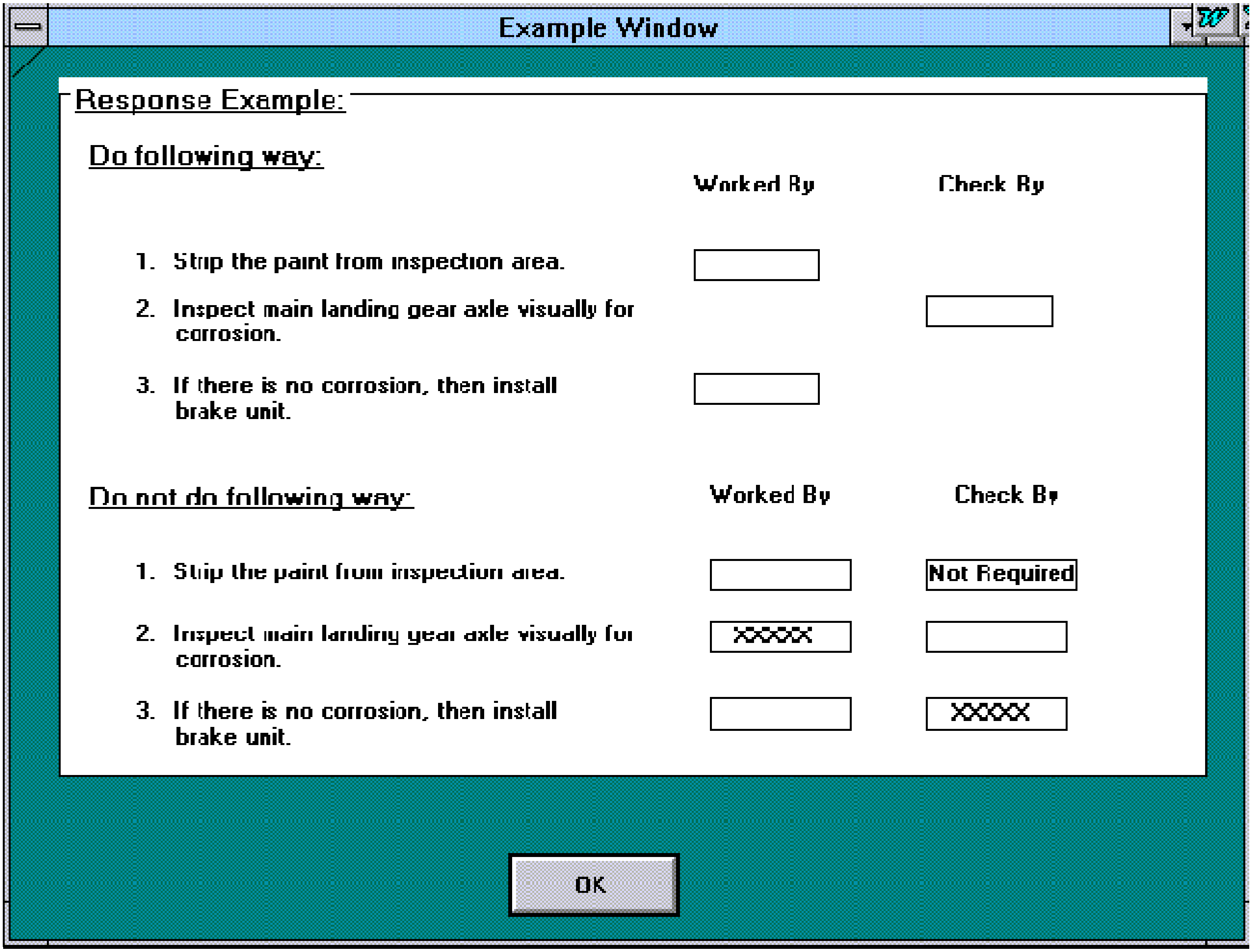


Figure 4.6 Example Screen for "Responses"

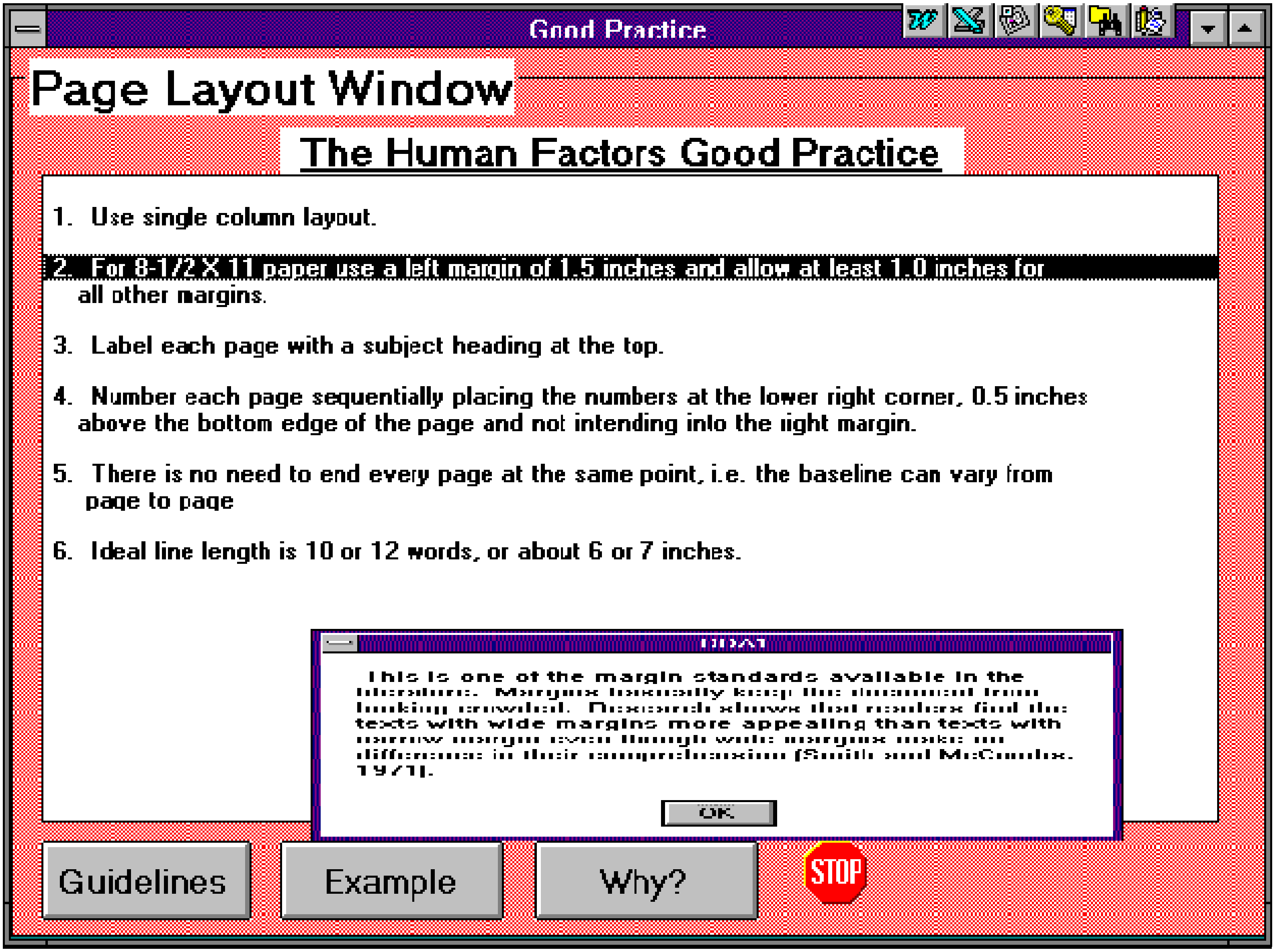


Figure 4.7 Reason Screen for "Page Layout: Margin"

4.5.4 Analyzing the EO Process

At the first meeting of the focus group (April 1996) a round-robin process was used to ensure that all present could raise issues about documentation design and the process by which EOs are generated and performed. This meeting provided over 70 issues of concern to group members. The issues ranged from the very general ("Need to encourage mechanics to take more responsibility for their work") to the highly specific ("Not Applicable" N/A policies are confusing in procedures which branch or have conditional statements."). All of the issues were listed, with no discussion or critique by the team. This list of issues was classified by the SUNY team and similar issues were combined. The final structured list is shown in Table 4.2.

Table 4.2 List of Original Issues Generated by Focus Group

Topic	Description	Number of Issues
1. Confusion about items marked "Not Applicable"	How should mechanics use "Not Applicable" (N/A) or "Previously Complied with" (PCW)?	7
2. Form design	e.g. Should there be a flow chart on EOs? Can we move some management material to end of EO?	10
3. Review of EOs		18
3.1 Review sheets	e.g. Does the review sheet ever reach a mechanic?	(3)
3.2 Other review processes	e.g. Does every EO need to go through review process?	(8)
3.3 Feedback forms	e.g. Difficulties in faxing feedback forms	(5)
3.4 Revisions	e.g. Can we revise just parts of an EO?	(2)
4. Development and distribution of EOs	Training of engineers to write EOs, time pressure to complete EOs.	13
5. Completion of EOs	e.g. How do we ensure a sensible sequence of tasks? Scheduling of EO work?	3
6. Other issues	e.g. Too much paperwork, how to ensure mechanics are careful.	3
Total		**54**

Issues listed in Table 4.2 formed the basis for improving forms design (Topics 1, 2) and for mutual understanding of the EO process by the focus group. Many members were unaware of how the EOs system affected other stakeholders, so that the mutual understanding within the group was of great help in finding appropriate interventions. Following this meeting, the SUNY team flowcharted the EO process, using both the airline's General Maintenance Manual and group knowledge. The above list of issues became the basis for the partner airline's changes to the EO process.

While these process-oriented issues were being considered, two representative existing EOs were selected for progressive redesign using the DDA guidelines. One was quite simple, the other more complex. Both had resulted in some paperwork errors, but were considered to be neither very good nor particularly poor designs. The *Main Landing Gear Wheel Axle Corrosion and Crack Verification* for a large transport aircraft will be used in this report as an example.

In each session with the focus group, specific points about the latest version of this EO were discussed and recommendations made for possible improvements. The SUNY team then modified the EO and distributed the revised version to the group, who analyzed the changes in time for the next meeting. It should be noted that the focus group took its mission very seriously and found time to make many insightful comments at each iteration. During this process, one SUNY team member (A. Sarac) worked with one focus group member (an inspector) in performing the EO. The inspector led the SUNY team member through each step, showing how to recognize each part on the aircraft, how to perform the procedure and how to make the correct written responses.

Midway through the project (after two redesign iterations), a more design-specific list of issues was generated by the focus group using the round-robin technique. These helped to further structure the EO design. They were later classified as Table 4.3.

Table 4.3 List of Design Issues Generated by Focus Group

Topic	Description	Number of Issues
1. Sign-off design	How can we ensure sign-off boxes are not missed?	10
2. Ordering of steps	How can we ensure a logical task sequence?	1
3. EO logical structure	How can we present the logic of the EO to the user?	4
4. Managing the EO process	How can we ensure AMT input into each EO?	11
5. Consistency of design	How can we achieve consistency across EO writers?	2
6. Layout/design of EO	Can some material be eliminated from EOs?	6
7. EO wording	How can we implant Simplified English in EOs?	3
8. Backup information	Should we ensure the EO is self contained?	1
Total		**38**

Typical issues addressed in the EO design process were:

1. Many items were moved from the front of the EO to the back as they are not needed by the main user.

2. A flowchart was placed at the beginning of the EO to show the logical ordering of steps and to indicate any branching. To help users branch correctly over a number of steps not required (e.g., because no corrosion was found), each box on the flow chart contained the step number in the procedure.

3. For better control of the work on the hangar floor it was agreed, that when an EO required the same task on both sides of the aircraft (or both engines), a separate EO should be issued for each side. This would prevent errors when tasks were interrupted or carried across shifts.

4. Graphical material was integrated with the text steps and sign-off boxes to ensure compatibility and availability of the graphics. As airlines move into electronic publishing, this becomes a feasible alternative to referencing source documents which must be copied and attached.

5. The original layout of task steps used vertical and horizontal lines forming "boxes" around each task step and sign-off area. This was changed to present the task steps in an open layout and only to include sign-off boxes where they were required. Besides being easier to use, this meant that sign-off boxes could be included exactly where they were needed. With a "box" layout, there is always a sign-off box for both the AMT and the inspector at each step. Where one is not needed, this is indicated by printing "XXXX" or "N/A" in the box. Where neither is needed, e.g. for a Caution, both boxes must be printed with one of these notations. With the more open layout, such unnecessary boxes are omitted so that there is a much cleaner indication of who needs to sign off each step. This should also make missed sign-offs by the AMT and/or the inspector much easier to detect during and after task performance.

6. Where a procedure contains a conditioned statement, the user must branch to different steps depending upon whether the condition is true or false. This means that the user must often sign many unnecessary steps as "N/A" in order that all steps are seen to be completed. Missing "N/A" indications are known to be quite error-prone. An alternative method was devised to make the process less error-prone, and incidentally easier for the user. Where there are a large number of "N/A" after a branch, single sign-off is made using a boxed step (Figure 4.8).

Following this step, the shape of subsequent sign-off boxes changes from a rectangle to an oval until applicable steps resume, when it changes back to a rectangle. The user can make a single sign-off at the boxed step, and then not have to "N/A" the ovals following this step. Again, the current move to electronic publishing gives technical writers more choices in the shaping and formatting of boxes, than were available under older documentation systems.

7. Choice of words and sentence structure for any document should now follow the rules of Simplified English for comprehension and consistency. Chervak, Drury and Ouellette (1996)6 showed that Simplified English led to lower error rates, particularly for complex documents and for nonnative English speakers. Parts of the EO used throughout this project were rewritten in Simplified English to demonstrate its utility. It was found that the document was indeed simpler, and in fact shorter, than the original version. In the future, it will be important to interface the DDA with the existing body of knowledge on Simplified English, particularly the glossary. This will make Simplified English more easily accessible to those who must produce technical documents.

To determine whether the revised EO met the needs of the focus group, changes made to the EO were checked off against the list of design issues raised by the group. In effect, the list of design issues became a design checklist for the EO design part of this project. As each issue was addressed, it was incorporated into the document design guidelines of DDA, to make that job aid more relevant to the design of procedures.

NOTE: If there is no evidence of corrosion found, then

-Stamp this signbox to indicate Step 13 thru 21 as "N/A". ☐

-Skill Step 13 thru 21.

-Go to Step 22.

Figure 4.8. Suggested "N/A" Block Structure

4.6 EVALUATING THE DDA

With any newly developed job aid two criteria must be established:

1. *Usability*: Is the job aid usable for its intended purpose by intended users?

2. *Effectiveness*: Can intended users perform their job better with the job aid?

Logically, evaluation of usability must precede evaluation of effectiveness. Usability testing of computer-based tools has become a standard human factors evaluation technique.17 Its aim is to ensure that the product can be used by its intended users, and that any problems of human use are found early in the product development cycle. A small sample of intended users are given appropriate briefing/training in use of the product, and then must use it in a typical task.

Here, the task was to modify an existing EO to conform to the human factors guidelines embedded in the DDA. A relatively short EO (23 pages) was chosen as providing an appropriate test of the usability of the DDA without requiring inordinate amounts of partner airline resources. An EO was chosen which contained a number of shortcomings when compared to human factors good practice. In fact, the EO was recently used at the partner airline, and some errors had occurred in the completed documentation. The sample group of six potential users, engineers, and technical writers at the partner airline was divided randomly into two groups. Half used the paper-based DDA while the remainder used the computer-based version. In this way, we could test the critical "first use" of each job aid to determine how well it could be expected to work in other airlines. Each user was video taped throughout the briefing and use of the DDA to determine where hesitations, false starts, and errors were made. Usability was measured not only from the video tapes but also from a series of rating scales completed by each user after performing the task. Times were measured for the preliminary briefing and learning, for taking a quiz on the briefing to ensure understanding, and finally for performing the EO modification task.

Effectiveness was measured by comparing the changes to the EO made by each user to the master list of 34 changes made by the SUNY team and members of the focus group. These "expert users" had had several weeks to study and amend the test EO, so that almost all of the changes required for it to conform to human factors good practice could be expected to have been found. Effectiveness was measured by the number of (correct) changes made to the EO in relation to the total number of possible changes. Where a single change was expected to apply to the whole document, as in "move all sign-off boxes to the right edge," this was counted as one change, not as one change per sign-off box. Changes were marked by users on the EO itself, and in case of doubt, the video tape was consulted to help determine the user's intentions.

Results of the evaluation were analyzed using the MINITAB(tm) program to compare the computer-based and hard copy versions of DDA. Comparisons of the times for the two versions showed no significant differences between versions, except for the times on the quiz where the number of questions differed between the two versions. When time per question was calculated, there was no significant different between versions.

As can be seen from Table 4.4, the DDA took less than 20 minutes to learn well enough to begin the task including completing the quiz. Modification of a 23-page EO took about one hour for first time users.

Documentation Design Aid Usability Evaluation Scales

Please respond on each scale with your honest opinion of the Documentation Design Aid. Each rating scale gives you a statement and asks how strongly you agree or disagree with that statement.

Please respond on each scale with your honest opinion of the Documentation Design Aid. Each rating scale gives you a statement and asks how strongly you agree or disagree with that statement.

1. The structure of the Documentation Design Aid was appropriate to the task.

P C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

2. It was easy to find my way around the Documentation Design Aid to get to the information I needed.

C P

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

3. When I found the information I needed, it was written so that I could understand it.

P C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

4. There were terms which I did not understand in the Documentation Design Aid.

C P

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

5. Overall, the Documentation Design Aid was useful to me.

P, C

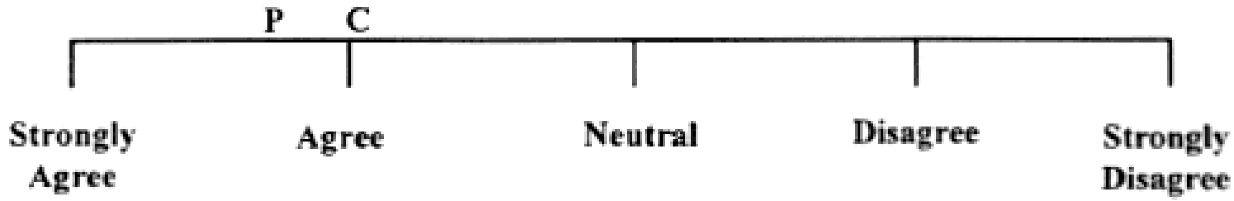
Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

6. Overall, the Documentation Design Aid was easy to use.

P C

Agree Agree Neutral Disagree Disagree

6. Overall, the Documentation Design Aid was easy to use.



Thank you for your time and effort in evaluating the Documentation Design Aid for us.

Figure 4.9. Usability Evaluation Scales. "P" represents mean rating for paper-based DDA and "C" represents mean rating for computer-based DDA.

Table 4.4 Analysis of times in usability tests

Measure	Time, Paper based DDA	Time, Computer based DDA	Probability of Difference
Briefing/Learning Time, min	7.7	6.7	0.79
Quiz Time, min	9.0	13.3	0.03
Quiz Time per Question, min	0.75	0.60	0.22
Task Completion Time, min	59.0	61.7	0.42

Effectiveness was measured by comparing the changes found by the users to those found by the SUNY team for each version of the DDA. Where a correct change was found by the users, this was scored as a "hit," where an incorrect change was found, this was counted as a "false alarm."

Because we asked for a reference in the DDA for each change, we could count the number of correct DDA references. Finally, the answers on the DDA quiz were scanned as a percentage correct. Table 4.5 shows the results of these analyses of effectiveness.

Again, there were no significant differences between the two versions of the job aid. Users found about a third of the changes noted by the SUNY team, again for first time users. Less than one unnecessary change was made on average by each first-time user. Both groups of users scored well on the knowledge quiz (averaging over 90%).

Usability Rating Scale data was analyzed by comparing the mean ratings for the two versions using a Wilcoxon text. Figure 4.9 shows the rating scales used which were common to both versions of the DDA with "P" and "C" marked on each scale to represent the mean ratings of paper-based and computer-based versions of the DDA.

Table 4.5 Analysis of effectiveness in usability tests

Measure	Score, Paper-based DDA	Score, Computer-based DDA	Probability of Difference
Percentage hits on task	**31.3%**	**39.2%**	**0.155**
Number of false alarms on task	**0.7**	**0.7**	**1.00**
Percentage correct on quiz	**88.9%**	**98.5%**	**0.44%**

Again, there were no significant differences between the two versions. Both versions were rated highly for appropriateness to the task (Q1), easy of finding information (Q2), overall usefulness (Q5), and overall ease of use (Q6). Users were less happy with the writing of the DDA itself and their own understanding of terms mentioned in the DDA. All of the additional evaluation scales used exclusively for the computer-based version scored a mean of 4.0 or above on their 5-point scales.

From the whole evaluation the effectiveness and usability were positive. First-time technical users of the DDA with less than 20 minutes of training-plus-quiz were able to find about a third of all the expert-recommended changes in a typical EO during about an hour's work. After the experience, they rated the design aid highly, although noting that some aspects of DDA wording could be improved. Neither version of the DDA was significantly better or worse than the other, although with only six users in two groups the tests were quite insensitive. In response to this evaluation, all of the text items within the DDA have been reviewed and revised to remove ambiguities and help explain technical terms.

4.7 CONCLUSIONS

To improve the ability of technical writers and engineers to write usable documents, two versions of a Documentation Design Aid were developed. The paper-based version merely lists the rules in a format suited to the user's needs. A computer-based version adds reasons for the rules and examples of their use. Both versions were similarly effective in allowing users to find and make changes in existing task documentation. During the process of developing these job aids, a number of other issues emerged which also impact the process of designing, testing and using technical documentation.

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4.9 APPENDICES

4.9.1 Appendix A - Bibliography

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4.9.2 Appendix B - DDA

1. INFORMATION CONTENT:

1.1 User-centered Design

Checked

- Write with the specific users in mind, e.g. AMTs (mechanics), inspectors. Given information has to be flexible and helpful for both novice and experienced user. ______
- Provide multiple levels of information to cater to the needs of both recently practiced as well as less familiar users. Provide more elaborate information for recently practiced and more concise information for experts performing the same task. ______
- Develop a standard framework for distinguishing between and writing multiple level of information. For example, provide main heading and checklist information for the most experienced user, and supplement this with more detailed information, perhaps in a smaller type, for the less experienced user. ______
- Information provided should be updated and supportive of the user's personal goal to 'read quickly and also understand the information', to ensure that it can be easily understood and used without error. ______
- Write for the appropriate reading level of the user. While AMTs have a high level of reading ability, keep a reading level down to grade levels 6-8 to reduce errors for complex instructions to be read under adverse conditions. ______

1.2 Logical Content

- Use a title for the document which increases the comprehension of the user.
- Determine hierarchical relations among the components of procedure.
- Keep a standard layout for the document as a whole. At the beginning of the document, use the headings of :
  - Purpose
  - Effectivity
  - Equipment
  - Materials

  Follow these by the task instructions and finish with any managerial information and the feedback sheet (if required).
- Determine appropriate and sensible job sequence. Write instructions precisely according to the logical and temporal order in which the individual task has to be carried out.
- If the blocks of task steps are not applicable, allow the user to sign off one block as "N/A" to cover them all.
- Prepare an outline form to show the operations required in step-by-step sequence with special attention directed to key points of the job.
- Use a flow chart to help design the document. Chart the sequence of tasks, particularly the choice points and alternative procedures. Put task step numbers on the flow chart.
- Use reminders of the critical procedures on the form itself instead of using preliminary instruction.
- Revisions, additions, and deletions shall be identified by a vertical black line or code letter "R" along the left margin of the page opposite only that portion of the printed matter that was changed.
- Include the most recent revision date at the start of the document.

1.3 Task Sequencing

- The task information should be ordered/sequenced in the natural order in which the tasks would be carried out by most users.
- Check the sequence to ensure that movement around the aircraft is minimized. Group physically-adjacent tasks close together to reduce user effort
- Each chunk of directive information should not include more than two or three related actions per step to eliminate action slip.
- Break the information used for work instruction into manageable chunks in logical order.
- Divide the information chunks into logical and sensible steps.

1.4 Headings and Levels

- Headings on the same level of organization should be placed and emphasized in a consistent way.
- Number the steps.
- The path among task instructions must be clearly visible .
- Do not use more than three levels of subordination (headings and subheadings) within each major division if it is possible.
- Use minimal number of visual characteristics necessary to differentiate among the headings as each difference implies an additional structural difference.
- Use short paragraphs, headings and sub headings to group and arrange the text.
- Use clear and understandable headings and subheadings .
- Prepare a topic diagram for the content of the document which will be helpful for hierarchical organization.

- You may number paragraphs and sections if necessary .
- Make clear difference among the category responses .
- Determine subdivisions and heading levels of the text in a sensible manner .

1.5 Notes/Warnings

- Insert notes, warnings, and comments into the instructions wherever necessary to ensure safe and accurate performance.
- Use warnings, cautions, and notes to highlight and emphasize important points when necessary.
- Distinguish among directive information, reference information, warnings, cautions, notes, procedures, and methods.
- Use cautions and warnings directly above text to which they relate and vertically in line .
- Use notes after the related text .
- Cautions, warnings, and notes must be on the same page as the text to which they apply .
- There should be a code for identifying the importance of a particular category of information over others, e.g. warnings, cautions, notes, procedures, methods, directive information, references in decreasing order of importance.

2. INFORMATION READABILITY:

2.1. Typographic Layout:

2.1.1. Page Size:

- Use a standard paper size. In the USA this should be 8-1/2" X 11. In the rest of the world use A4.

2.1.2. Page Layout:

- Use a single column layout as this is easier for lower level readers, and does not affect more experienced readers
- For 8-1/2" X 11 paper use a left margin of 1.5 inches and allow at least 1.0 inches for all other margins. The ideal line length is 10-12 words, or about 6"-7."
- Label each page with a subject heading at the top .
- Number each page sequentially placing the numbers at the lower right corner, 0.5 inches above the bottom edge of the page and not extending into the right margin.
- There is no need to end every page at the same point, i.e. the baseline can vary from page to page.

2.1.3. Justification:

- Use left justification, i.e. typing lines up at left edge only. Center and right justification is distracting and can slow reading speed.

2.1.4. Paragraphs and Indentation:

- Use modified block style with two space indentation for subdivisions, as used in this document.
- Label each leading and subheading sequentially 1, 1.1, 1.1.1, etc. as used in this document.
- Within a heading, keep paragraphs below half a page in length, to help the reader's concentration.

- Leave one blank line between paragraphs.
- Do not indent the start of each paragraph.

2.1.5. Spacing:

- Use 1:2 space ratio between sentence spacing and paragraph spacing .

2.1.5.1. Vertical Spacing:

- Use one blank line to separate all paragraphs, and headings .

2.1.5.2. Horizontal Spacing:

- Use one space after commas, colons and semicolons .
- Use two spaces after periods, question marks and exclamation marks .

2.1.6. Typeface:

- Use the typefaces which have a relatively large height , are moderately expanded, solid rather than delicate looking, and have fairly uniform type color such as Times Roman, Century Series, New Gothic, Helvetica in which Times Roman font style is the most common and the least fatiguing to proof readers due to its easy readability.
- Keep the font consistent throughout the document and between documents.

2.1.7. Typesize:

- Use sizes between 9 and 12 point for ease of reading. The best size for most uses is 11 or 12 point.

2.1.8. Emphasis:

- Keep a consistent use of emphasis throughout the document and between documents .
- For a single word use bold (most preferred), underlining, italic or all capitals (least preferred) for emphasis.
- For lengthy passages use bold or underlining for emphasis. Avoid CAPITALS or *italics* as they slow reading and reduce comprehension.
- Use only one or two emphasis techniques within a document to increase comprehension. Bold and underlining are good choices.
- Do not overuse emphasis techniques as it causes confusion and reduces comprehension.

2.1.9. Responses:

- If you are using a check box following the related instruction, do not use large gap between the check box and the instruction.
- Avoid the use of a sign box with " Not Required" or "XXXXX" if the user of the document is not responsible for the instruction accomplishment.
- Use a consistent check box design throughout the document if it is possible .
- Give enough space if you are expecting any answer from the user .

2.1.10. Color:

- Avoid regular use of color in illustrations. Use distinctive shading patterns within black line images instead of color.

2.2 Pagination

- Avoid use of any reference back to previous text .
- Avoid references to other sections of the document as far as possible. Unavoidable cross-references must be precise and unmistakable.
- The page should act as a naturally occurring information module, i.e. it should contain an appropriate number of tasks and avoid carryover of task across pages.
- Each task that begins on a page should also end on that page .
- Minimize the routing; in other words, do not route the user from page to page since it can cause serious defects.

2.3. Letters, Words, Numbers:

2.3.1. Letters and Numbers

- Use lower case letters instead of upper case in the text since lower case letters are much easier to read than upper case letters due to the lower case letters' more distinguishable shapes (ascenders and descenders). Besides, upper case letters occupy more space (40%-45% more than lower case letters do) and reduce the reading speed between 13% and 20%.
- Use mixed-case headings and sub-headings instead of all capitals to improve readability.
- Avoid hyphens which merely indicate word division at the end of line.
- In series of words or statements which present mutually exclusive choices, making the "or" explicit throughout the series enhances comprehension.
- Avoid using Roman numerals since they are not easy to read and cause confusion.
- Use Arabic numbers followed by a period for each item in your list if you should use the numbers. If not, you can use a bullet or dash to get the attention of user.
- Do not enclose the number in parentheses.
- Use a conventional dash-number breakdown : chapter-section-subject-page: 26-09-01-02.

2.3.2 Words

- Avoid using multiple terms for the same object .
- Use precise, unambiguous and common words, with which the user of document is familiar, throughout the document for consistency.
- Do not use many prepositions, they cause user to read slowly.

2.3.3. Abbreviations

- Use only approved acronyms and proper nouns.
- Avoid abbreviations. If you have to use abbreviations, then
  - Use them consistently,
  - Use first few letters to remind the word.

- Provide a glossary if the users need. In particular, if there is an unavoidable inconsistency for abbreviations, then use glossary of interchangeable designations.

2.4. Writing Well:

2.4.1 General Considerations on Writing

- Try to achieve a balance between brevity, elaboration and redundancy of information.
- Complement verbal material by appropriate pictorial representation.
- Adapt the format of instruction to the characteristics of the respective task.
- Write clear, simple, precise, and self-explanatory instructions.
- Minimize writing requirement from the users of documents.
- Summarize the main ideas of lengthy prose passages in a section before the text since it aids in learning the context.
- Use adequate information in the instruction steps.
- The text should be written in a consistent and standardized syntax.
- Text shall be as brief and concise as practicable.
- Use a logical structure sentences and paragraphs since they are easier to understand and remember;

  Logically: - place general before specific provisions,
  - place important before lesser provisions,
  - place frequent provisions first,
  - place permanent before temporary provisions.

2.4.2. Sentences

- Use Simplified English as much as possible .
- Use short sentences instead of long ones since short sentences are easier to read and understand.
- Use definite and affirmative sentences in active tense instead of using negative forms and passive tenses since active voice increases comprehension.
- Use sentences with personal pronouns since they increase comprehension and reader's motivation.
- Sentences with many subordinate clauses are difficult to comprehend.
- Sentences with action verbs are easier to read and understand than sentences with nominalization.
- Do not use the sentences with a long noun string, since they are hard to understand.
- Do not use the sentences with whiz deletions since they create ambiguity and are hard to read.

- Use third person for definitions as follows:

  " The torsion link assembly transmits torsional loads from the axle to the shock strut."

- Use second person imperative only for operational procedures as follows :

  " Check the oil level."

- Ideas expressed in positive terms are easier to understand.
- State directly what you want to say without excess or unnecessary words since the sentences with unnecessary words are harder to understand and take longer to read.

2.4.3 Lists and Tables

- Data and information presented in the tables facilitate understanding and comparison.
- In lists and tables, do not leave blanks within a line greater than half an inch or five spaces.
- Group the lines in lists and tables according to content.
- Do not group more than five lines together.
- Separate the groups in the list and table by spacing.
- Write the list of items in parallel construction since that way is easier to read and remember.
- List a series of items, conditions, etc. rather than displaying them in a series separated by commas.
- Avoid using compound questions and statements.
- Minimize the logically related question as much as possible.
- Construct the questions in a way which requires minimum memory use from the user of the document.

2.5 Graphic Information:

- Place the visual item in the text of a document, near the discussion to which it relates. If it is not possible, place the visual item in an appendix, label and refer it.
- Use a clear title with a figure or a table number on the line directly below all illustrations.
- Use the same title for illustrations as corresponding text subject title .
- Use either a horizontal-landscape format with the top of the illustration at the binding edge or vertical layout to present graphic information for ease of reading and cross reference consistently.
- Adequate text must be supplied to support illustration not vice versa.
- Draw the illustration in a size and line weight such that they can be used without any rework for the production of projectables.
- Develop uncluttered illustration with limited information/learning points, and presented in a self-explanatory way.

- Use illustrations as the primary source of the information transfer.
- Present all spatial information in graphical format instead of in textual format.
- Label each table or figure with Arabic numeral such as Table 1, Figure 1.
- Use simple line drawings which are superior in most cases.
- Use a consistent format for figure layout and numbering.
- Use illustrations whenever they will simplify, shorten, or make the text easier to understand.
- Do not use complicated reference numbers for figures, e.g. T07-40423-001.
- Avoid use of perspective part drawings as figures.
- The figure views should be as the user sees it.
- Use standard and correct technical drawing terminology, e.g. avoid use of terms 'section' and 'view' interchangeably.
- Reference all tables and figures in the text by the numbers.
- Use bar charts to make accurate comparison of numerical data whenever you can.
- Line charts (or graphs) help to understand trends and allow accurate comparison between two or more numerical values.

2.6. Printing and Copying Quality:

- Check the toner box regularly to have consistent copy quality.
- Make sure that no major image degradation occur with reproductions of originals.
- Use the paper which has a reflectance of at least 70%.
- Use low visual acuity and large typesize if user is going to use the document under low illumination level.
- Readers prefers matt paper to medium or glossy paper.
- High opacity paper is preferable.
- Use black ink on white paper since it is more effective than white ink on black paper.
- Develop and implement standards for changing printer ribbons, toner boxes etc. to ensure a consistent print quality at all times.

3. OTHER ORGANIZATIONAL ISSUES:

- Allow the prospective users of workcards to participate in the design of the document.
- Check every individual instruction by testing it in the field situation.
- If your document is going to include multiple copies, color can be a useful processing aid.
- Make sure that user is aware of how to correct an erroneous entry.
- If the feedback sheet is to be faxed, provide unambiguous instructions which will work for all users.