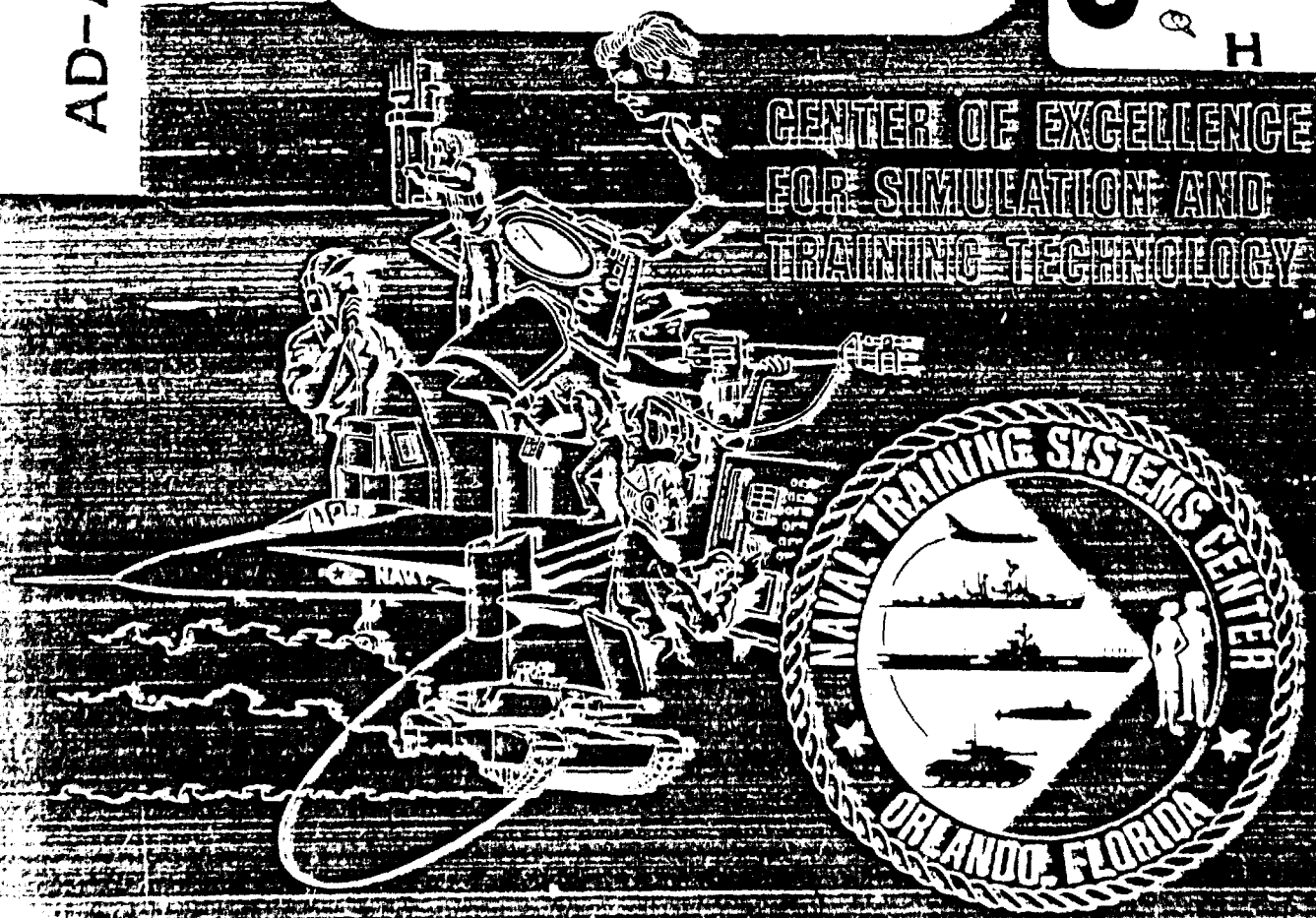
NAVAL TRAINING SYSTEMS CENTER
ORLANDO, FLORIDA

TECHNICAL REPORT TR87-030

AN EVALUATION OF CHARACTERISTICS CONTRIBUTING TOWARDS EASE OF USER-COMPUTER INTERFACE IN A COMPUTER-AIDED INSTRUCTION EXERCISE

DECEMBER 1987



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AN EVALUATION OF CHARACTERISTICS CONTRIBUTING TOWARDS EASE OF USER-COMPUTER INTERFACE IN A COMPUTER-AIDED INSTRUCTION EXERCISE

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Kent E. Williams
Institute for Simulation and Training
University of Central Florida

Cheryl J. Hamel
Naval Training Systems Center

Lisa B. Shrestha
Institute for Simulation and Training
University of Central Florida

NAVAL TRAINING SYSTEMS CENTER
ORLANDO, Florida 32813-7100

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W.A. RIZZO, Head
Human Factors Division

H.C. OKRASKI, Director
Research & Development
Department

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This research tests the effectiveness of the five user-computer interface principles: brevity, consistency, flexibility, compatibility, and responsiveness as proposed by Williges and Williges (1984) to facilitate user interaction with computer-aided instruction. These categories were further refined by Hamel and Clark (1986) into a checklist of characteristics under each category. An experimental training program was created embedding the 53 user-computer interface characteristics in computer-aided instruction exercises. Test subjects were required to run through the experimental training program and to evaluate the contribution of each characteristic to ease of interaction and training gain. Multiple regression correlation analyses were applied to the data to determine the magnitude of effect of each characteristic to ease of use. As a result of this work, a handbook describing and providing illustrative examples of characteristics was developed along with a system to score CAI exercises in terms of user-computer interaction.

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EXECUTIVE SUMMARY

INTRODUCTION

Developing a system that promotes ease of interaction with the computer can not only aid learners in the effective assimilation of new or difficult material, but may also inhibit any demotivating influences which may result from difficulty in interacting with the system. Incorporating good user-computer interface (UCI) in a computer-aided instruction (CAI) exercise that is designed in accordance with human factors guidelines can lead to increased training efficiency by reducing stress and errors made on the part of the learner.

Hamel and Clark (1) developed a checklist based on five human factors principles found to contribute to good UCI as outlined by Williges and Williges (2). These five principles (brevity, consistency, flexibility, compatibility, and responsiveness) are made up of identifying characteristics that were embedded into an experimental training program, as they have never been formally studied, nor empirically assessed as to their contribution to UCI.

The objective of this research was to evaluate how subjects rated these characteristics' contribution towards ease of interaction and training gain and to develop a handbook for CAI designers with a weighted scoring technique based on these subject ratings.

METHOD

Forty-five subjects from the University of Central Florida voluntarily participated in this experiment. An IBM PC/XT with single floppy, hard disk drive, 640 KB memory, and color monitor was used to run the pretest, the CAI program embedding the UCI characteristics, and the posttest, accordingly, for each subject, on an individual basis. A questionnaire was developed using a seven-point Likert scale so that subjects could rate the perceived effectiveness of the UCI characteristics with regards to ease of interaction and training gain. Additionally, the questionnaire was converted to a handbook with illustrative examples for courseware designers to use in evaluating the user-computer interface of a CAI exercise.

RESULTS AND DISCUSSION

The data recorded was subjected to a full model multiple regression correlation analysis to determine the contribution of each category to ease of use of the CAI program. The results of the analyses indicated that each category significantly contributed to perceived ease of use of the CAI exercise. This empirically substantiates the principles proposed by Williges and Williges (2). Subjective ratings of the importance of each characteristic to ease of use and training gain were averaged for each of the five categories. Category means were used in a multiple regression analysis to predict actual training gain. Responsiveness contributed a significant amount of the variance in both sets of ratings. Consistency made a significant contribution to the variance when the ease of use ratings were analyzed.

The results provide a checklist with a weighted scoring method for the evaluation of CAI. The data also provides direction for future research.

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SECTION 1

INTRODUCTION

Learning new and involved information can be taxing enough without the added pressure of understanding the medium of instruction, especially in a computer oriented setting (3). A computer-aided instruction (CAI) exercise designed in accordance with human factors guidelines can help learners interact with the medium with reduced stress and errors. Therefore, the ease with which learners interact with the computer can contribute to the efficiency of processing students through computer based instruction. Thus, user-computer interface (UCI) is an important concept to be addressed in any CAI exercise so that training efficiency can be maximized.

Recently Hamel and Clark (1) developed a checklist of items which have been espoused by experts to contribute toward the ease with which trainees can interact with CAI systems. Hamel and Clark's (1) report cites numerous studies which recognize that the user-computer interface can contribute towards the acceptance of CAI by the user in order to maximize the utility of CAI (See Section VI, Bibliography). CAI designed with the best instructional technology can suffer from lack of acceptance by the user community due to a poorly designed UCI.

Poorly designed UCI may also promote processing difficulties for the trainee. In so doing, interference in assimilating information can have negative learning affects as well as demotivating the user to interact with a frustrating system. Therefore, UCI may directly affect training gain along with its impact upon training efficiency and user acceptance. Since the trainee is, in essence, an information processor, and since information processing is a necessary prerequisite for learning, UCI can directly affect both training gain (learning) and training efficiency. However, because learning is dependent upon processing information and computer interfaces provide the source of information, it is difficult to separate the impact of this information on learning independent from its effects upon training efficiency.

The checklist developed by Hamel and Clark (1) contains human factors design guidelines for CAI organized into five categories which are based on principles of UCI suggested by Williges and Williges (2). The checklist categories - brevity, consistency, flexibility, compatibility, and responsiveness - contain guidelines which support the principle. The guidelines were produced from a review of the behavioral research literature, existing UCI guidelines, and verbal reports of experienced CAI developers. The categorized checklist items were distributed to one expert each in the areas of computer software, education, and human factors for their review and comments. They provided constructive comments on the clarity and importance of items and their appropriateness to a given category. The authors used these comments to make appropriate modifications to the checklist. A checklist scoring method was developed which allowed quantitative measurement of those qualities of the UCI represented by the five checklist categories. The principles used to define the categories are described below.

Brevity is a concept that deals with shortness and conciseness. In particular, brevity is concerned with minimizing the amount of information to be attended to.

Consistency enables the learner to predict what is expected of him/her and is of particular interest in any training program. The format and the location on the screen where specific kinds of information are placed are kept constant. In this way, the learner should be able to relate more easily to the task at hand instead of being more concerned with sudden changes in the format.

Flexibility helps to meet the different and changing needs of the learner. Each individual interacting with the training program may have different preferences for mode of interaction as well as different learning abilities. Thus, flexibility can be built into a system to ensure that every learner has an equal opportunity to master the material at an appropriate pace and to be presented the material in an appropriate sequence.

Compatibility refers to the agreement between typical expectations and the manner in which information is presented. The learner should be able to interact with the computer in a manner which fits

preestablished conceptions. For example, red and green commonly suggest negative and positive meanings (i.e., incorrect/correct responses). Additionally, text is typically presented in a left-right sequence.

Responsiveness deals with providing the learner with informative feedback at the appropriate time. It also gives information to the student about the operations of the system. Responsiveness can be incorporated into a training program so that every individual knows where he/she stands and can choose a suitable path to fit one's own learning needs.

The following research was undertaken to meet several objectives: (1) to evaluate the contribution of these five principles to ease of interaction with a CAI program, (2) to determine the relative effectiveness of characteristics within each category in order to supply weights for each characteristic, (3) to determine the impact of characteristics on training gain, and (4) to develop a handbook for CAI designers describing and providing examples of each characteristic along with a scoring technique to evaluate CAI programs.

SECTION II

METHOD

SUBJECTS

Forty-five subjects having some college background participated in this research on a voluntary basis. These subjects were students and/or personnel from the University of Central Florida. There were 17 males and 28 females between the ages of 18 and 50 years. Two subjects were excluded because they failed to complete the ratings. Another three were excluded because they placed maximum subjective ratings in all categories for all characteristics of their evaluations. (It was felt that this data reflected a lack of diligence in providing evaluations on the part of these test subjects.) Two additional subjects were eliminated from the training gain part of the experiment as they obtained perfect pretest scores and would therefore not show any training gain.

MATERIALS

An IBM PC/XT with single floppy, hard disk drive, 640 KB memory, and color monitor served as the training workstation. The Trainer Turned Author authoring system (distributed by Raster Sciences, Inc.) was used to create the pretest and posttest as well as the CAI program.

The CAI program consisted of a series of graphic and text frames developed to instruct students in logic diagramming. The instruction consisted of translating verbal statements of formal logic syntax into graphic diagrams and translating graphic diagrams into verbal statements of formal logic. At the simplest level, the student is taught how to translate one verbal statement of formal logic into a graphic diagram. An example of a typical page of instruction from the training program as viewed by subjects is shown below in Figure 1.

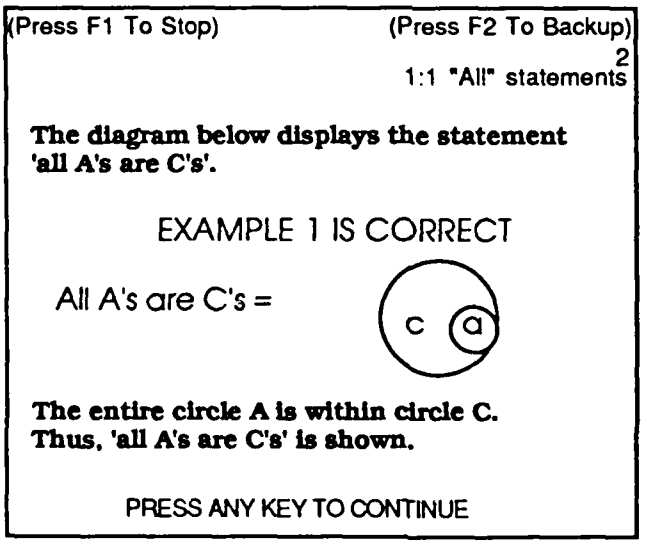

Figure 1. A Simple Instructional Frame from the CAI Program

At the most difficult level, the student is instructed how to translate seven verbal statements of formal logic into a graphic diagram. Figure 2, shown below, is another example from the training program depicting a typical page in a lesson sequence.

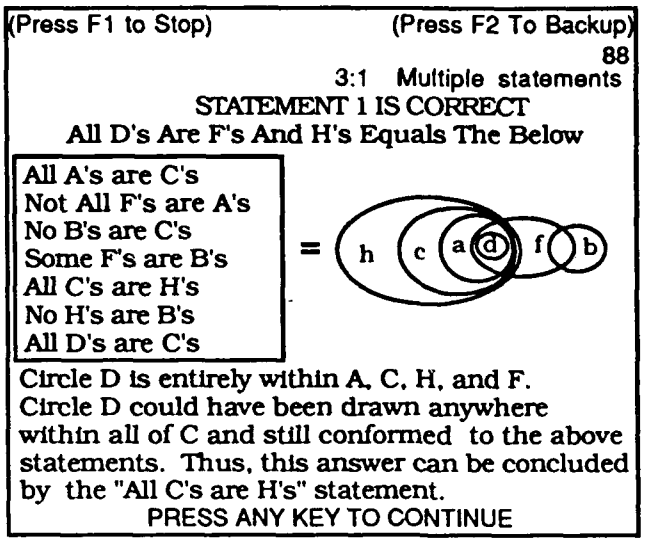

Figure 2. A Difficult Instructional Frame from the CAI Program

The instructional sequence progressed from the simplest to the most difficult as the examples of Figure 1 and Figure 2 demonstrate. It was assumed that no special skills were required of the college level students to complete the course of instruction.

A questionnaire incorporating a seven- point Likert scale for each characteristic was developed in order for subjects to subjectively weigh the contribution of each characteristic to training gain and to ease of use of the CAI program. This questionnaire was developed to also serve as a handbook for courseware designers to use in evaluating their CAI programs in terms of user-computer interface design.

PROCEDURE

All subjects read and then signed a consent form before participating in the research. The consent form emphasized that a subject could discontinue participation at any time without penalty and that all personal information would be kept strictly confidential. A statement of standard instructions concerning the objective of the experiment was given to each subject to read prior to participation.

First, each subject took a six-question pretest to assess his/her prior knowledge of logic diagramming, the topic presented in the CAI program. Subjects then underwent the training program which embedded the various UCI characteristics presented in Appendix A. Subjects were instructed to go through each of the four levels of the training program sequentially to ensure that they would view all of the UCI characteristics. Following completion, they took a posttest identical to the pretest to assess their gain in knowledge.

Following the posttest, each test subject then paged through the questionnaire of UCI features (see Appendix A). Each subject was presented with the categories of UCI characteristics in one of five counterbalanced orders so as to minimize any order of presentation effects of questionnaire items. For each item of the questionnaire, subjects judged the contribution of each feature by circling a number ranging from one to seven on a Likert scale. Each item was judged for contribution towards ease of use of the system. Following judgements on all characteristics for ease of use, subjects were instructed to record their judgements on each characteristic's contribution to training gain.

ANALYSIS

The simultaneous model for multiple regression correlation (MRC) analysis was selected for purposes of data analysis (4). This model is most appropriately used as compared to a hierarchical or stepwise model when there is no a priori rationale for ordering variables in terms of their importance (5). The first set of analyses is analogous to an item analysis whereby item to total correlations are obtained (6). The ratings for each characteristic in each category were correlated to the sum totals of all ratings for all subjects. The sum totals of all ratings for each subject were converted to *z* scores. This set of analyses was conducted to determine the contribution of each characteristic within each category to the total of all ratings.

A second set of analyses was conducted to compare ease of use and training gain category ratings to actual training gain. First, the ratings were averaged for each category. Then these averages were used in a multiple regression analysis which computed the relative contribution of each category variance to actual training gain. Two multiple regression analyses were conducted, one on the ease of use ratings and the second on the training gain ratings.

A power analysis was also conducted to determine the number of test subjects needed to obtain reliable results for large effect sizes. In an analysis of partial regression correlation coefficients, a power of .80 can be obtained for large effect sizes employing 40-50 test subjects. This determination of power was calculated employing the conventions described by Cohen (7). Additionally, a post hoc power analysis was conducted to aid in evaluating the potential for finding other characteristics which might yield significant results given that more test subjects are run. This post hoc analysis allows the experimenter to determine if characteristics having a medium effect size might prove to be significant in the event that additional test subjects are run or further research is conducted.

In the present context, a large effect size is associated with a partial variance of approximately .20. Therefore, effect sizes approximating .20 would have a power of .80 if approximately 40-50 test subjects were run. A medium effect size, in this context, is associated with a partial variance of approximately .09. To obtain a power of .80, given this effect size, approximately 90-100 test subjects would have to be run. A small effect size, in this context, is associated with a partial variance of .02. To obtain a power of .80, given this effect size, approximately 400 test subjects would have to be run. To have reliable large effects, in this study, 45 subjects were tested. To reliably detect medium and small effect sizes among the characteristics identified, an N of approximately 90-100 and 400 would be required, respectively. Running these large numbers of subjects was beyond the scope of this initial effort. However, by examining characteristics which have medium effect sizes, experimenters can get some insight as to the likelihood of certain characteristics proving to be significant upon further research or extensions of the present research.

SECTION III

RESULTS

TRAINING GAIN

On the average, there was a 52% improvement, as measured by pretest and posttest scores by subjects who completed the CAI logic diagramming program. The mean training gain for pretest scores was 52.58 and for posttest scores was 79.82, with a standard deviation of 25.99 and 20.85, respectively.

RATINGS OF EASE OF USE

The mean scores of ratings of the importance of checklist items to ease of use ranged from 4.35 to 6.35. Table B-1 provides the means and standard deviations of all ease of use ratings. The sums of all ratings for each subject were converted to *z* scores. These *z* scores were used in the multiple regression analyses performed on the ease of use data.

Full model multiple regression analyses (4) were conducted to determine the contribution of characteristics to the total ease of use variance. Likert Scale ratings for each characteristic within each category were correlated with the *z* scores obtained for each subject. Five multiple regression analyses were conducted, one for each of the five categories. Tables 1-5 show the results of these analyses. All of the categories had a multiple R significant at $p < .05$, indicating that the variances of all categories contributed significantly to the overall variation.

Effect sizes are represented by the partial r^2's in the last column. According to a power analysis, several items demonstrated large effects. That is, they contributed more than 20% (approximately) of their category variance. These items are marked by an asterik in the tables. Several items demonstrated medium effects. That is, they contributed more than 9% (approximately) of their category variance. These items are marked by a crossbar in the tables. The coefficients in the first column, which are directly correlated with the partial r^2's are the Beta weights used to derive the weighted scoring method for the CAI Evaluation Handbook (8).

TABLE 1. CONTRIBUTION OF INDIVIDUAL CHARACTERISTICS OF BREVITY TO EASE OF INTERACTION

	Regression Analysis					
Characteristic	Coefficient	Std. Error	T (DF=29)	Prob.	Partial r^2	
Text broken into meaningful chunks	0.24	0.09	2.58	.015	0.19	*
Seven to eight lines of text per screen	0.02	0.08	0.20	.842	0.01	
Graphics take up 15-25% of screen area	-0.01	0.05	-0.12	.903	0.01	
Menus have no more than 5-9 choices	0.07	0.08	0.86	.397	0.02	
Use of color, boxing, highlighting, and text style for important items	0.04	0.09	0.42	.678	0.01	
No more than 3-4 screens without interactivity	0.32	0.09	3.38	.002	0.28	*
Time required for a session is within attention span of audience	0.05	0.05	1.00	.324	0.03	
Sentences have simple syntax: active voice, not compounded	-0.06	0.08	-0.69	.493	0.02	
Data entries are no more than 8-10 characters	0.14	0.07	2.03	.052	0.12	†
Field width for each line is 40 characters or less	0.06	0.08	0.73	.473	0.02	
CONSTANT	-5.02					

Adjusted R Squared =0.84

R Squared = 0.88

Mulüple R = 0.94

Analysis of Variance					
Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	34.23	10	3.42	20.80	1.25E-10
Residual	4.77	29	0.16		
Total	39.00	39			

* = demonstrate large effect sizes (contribute more than approx. 20% of their category variance)
† = demonstrate medium effect sizes (contribute more than approx. 9% of their category variance)

TABLE 2. CONTRIBUTION OF INDIVIDUAL CHARACTERISTICS OF CONSISTENCY TO EASE OF INTERACTION

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=29)	Prob.	Partial r^2
Functionally alike screens are formatted in the same way	0.02	0.15	0.14	.89	0.01
When erased, functional areas are rewritten in the same order	0.31	0.18	1.74	.09	0.09 †
Consistent use of labels and graphics	0.01	0.11	0.12	.90	0.01
Critical information comes at beginning of message or centered on screen	0.12	0.11	1.03	.31	0.04
Constant delay of feedback	-0.08	0.09	-0.85	.40	0.02
Similarity in the way questions are asked and responses are made	0.18	0.13	1.35	.19	0.06
Overall structure is clear through use of menus and maps	0.06	0.06	0.98	.34	0.03
A symbol always has the same meaning	0.20	0.10	2.05	.05	0.13 †
Input prompts are always in the same area of display	0.10	0.12	0.78	.44	0.02
Page numbers shown in upper right-hand corner for multiscreen transactions	0.04	0.05	0.93	.36	0.03
CONSTANT	-5.66				

Adjusted R Squared =0.79

R Squared = 0.84

Multiple R = 0.92

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	32.86	10	3.29	15.53	4.13E-09
Residual	6.14	29	0.21		
Total	39.00	39			

† = demonstrate medium effect sizes (contribute more than approx. 9% of their category variance)

TABLE 3. CONTRIBUTION OF INDIVIDUAL CHARACTERISTICS OF FLEXIBILITY TO EASE OF INTERACTION

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=29)	Prob.	Partial r^2
Students can page back to review	0.16	0.12	1.31	.202	0.06
Students can exit lessons, return to menus, and exit the program	0.07	0.09	0.72	.478	0.02
Student has control over rate of presentation of frames	0.19	0.13	1.52	.138	0.07
Student can request more lengthy messages for further clarification	-0.14	0.16	-0.89	.381	0.03
Activities for diagnosis of skills already mastered	0.20	0.12	1.68	.104	0.09 †
Remedial exercises for skill deficiencies	0.06	0.14	0.42	.678	0.01
Modularized program allows student to begin at appropriate place	-0.00	0.12	-0.03	.979	0.01
Student can choose difficulty level of problems or exercises	0.09	0.11	0.84	.408	0.02
Student can correct input errors	-0.12	0.08	-1.53	.137	0.07
Student can choose an important option and implement it at any time	0.36	0.09	4.17	.001	0.37 *
CONSTANT	-5.04				

Adjusted R Squared =0.75

R Squared = 0.81

Multiple R = 0.90

Analysis of Variance					
Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	31.61	10	3.16	12.41	5.27E-08
Residual	7.39	29	0.25		
Total	39.00	39			

* = demonstrate large effect sizes (contribute more than approx. 20% of their category variance)

† = demonstrate medium effect sizes (contribute more than approx. 9% of their category variance)

TABLE 4. CONTRIBUTION OF INDIVIDUAL CHARACTERISTICS OF COMPATIBILITY TO EASE OF INTERACTION

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=25)	Prob.	Partial r^2
Response mode is appropriate to audience	0.06	0.07	0.87	.395	0.03
Students are required to use codes for responding only when necessary	0.08	0.07	1.20	.242	0.05
Visual information and tasks are presented graphically	0.06	0.08	0.77	.446	0.02
Where frames are labeled, title, not number is used for identification	-0.03	0.03	-0.81	.423	0.03
Input, output is consistent with user population stereotypes	0.06	0.04	1.36	.186	0.07
Menu options are listed by number where order of lessons is important	0.29	0.06	4.75	.001	0.47 *
A sample item is answered before quiz to clarify drill or test instructions	0.23	0.06	4.09	.001	0.40 *
Response is demanded while instructions are on screen	0.08	0.07	1.27	.216	0.06
Routing menus are limited to three levels	0.06	0.10	0.59	.563	0.01
Text is displayed row by row	0.04	0.12	0.33	.748	0.01
Opposite colors are used to make items distinct	0.03	0.05	0.75	.458	0.02

(table continues)

Characteristic	Regression Analysis Coefficient	Std. Error	T (DF=25)	Prob.	Partial r^2
Graphics are used for further clarification of text	0.03	0.09	0.29	.777	0.01
Menu selections are left justified and in columns	0.16	0.07	2.10	.046	0.15 †
Directions come before menu selections	-0.13	0.10	-1.40	.175	0.07
CONSTANT	-5.64				

Adjusted R Squared = 0.92

R Squared = 0.95

Multiple R = 0.97

Analysis of Variance Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	36.94	14	2.64	32.04	1.79E-12
Residual	2.06	25	0.08		
Total	39.00	39			

* = demonstrate large effect sizes (contribute more than approx. 20% of their category variance)

† = demonstrate medium effect sizes (contribute more than approx. 9% of their category variance)

TABLE 5. CONTRIBUTION OF INDIVIDUAL CHARACTERISTICS OF RESPONSIVENESS TO EASE OF INTERACTION

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=30)	Prob.	Partial r^2
Periodic feedback indicates normal operation when waiting	0.14	0.08	1.74	.09	0.09 †
Computer tracks response patterns and gives option to pursue remediation	-0.01	0.10	-0.13	.90	0.01
Feedback and directions are distinguishable from other text	0.09	0.05	1.80	.08	0.10 †
At higher levels, more lengthy feedback is delayed until end of session	-0.03	0.11	-0.27	.79	0.01
Pause after feedback allows consolidation of material	0.25	0.10	2.54	.02	0.18 *
Access to helps, references, or resources are easily available	0.15	0.09	1.70	.10	0.09 †
Feedback is response specific at beginning of training	0.14	0.10	1.35	.19	0.06
Takes no more than 5 seconds for text and graphics to fill screen	0.05	0.09	0.62	.54	0.01
More than one chance to give answer	0.21	0.07	2.84	.01	0.21 *
CONSTANT	-5.57				

Adjusted R Squared =0.81

R Squared = 0.85

Multiple R = 0.92

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	33.27	9	3.70	19.36	3.48E-10
Residual	5.73	30	0.19		
Total	39.00	39			

* = demonstrate large effect sizes (contribute more than approx. 20% of their category variance)

† = demonstrate medium effect sizes (contribute more than approx. 9% of their category variance)

LARGE EFFECT SIZES

In accordance with the power constraints placed upon the design and analysis of the experiment, those significant results for large effect sizes (i.e., $r^2 \geq .20$) are shown below.

Ease of Use Ratings on Individual Characteristics Related to Overall Ease of Use Score

The significant large effect size characteristics for ease of use ratings on individual characteristics related to overall ease of use scores are shown below.

Brevity. "Text broken into meaningful chunks" was found to account for 19% of Brevity's contribution to ease of interaction ($p < .015$). Also "No more than 3-4 screens without interactivity" accounted for 28% of Brevity's contribution to ease of interaction ($p < .002$).

Flexibility. "Student can choose an important option and implement it at any time" accounted for 37% of Flexibility's contribution to ease of interaction ($p < .001$).

Compatibility. "Menu options are listed by number where order of lessons is important" and "A sample item is answered before quiz to clarify drill or test instructions" accounted for 47% ($p < .001$) and 40% ($p < .001$), respectively, of Compatibility's contribution.

Responsiveness. "Pause after feedback allows consolidation of material" and "More than one chance to give answer" accounted for 18% ($p < .02$) and 21% ($p < .01$), respectively, of Responsiveness's contribution to ease of interaction.

MEDIUM EFFECT SIZES

Some characteristics that are categorized under a medium effect size do meet significance criterion *and some do not. Those which do meet an alpha criterion, however, do not meet* beta criterion or power criterion. Therefore, their reliability is questionable. Due to the nature of this screening experiment, it is felt that medium effect sizes are worthy of further research consideration employing a larger number of subjects.

Ease of Use Ratings on Individual Characteristics Related to Overall Ease of Use Score

The medium effect size characteristics of ease of use ratings on individual characteristics related to overall ease of use scores are shown below.

Brevity. "Data entries are no more than 8-10 characters" accounted for 12% ($p < .052$) of brevity's contribution to ease of use.

Consistency. "When erased, functional areas are rewritten in the same order" and "A symbol always has the same meaning" accounted for 9% ($p < .09$) and 13% ($p < .05$) of consistency's contribution to ease of interaction.

Flexibility. "Activities for diagnosis of skills already mastered" accounted for 9% ($p < .104$) of flexibility's contribution to ease of interaction.

Compatibility. "Menu selections are left justified and in columns" accounted for 15% ($p < .046$) of compatibility's contribution to ease of interaction.

Responsiveness. "Periodic feedback indicates normal operation when waiting", " Feedback and directions are distinguishable from other text", and "Access to helps, references, or resources are easily available" accounted for 9% ($p < .09$), 10% ($p < .08$), and 9% ($p < .100$) of responsiveness's contribution to ease of use, respectively.

COMPARISONS OF EASE OF USE AND TRAINING GAIN RATINGS

The mean scores of ratings of the importance of checklist items to training gain ranged from 3.24 to 6.63. Table B-2 provides the means and standard deviations of training gain ratings.

These ratings were used in a multiple regression analysis which averaged ratings in each category and then looked at the relative contribution of the category to actual training gain. The same type of regression analysis was done with the ease of use ratings, so that the two could be compared on their relationship to training gain. The results are shown in Tables 6 and 7.

Table 6 indicates that the responsiveness category contributed a significant amount of the variance ($p < .02$) accounting for 17% of the overall variation. The correlation was negative, i.e., the ratings of the importance of responsiveness to training gain were inversely related to actual training gain.

Table 7 indicates that two categories, responsiveness and consistency, contributed a significant portion of the variance ($p < .02$) accounting for 24% and 17% of the overall variation, respectively. The correlations were negative, i.e., the ratings of the importance of responsiveness and consistency to ease of use were inversely related to actual training gain.

TABLE 6. CONTRIBUTION OF TRAINING GAIN RATINGS OF MAIN CATEGORIES TO TRAINING GAIN

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=32)	Prob.	Partial r^2
Brevity	-0.28	0.28	-0.99	.33	0.03
Consistency	-0.29	0.29	-0.97	.34	0.03
Flexibility	0.21	0.18	1.19	.24	0.04
Compatibility	0.47	0.25	1.86	.07	0.10
Responsiveness	-0.74	0.29	-2.55	.02	0.17

CONSTANT 3.49

Adjusted R Squared =0.23

R Squared = 0.34

Multiple R = 0.58

Analysis of Variance					
Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	12.43	5	2.49	3.24	0.02
Residual	24.57	32	0.77		
Total	37.00	37			

TABLE 7. CONTRIBUTION OF MAIN CATEGORIES EASE OF USE RATINGS TO TRAINING GAIN

	Regression Analysis				
Characteristic	Coefficient	Std. Error	T (DF=32)	Prob.	Partial r^2
Brevity	0.25	0.24	1.03	.310	0.03
Consistency	-0.76	0.24	-3.20	.003	0.24
Flexibility	0.29	0.17	1.68	.103	0.08
Compatibility	0.45	0.32	1.39	.174	0.06
Responsiveness	-0.74	0.29	-2.53	.017	0.17
CONSTANT	3.01				

Adjusted R Squared =0.34

R Squared = 0.43

Multiple R = 0.65

Analysis of Variance					
Source	Sum of Squares	DF	Mean Square	F Ratio	Prob.
Regression	15.83	5	3.17	4.79	2.23E-03
Residual	21.17	32	0.66		
Total	37.00	37			

SECTION IV

DISCUSSION

The major issue of this research was the application of five human factors principles to the design of the user interface for CAI. A CAI program on logic diagramming was developed using characteristics of user interface design taken from Hamel and Clark (1). Subjects who completed the lessons showed an average of 52% improvement as measured by pretest and posttest scores.

Subjects were asked to rate the importance of interface characteristics used to design the CAI program after they completed the lessons. The results of the analyses of subjects' "ease of use" ratings of the CAI system indicated that each of the categories incorporated into the ratings checklist significantly contributed to the ease of use variance. Comparisons of mean ratings for each principle revealed insignificant differences between categories. The results suggest that the categories or principles of brevity, consistency, flexibility, compatibility, and responsiveness all significantly contributed to ease of use of a CAI system.

In conjunction with this research, a handbook was developed to explain the user interface characteristics and provide examples. The evaluation checklist, first developed by Hamel and Clark (1), was included in the handbook in a revised form. The checklist is intended to be used as a way to determine if known user interface characteristics have been incorporated appropriately into a CAI system. Based on the number of characteristics that have been implemented, scores can be obtained for each of the five categories listed above. With the assumption that some items in the checklist contribute more than others to ease of use, a weighted scoring method was desired to produce more accurate assessment measures. Subjects in the experiment were given the revised checklist as part of a handbook to use to rate the user interface of the CAI logic diagramming program. Weightings indicating the relative contributions of individual items were derived from the multiple regression analyses performed on the "ease of use" ratings. The Beta coefficients shown in Tables 1-5 were used to assign weights to the items in the checklist, and this revised scoring method has been incorporated into the CAI Evaluation Handbook (8).

Based on a power analysis, the majority of characteristics found to have made a significant contribution to their respective categories had large effect sizes; a few had medium effect sizes. Eight additional characteristics had medium effect sizes but were not significant. A majority of the characteristics demonstrating a medium effect may have been significant if another forty or fifty test subjects were run yielding a power value of .80. It is suggested that checklist items with both medium and large effect sizes be given special attention when conducting UCI research and evaluation. Future research is necessary to ascertain the importance of the characteristics demonstrating a medium effect size as a result of this experiment.

The remaining characteristics, which demonstrate small effect sizes, are nonsignificant; however, the weights derived provide a best estimate of their relative contribution to ease of use. When all of the characteristics in a category are pooled together, the category contributes significantly to the ease of use variance. New interface technologies are continuously under development. The contributions of new characteristics derived from these technologies may have greater effect sizes. Future research efforts may produce a greater return by focusing upon more recent technological developments, rather than studying the subtleties represented by the checklist items with small effect sizes.

Further analyses were conducted to determine if perceived ease of use is related to actual training gain in CAI. This question assumes that a system which is easier to use shall reduce frustration and interference in learning activities leading to improved training gain. Several characteristics listed in the checklist could be inferred to represent both a learning principle and an interface property, increasing the likelihood that ease of use would be significantly correlated with actual training gain. It was found that both ratings of responsiveness and consistency were negatively correlated with actual training gain. That is, the lesser the actual training gain accomplished during the lessons, the higher were the ratings of the perceived importance of responsiveness and consistency to ease of use. It may be that subjects who were having trouble learning the CAI material were most in need of a good user interface, and so rated the characteristics as more important. Along these lines, other investigators (9) have found an interaction

between student aptitude and training material format. In a controlled study, it was demonstrated that those with lower aptitudes benefited from the experimental formats more than higher aptitude trainees. Those with higher aptitudes learned better with the experimental formats, but not to the degree that the lower aptitude trainees did. Future research on UCI characteristics requires controlled experiments to test the actual contribution of UCI characteristics to learning. More objective measures of ease of use will be needed. Such measures could include human information speed, indicated by reaction time, as employed by Card, Moran, and Newell (10) in their Goals Operations Methods and Selection (GOMS) model. Another measure could be cognitive complexity measured by the number of productions required to efficiently interact with the device, as proposed by Kieras and Polson (11).

It is not surprising that the ratings of the importance of responsiveness to ease of use were found to be correlated with actual training gain. Several characteristics in that category pertain to feedback, which is obviously related to learning. In another set of analyses which correlated ratings of perceived training gain to actual training gain, similar results were found. Subjects' ratings of the importance of responsiveness to perceived training gain were found to be negatively correlated with actual training gain.

The similarity of subject ratings on ease of use and training gain suggest that subjects did not distinguish the characteristics along these dimensions. In the special case of the UCI for CAI systems, it may be impossible to separate these two properties. Future research must take into account the overlap of the human factors principles described in this research and well-documented learning principles. The human factors principles, based on human information processing theory, complement well-established theories of human learning.

In conclusion, the research provides validation of the human factors principles of user interface design proposed by Williges and Williges (2). The research also provides a weighted scoring method for a CAI evaluation checklist. Statistical analyses aimed at assessing the importance of individual checklist items revealed directions for future research. An issue of concern for future UCI research is the obvious overlap of learning principles and interface design principles based on human information processing theory.

SECTION V

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SECTION VI

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SECTION VII

APPENDIX A

CAI HANDBOOK/CHECKLIST ITEMS

The questionnaire was designed to obtain subjective evaluations of the training program. It was specifically designed to acquire reactions to the contributions of certain program characteristics towards ease of interaction. The questionnaire was also developed to serve as a handbook describing and providing examples of how each characteristic could be implemented in a CAI program. This handbook can be used by designers to evaluate the UCI of CAI programs which they create. The handbook/questionnaire was divided into the five major categories of brevity, consistency, flexibility, compatibility, and responsiveness. Each category has certain characteristics contained within it. The handbook/questionnaire contains descriptions of the specific characteristics as well as of the five major categories. Each characteristic is accompanied by an example of screens taken directly from the training program. A pair of seven-point Likert scales was provided on the bottom of each page which described a characteristic; this allowed the subjects to subjectively evaluate the characteristic's contribution towards ease of interaction and training gain. Figure A-1 provides an example page from the handbook.

The following is a list of those characteristics compiled by Hamel and Clark (1) plus some additional characteristics grouped by their respective categories.

Brevity

- Large portions of text are broken into meaningful "chunks." This minimizes the amount of information to be attended to at one time.
- No more than seven to eight lines of text per screen.
- Graphics displays take up 15% to 25% of the screen area.
- Main menus and submenus have no more than five to nine choices.
- Use of color, boxing, highlighting, and text style rather than blinking to focus attention on important items.
- No more than three or four text screens without interactivity.
- The time required for a typical session (or lesson) is within the attention span of the target audience.
- Sentences have simple syntax: active voice, not compounded.
- Data entries by the student are no more than eight to ten characters.
- The field width for each line is 40 characters or less.

Consistency

- Functionally alike screens are formatted in the same way.
- When functional areas are erased, they are consistently rewritten in the same order.

- Consistent use of labels and graphics keeps the same type of frames identified as such. Directions, instructions, example, and question screens each have their distinctive format.

- Critical information is always presented at the beginning of a message and centered on the screen.

- Students receive constant delay of feedback (no more than two seconds), rather than variable delays.

- Similarity in the way questions are asked and similarity in the way responses are made.

- The structure of the presentation is evident to the user through the use of menus and concept maps.

- A symbol has the same meaning all the time.

- Input prompts are positioned in the same area of display consistently.

- A page number is always shown in the upper right-hand corner of the display for multiscreen transactions.

Flexibility

- A page-back capability allows the student to review previous material.

- Students can easily exit lessons, return to menus, and exit the program.

- The student has control over the rate of presentation of frames.

- The student can request more lengthy messages if further clarifications are needed.

- The program contains activities for diagnosis of skills already mastered.

- There are remedial exercises for skill deficiencies.

- Modularized program (with menus) allows the student to begin at a point appropriate to past achievement.

- The student can choose the difficulty level of problems or exercises.

- The student can correct an input error (e.g., with BACKSPACE) or recover from input errors without disrupting the lesson sequence.

- The student is able to choose an option that is used often or is of critical importance and implement it at anytime.

Compatibility

- The response mode is appropriate to the target audience. Research has found that information that is presented auditorily is cognitively compatible with verbal responses. Likewise, information that is presented spatially is cognitively

compatible with motor responses. Thus, in a CAI program, motor responses are appropriate.

- Students are required to use codes for responding only when necessary, as in multiple choice answering (e.g., 1=yes, 2=no, is unnecessary coding).

- Visual information and visual tasks such as locating or repositioning are presented graphically. The trainee is asked in a CAI program to respond to information which is primarily visual, and consequently graphic or pictorial information should be presented throughout.

- Where frames are labeled, title, not number, is used for identification.

- Input, output is consistent with user population stereotypes (e.g. correct response feedback is in green).

- Where order of lessons is important, menu options are listed by number, not by letter.

- To clarify drill or test instructions, a sample item is answered before the drill or quiz begins.

- A response is demanded while instructions on how to respond are still on the screen.

- Routing menus are limited to a maximum of three levels.

- Text is displayed row by row, not in column formations.

- To make items distinct and separate from one another, opposite colors are used.

- Graphics and illustrations are used for further clarification of text.

- Menu selections available to the student are left justified and in column formation.

- Directions always come before the menu selections.

Responsiveness

- When the student must stand by, periodic feedback indicates normal operation.

- The computer tracks response patterns and gives the student the option to pursue further remediation if desired.

- Feedback and directions are clearly distinguishable from other text through the use of color, boxing, reverse video, etc.

- At higher mastery levels, students are given immediate knowledge of right and wrong responses, and more lengthy feedback is delayed until the end of the session.

- There is a pause after feedback, before the lesson continues, to allow time for consolidation of the newly acquired material.

- Access to helps, references, or resources are easily available.

- At the beginning of training, feedback is response specific. (e.g., "the — part of your answer is incorrect.")

- It takes no more than five seconds for text and graphics to fill the screen.

- The student gets more than one chance to give the answer (with prompts).

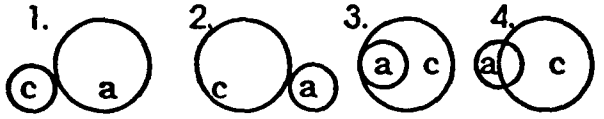
Fig. A-1. Example Page From Handbook

Examples:

1

(Press F1 To Stop) (Press F2 To Backup)
14

Some A's are C's = ?



Press selected number. Then press enter.

1. Set 1
2. Set 2
3. Set 3
4. Set 4

→ ENTER A NUMBER:___

2

(Press F1 To Stop) (Press F2 To Backup)

Submenu for Training Level 2

Press selected number. Then press enter.

1. Level 2:1 multiple diagrams of 'all' statements
2. Level 2:2 multiple diagrams of 'some' and 'not all' statements
3. Return to main menu for view of training levels

→ ENTER A NUMBER:___

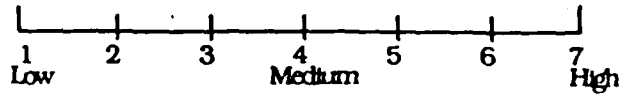
CHARACTERISTIC: Input prompts are positioned in the same area of display consistently.

DESCRIPTION: The input prompts are always centered on the bottom of each page. Thus, this is a signal to the user that a response of some kind is needed. The above examples illustrate this point with bold print and arrows.

Questions

1. Indicate how much this characteristic contributed towards the ease of interaction with the computer.

2. Indicate how much this characteristic contributed towards the amount that was learned.



SECTION VIII

APPENDIX B

MEANS AND STANDARD DEVIATIONS FOR EASE OF INTERACTION AND TRAINING GAIN RATINGS

TABLE B-1. MEANS AND STANDARD DEVIATIONS OF SUBJECTIVE EVALUATIONS FOR EASE OF INTERACTION

Characteristic	Mean	Std. Dev.
Brevity	5.74	0.95
Text broken into meaningful chunks	5.78	1.33
Seven to eight lines of text per screen	5.55	1.47
Graphics take up 15-25% of screen area	5.18	1.78
Menus have no more than 5-9 choices	5.95	1.18
Use of color, boxing, highlighting, and text style for important items	5.98	1.25
No more than 3-4 screens without interactivity	5.70	1.32
Time required for a session is within attention span of audience	5.33	1.47
Sentences have simple syntax: active voice, not compounded	5.93	1.35
Data entries are no more than 8-10 characters	6.10	1.22
Field width for each line is 40 characters or less	5.35	1.49
Consistency	5.79	0.90
Functionally alike screens are formatted in the same way	6.15	1.25
When erased, functional areas are rewritten in the same order	6.00	1.30
Consistent use of labels and graphics	5.83	1.24
Critical information comes at beginning of message or centered on screen	5.98	1.14
Constant delay of feedback	5.58	1.50
Similarity in the way questions are asked and responses are made	6.00	1.11
Overall structure is clear through the use of menus and maps	5.15	1.59
A symbol always has the same meaning	6.08	1.25

(table continues)

Characteristic	Mean	Std. Dev.
Input prompts are always in the same area of display	6.18	0.98
Page number shown in upper-right-hand corner for multi-screen transactions	4.35	1.98
Flexibility	5.74	1.10
Students can page back to review	5.68	1.44
Students can exit lessons, return to menus, and exit the program	5.50	1.71
Student has control over rate of presentation of frames	6.35	1.05
Student can request more lengthy messages for further clarification	5.53	1.55
Activities for diagnosis of skills already mastered	5.70	1.30
Remedial exercises for skill deficiencies	5.58	1.55
Modularized program allows student to begin at appropriate place	5.70	1.59
Student can choose difficulty level of problems or exercises	5.53	1.52
Student can correct input errors	5.68	1.59
Student can choose an important option and implement it at any time	5.70	1.51
Compatibility	5.62	0.84
Response mode is appropriate to target audience	5.50	1.26
Students are required to use codes for responding only when necessary	5.95	1.06
Visual information and tasks are presented graphically	5.93	1.35
Where frames are labeled, title, not number, is used for identification	4.48	1.81
Input, output is consistent with the user population stereotypes	4.50	1.80
Menu options are listed by number where order of lessons is important	5.58	1.34

(table continues)

Characteristic	Mean	Std. Dev.
A sample item is answered before quiz to clarify drill or test instructions	5.68	1.44
Response is demanded while instructions are on screen	6.20	1.11
Routing menus are limited to 3 levels	5.65	1.21
Text is displayed row by row	5.95	1.24
Opposite colors are used to make items distinct	4.95	1.84
Graphics are used for further clarification of text	6.08	1.21
Menu selections are left justified and in columns	5.68	1.21
Directions come before menu selections	5.98	1.07
Responsiveness	5.70	0.93
Periodic feedback indicates normal operation when waiting	5.95	1.22
Computer tracks response patterns and gives option to pursue remediation	5.80	1.32
Feedback and directions are distinguishable from other text	5.15	1.66
At higher levels, more lengthy feedback is delayed until end of session	5.65	1.46
Pause after feedback allows consolidation of material	5.78	1.21
Access to helps, references, or resources are easily available	5.90	1.10
Feedback is response specific at beginning of training	5.45	1.24
Takes no more than 5 seconds for text and graphics to fill screen	5.88	1.20
Student gets more than one chance to give answer	5.53	1.57

TABLE B-2. MEANS AND STANDARD DEVIATIONS OF SUBJECTIVE EVALUATIONS FOR TRAINING GAIN

Characteristic	Mean	Std. Dev.
Brevity	5.47	0.86
Text broken into meaningful chunks	5.66	1.38
Seven to eight lines of text per screen	5.26	1.20
Graphics take up 15-25% of screen area	5.53	1.16
Menus have no more than 5-9 choices	5.11	1.57
Use of color, boxing, highlighting, and text style for important items	5.61	1.24
No more than 3-4 screens without interactivity	6.00	1.19
Time required for a session is within attention span of audience	5.03	1.64
Sentences have simple syntax: active voice, not compounded	6.08	1.05
Data entries are no more than 8-10 characters	5.32	1.45
Field width for each line is 40 characters or less	5.11	1.43
Consistency	5.14	0.85
Functionally alike screens are formatted in the same way	5.95	1.11
When erased, functional areas are rewritten in the same order	5.61	1.31
Consistent use of labels and graphics	5.37	1.36
Critical information comes at beginning of message or centered on screen	5.32	1.30
Constant delay of feedback	5.39	1.55
Similarity in the way questions are asked and responses are made	5.58	1.27
Overall structure is clear through the use of menus and maps	4.53	1.59
A symbol always has the same meaning	5.34	1.51

(table continues)

Characteristic	Mean	Std. Dev.
Input prompts are always in the same area of display	5.08	1.28
Page number shown in upper-right-hand corner for multi-screen transactions	3.24	1.76
Flexibility	5.29	1.33
Students can page back to review	4.74	2.15
Students can exit lessons, return to menus, and exit the program	4.32	2.23
Student has control over rate of presentation of frames	6.39	1.15
Student can request more lengthy messages for further clarification	5.53	1.87
Activities for diagnosis of skills already mastered	6.21	1.23
Remedial exercises for skill deficiencies	6.03	1.35
Modularized program allows student to begin at appropriate place	4.74	1.83
Student can choose difficulty level of problems or exercises	5.42	1.67
Student can correct input errors	4.58	2.13
Student can choose an important option and implement it at any time	4.97	1.79
Compatibility	5.08	0.93
Response mode is appropriate to target audience	4.95	1.54
Students are required to use codes for responding only when necessary	5.00	1.51
Visual information and tasks are presented graphically	6.24	1.05
Where frames are labeled, title, not number, is used for identification	3.47	1.59
Input, output is consistent with the user population stereotypes	4.00	2.03
Menu options are listed by number where order of lessons is important	4.50	1.61

(table continues)

Characteristic	Mean	Std. Dev.
A sample item is answered before quiz to clarify drill or test instructions	6.39	1.05
Response is demanded while instructions are on screen	5.84	1.57
Routing menus are limited to 3 levels	4.42	1.48
Text is displayed row by row	5.61	1.42
Opposite colors are used to make items distinct	4.47	1.90
Graphics are used for further clarification of text	6.63	0.75
Menu selections are left justified and in columns	4.71	1.35
Directions come before menu selections	4.84	1.57
Responsiveness	5.45	0.87
Periodic feedback indicates normal operation when waiting	3.71	1.94
Computer tracks response patterns and gives option to pursue remediation	5.97	1.37
Feedback and directions are distinguishable from other text	4.74	1.72
At higher levels, more lengthy feedback is delayed until end of session	5.95	1.35
Pause after feedback allows consolidation of material	5.95	1.11
Access to helps, references, or resources are easily available	5.16	1.64
Feedback is response specific at beginning of training	6.11	0.98
Takes no more than 5 seconds for text and graphics to fill screen	5.39	1.44
Student gets more than one chance to give answer	6.11	1.45

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Aberdeen Proving Ground, MD 21005-5001

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ATTN: Dr. Edgar Johnson
5001 Eisenhower Avenue
Alexandria, VA 22333

Chief, U.S. Army Research Institute
ATTN: Dr. Hiller
5001 Eisenhower Avenue
Alexandria, VA 22333

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Analysis Division 1-WHA
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White Sands Missile Range
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Army Training Support Center
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USAFA, CO 80840

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Randolph AFB, TX 78150-5001

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USAFA, CO 80840

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Cameron Station
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Scientific Advisor
Washington, DC 20380

Institute of Defense Analysis
Science and Technology Division
ATTN: Dr. Jesse Orlanski
1801 Beauregard Street
Arlington, VA 22311

National Defense Institute
Research Directorate
Ft McNair, DC 20319

OUSDR&E (E&LS)
ATTN: Dr. Earl Alluisi
The Pentagon
Washington, DC 20301-3080

Director, TPDC
3280 Progress Drive
Orlando, FL 32826

U.S. Coast Guard
Commandant (G-KOM-1)
Washington, DC 20590

DASD (MM&PP/Tng Policy)
ATTN: Mr. Gary Boycan
The Pentagon, Rm 3B930
Washington, DC 20301-4000

Institute for Simulation and Training
ATTN: Dr. L. Medin
P. O. Box 25000, Bldg #534
Orlando, FL 32816-0544

Nasa Ames Research Center
ATTN: Mr Michael Vidulich
Moffett Field, CA 94035

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