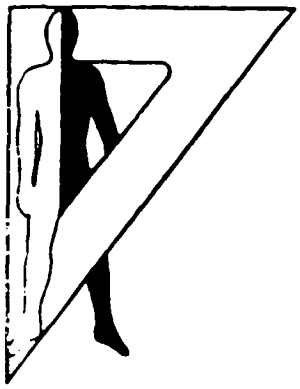
(4)



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Technical Note 8-88

TEXT-EDITING PERFORMANCE AS A FUNCTION OF SCREEN SIZE: A PILOT STUDY

Clifford C. Baker

October 1988
AMCMS Code 612716.H7000700011

U. S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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A pilot study was performed to experimentally assess the implications of (CRT) screen size and definition on text-editing performance. The study manipulated line length (16, 32, and 64 characters displayed per line), window height (1, 4, 8, and 19 line text pages), and edit field location (text to be edited was located at the beginning, middle, or end of text messages) to measure effects on text-editing performance as measured by edit field location time, editing time, and errors. Of these, text location time and location errors (as measured by vertical scroll reversals) were significantly influenced by line length and edit field location.

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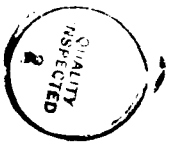

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INTRODUCTION

Computer interface has become a necessary element of a soldier's job. Much of the new and developing tactical equipment, including weapons, sensors, and communications devices, requires that the soldier knows how to access, edit, or otherwise modify information resident in a computer. One aspect of this data acquisition and input task concerns the presentation of information on a computer screen. Information acquisition may be affected by the height of the text window, the width (character string length) of the line, and the length of the text. These in turn determine the amount of information presented on a page of text. Human performance data concerning these display elements, in the context of retrieval of text-embedded data, can have significant implications for computer interface display design. This will particularly be the case where constraints on display size may exist, such as in portable and transportable military hardware. Research that will identify screen design elements associated with text-editing performance is required. These data will be valuable in the generation of soldier-computer interface design requirements and criteria and in the conduct of design trade-off studies.

A previous study (Larkin, 1987) manipulated window height (number of lines presented per page) and message length to study their effects on text-editing performance, using error rates, text-locating time, text-editing time, and total time on task as dependent measures. In the Larkin study, no significant main or interaction effects were found for window height. There were significant effects for message length, both for mean locating time and mean total time. A logical extension of the above study is to expand the design to examine the effects of line length (characters per line), window height (lines presented per page), and edit field location on text-editing performance.

A pilot study was performed to experimentally assess the implications of the above on text-editing performance. This pilot study manipulated line length (16, 32, and 64 characters per line), window height (1, 4, 8, and 19 line text pages), and edit field location (beginning, middle, and end of text message) to measure effects on text-editing performance by edit field location time, editing time, and errors.

METHOD

Objectives

The objectives of this investigation were to conduct a pilot study to experimentally compare the effects of line length and window height on text-editing task performance and to identify issues for future research.

Subjects

Nine civilian personnel served as subjects for this study. Seven subjects were employees of Carlow Associates Incorporated, and two were

employees of the Human Engineering Laboratory, Aberdeen Proving Ground, Maryland. Four subjects were female and five were male. All had experience and familiarity with a QWERTY typewriter keyboard. Each subject was tested individually in a session that lasted about 1 hour.

Apparatus and Materials

Stimulus messages were presented to subjects on an Apple® Macintosh™ Plus microprocessor and display. The processor contained an internal clock. Subjects interacted with a modified Macintosh™ keyboard that had edit function keys and cursor control keys. These special keys were created so that the apparatus and procedures in this pilot study would approximate those that were used in the Larkin (1987) study. Data were logged using an Apple™ ImageWriter II printer with a 20-foot serial cable for remotely locating the printer from the test subjects. Data were also stored on an 800-kilobyte disk drive. The test software, which ran under Microsoft® BASIC, was also contained on this drive.

The modified keyboard used in the study is shown in Figure 1. Nine key functions were modified and labeled for subject use. These modifications included the following:

- four cursor keys (up, down, left, and right)
- four edit function keys (insert word, insert character, delete word, and delete character)
- a DONE key to exit edit mode and proceed to next edit task

Text Displays

All edited displays were presented on the Macintosh™ monitor. Displays were generated by the experimental software for all combinations of window height and line length. All text messages were about 1300 characters in length. All text displays were single-spaced and left-justified. Text was displayed in black characters over a contrasting white background. Text font was monospaced (nonproportional) Monaco (resident in Macintosh™ operating system), 12-point plain. The active text editing window height was demarcated by a line above and a line below the displayed text field. Regardless of window height, the first line of text appeared on the first line of the monitor. Each of the three line lengths was centered in the display window. Figures 2, 3, and 4 demonstrate text appearance for 3 of the 12 window height by line length text display areas.

Cursor position was indicated by a flashing of the character over which the cursor resided. A cursor positioned over a space was indicated by a flashing "•" (see Figure 3). For word or character insertions in the text field, a special insertion character was used to indicate insertion point. Figure 4 demonstrates this insertion character.

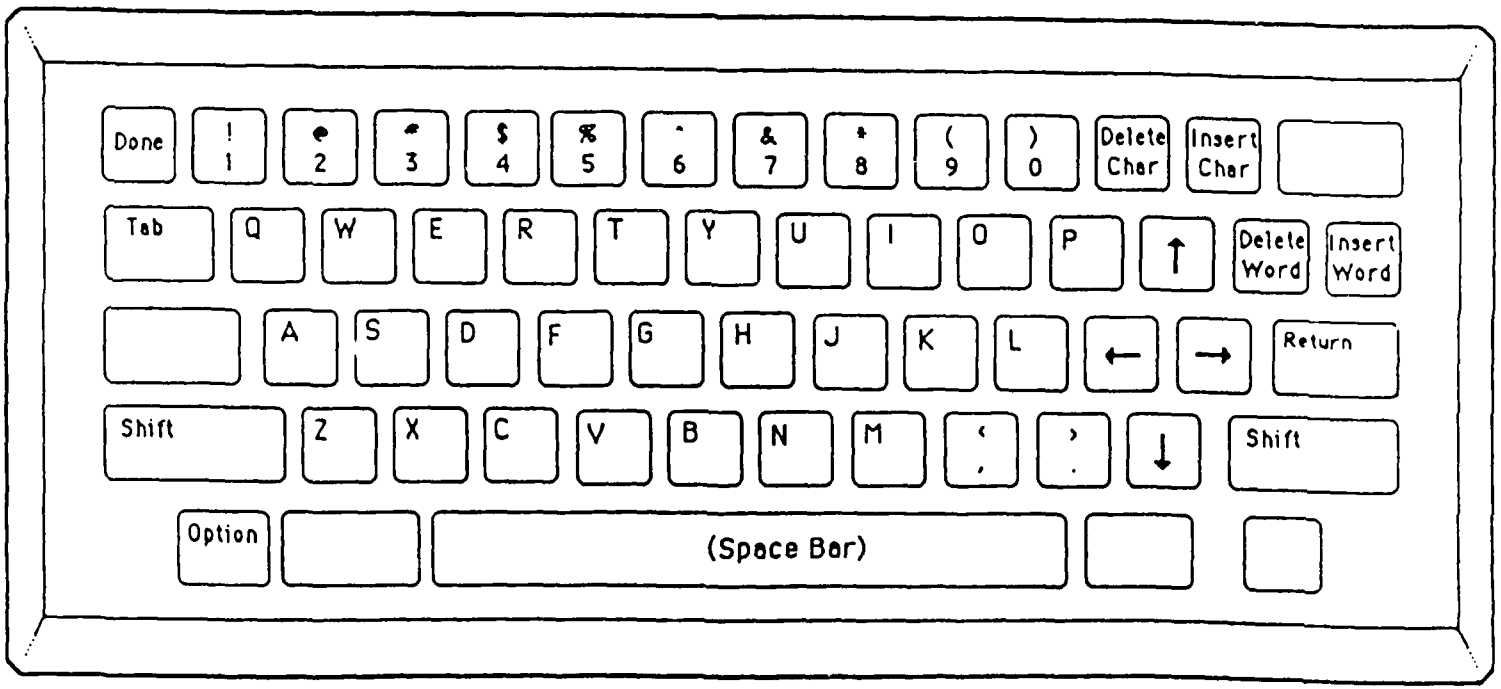

Figure 1. Modified keyboard (blank keys unused).

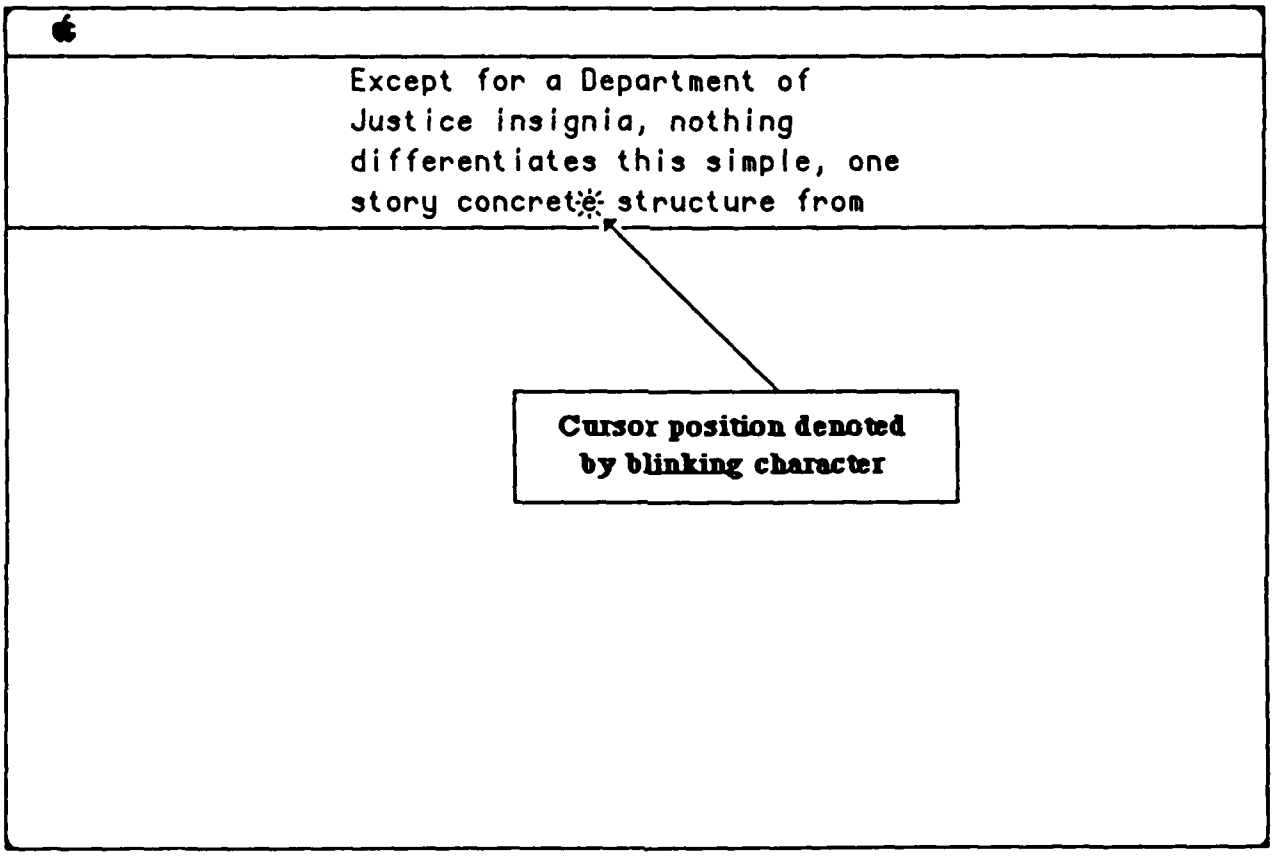

Figure 2. Example of screen display with cursor positioned over a letter (32 characters per line by 4 lines per page).

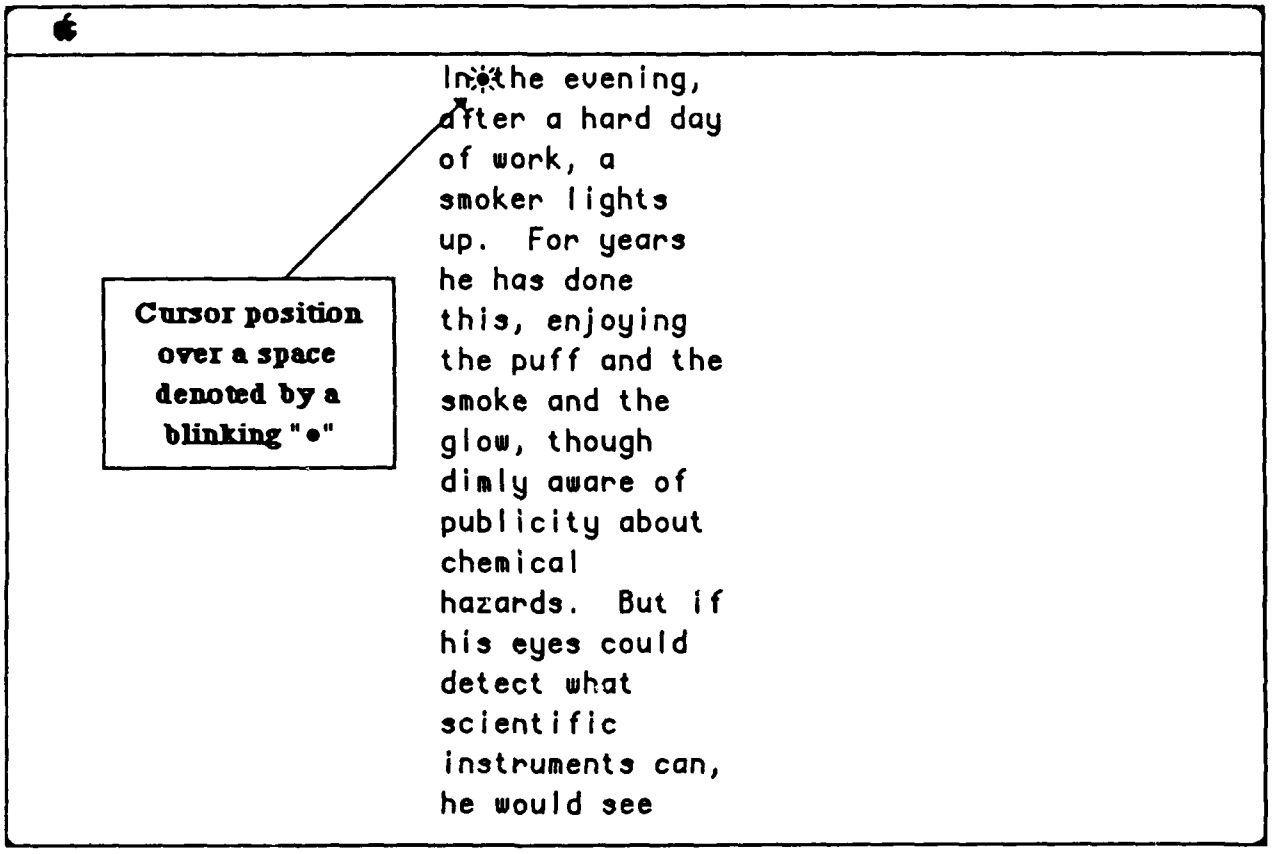

Figure 3. Example of screen display with cursor positioned over a space (1o characters per line by 19 lines per page).

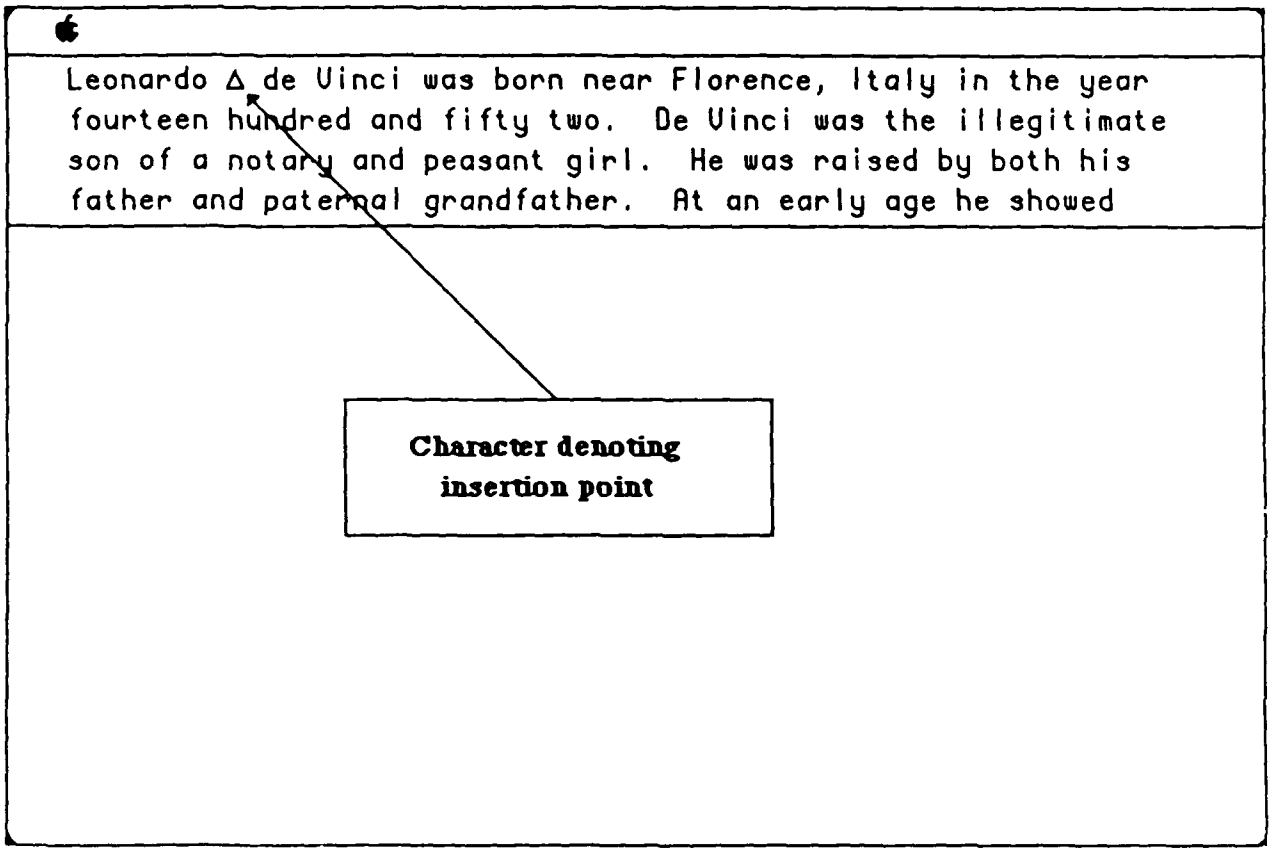

Figure 4. Example of screen display with insertion symbol (64 characters per line by 4 lines per page).

Text Editor

A limited function text editor was written in Microsoft® BASIC. This editor provided the following text editing functions:

- text display
- cursor movement
- edit functions (insert or delete words or characters)
- exit

During the interval between text presentations, the experimental software

(1) read into memory the text of the next message to be edited,
(2) partitioned the text into the appropriate line length segments (up to 16, 32, or 64 characters, including blanks) and stored these in an array, and
(3) displayed the appropriate number of lines (window height) on the display screen.

The text was partitioned such that the lines were up to 16, 32, or 64 (as appropriate) characters without splitting words. Hyphenations were not used. During editing, the software monitored the keyboard for inputs. While in the cursor mode, all keys except the cursor direction keys were ignored. Cursor key depression invoked a routine that moved the cursor position to the appropriate location (one character left or right, or one line up or down). Scrolling up or down through text, when at the top or bottom of a window, invoked a screen move (window scroll) of up or down one line and the print of the new text line. Screen scroll time was immediate (about the same length as it took to write a single character to the screen).

The edit mode was entered by pressing and holding down the OPTION key and then pressing one of the four edit function keys. Word or character insertions occurred at the character position to the immediate left of the cursor position. When entered, the text on the edit line separated one character position and the insertion character appeared. For character insertion, one subsequent keystroke replaced the insertion character, closed the text, and exited the edit mode. For a word insertion, subsequent keystrokes inserted characters appropriate to the keystroke, separated the text line, and reprinted the insertion character. Exiting the word insertion edit mode required a stroke of any cursor direction key or the DONE key. These resulted in removal of the insertion character and closure of the text line. In the case of word insertion, a leading or trailing space had to be inserted along with the inserted characters. In the case of word or character deletion, the option key along with the DELETE WORD or DELETE CHAR was depressed. To delete a character, the cursor had to be placed directly over the character to be deleted. Depression of the OPTION key along with the DELETE CHAR key immediately deleted the character and exited the edit mode. To delete a word, the cursor had to be placed anywhere within the word (continuous string of nonblank characters) to be deleted. Depression of the OPTION key along with the DELETE WORD key immediately deleted the entire word, along with its trailing blank, and then exited the edit mode. At any time after screen presentation of the text, use of the DONE key terminated both the text scroll mode or the edit mode, initiated data logging and storage, and prepared the next message to be displayed and edited.

Subject Tasks

For each subject, the four editing tasks were performed under each combination of window height (1, 4 , 8, and 19 lines of text displayed per page), line length (16, 32, and 64 characters per line of text) and edit field location (beginning, middle, or end of text). There were, therefore, 3 by 3 by 4, or 36 combinations of text presentations. Each subject was exposed to 36 messages of approximately equal length. The text for the messages was taken from articles in Reader's Digest.

Each of the 36 stimulus messages was presented to subjects both on 8-1/2 by 11 inch sheets of paper and on the Macintosh™ monitor. Each printed sheet was marked with an editing comment indicating the text editing that the subjects were to make. An example of a printed edit message is presented as Figure 5. Three different orders of message presentation were used. For each order, printed messages were contained in a three-ring binder.

Procedures

Briefing

Each subject was given an overview of the experiment describing the purpose of the study and the procedures to be used (see Appendix).

Training

Each subject received a description of the editing tasks to be performed (word insertion, character insertion, word deletion, character deletion, cursor movement, and text scrolling). The exact messages to be edited, along with the edit annotations, were presented to the subject in book form. Use of the edit message book was explained to each subject. The experimenter demonstrated each type of editing task, using four demonstration text messages contained in the edit message book. Once this was complete and the subject understood use of the keyboard and the nature of the editing tasks, subjects performed eight practice editing tasks, two each of word deletion, word insertion, character deletion, and character insertion.

Testing and Data Collection

After the eight training edit messages were completed and the subject asked any questions and ultimately asserted he or she understood the task, the experimenter left the subject to complete the 36 editing tasks in the book. Distribution of the tasks (delete word, insert word, etc.) was random throughout the messages. Presentation order of line length and window height was counterbalanced. As each message was edited, as signified by the subjects' depression of the DONE key, the cathode-ray tube (CRT) screen blanked. After 3 seconds, the message "Press Space Bar to Continue" appeared on the screen.

When the space bar was depressed, the next text message appeared on the screen, and the subject turned to the next page of the text edit message book to identify the text passage to be located and edited.

Upon completion of all messages, the CRT screen blanked, and the message "Thank you, this session is over. Please go to test director" appeared on the screen.

Drivers are entering a new golden age of the automobile. After more than a decade of pursuing drab, utilitarian goals automakers are tempting consumers with an array of high tech innovations, from fluorescent dashboards to computerized gears to hood raindrop detectors that automatically activate the windshield wipers. By the nineties, the most advanced cars may be shaped more alike than are the cars of today, as they converge on an aerodynamic ideal that makes them look like fish without fins. But each will be a custom car underneath. Evolving between driver and car is a network of computer controls that will make the car better able to heed the drivers instructions, adjust to road conditions, and rescue the driver from mistakes. Such cars should be more fun to drive, more economical to operate, and less bother to own. The automotive electronics revolution has brought an explosion in passenger compartment amenities, among them computerized rear view mirrors that adjust automatically to day and night driving, and memory seats that automatically assume the settings four different drivers prefer. With a trip computer, available in cars today, a driver can monitor gas mileage and the outside temperature, and find out how much time will pass before he reaches his destination.

INSERT THE WORD " many "

Figure 5. Example of printed text showing editing to be performed.

Data collection and storage

All data were automatically captured and stored by the experimental software. Data collected and stored for each message edited were as follows:

- **file record number** - a random access file structure is used
- **subject identification number** - subjects are numerically identified
- **counterbalance order**
- **number of characters/line** - 16, 32, or 64
- **number of lines/page** - 1, 4, 8, or 19
- **text message number**
- **locating time** - clock begins upon initial presentation of text; clock stops when edit mode initially entered
- **edit time** - internal clock starts upon entering edit mode; clock stops upon depression of DONE key
- **total time on task** - sum of edit and locating time monitored; total of search and edit time
- **total keystrokes** - total number of keystrokes (cursor movement, edit task, DONE key) for each edit task
- **error assessment** - editing correctness was automatically assessed by the experimental software, as follows:
    - performs in-string search for incorrect text; if found, assigns an accuracy value of 0 (incorrect); also reports line number and character position of incorrect text
    - if not found, performs an in-string search of correct text; if correct text is found, assigns an accuracy value of 1 (correct); also reports line number and character position of correct text
    - if neither correct nor incorrect text string is found, incorrect editing is determined; assigns an accuracy value of 0, and also reports line number edited
    - in all cases, the text line edited is printed, as well as the correct and incorrect text strings (e.g., "incorrect string <--> correct string")
- **edit line number** - the line number of the text in which the edit field resided

An example of printed output for each edited message is presented as Figure 6.

```
----------------------------------------------------------------
 37
Subjt->2       Order->2      Chrs/Ln-> 64  WinHt-> 8     Edit Msg-> 14
Tot Tm-> 60   Loc Tm-> 59   Ed Tm-> 1      Keystrokes-> 74
Generral  <--->  General
Editing correct, ' General ' on line # 20 character position 31
Line befor editing--> 'factories.  The largest user, Generral Motors, has four thousand  '
Edited line read--> ' factories.  The largest user, General Motors, has four thousand  '
Edited line  12  lines below opening text window.
` ` v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v ^ ^ ^ ^ v > > > > > > >
. > > > > > > > .   . > > > > > > > > > > > > > > DC Quit
UP = 6          DOWN = 32     LEFT = 0       RIGHT = 34


----------------------------------------------------------------
 38
Subjt->2       Order->2      Chrs/Ln-> 16  WinHt-> 4     Edit Msg-> 16
Tot Tm-> 41   Loc Tm-> 38   Ed Tm-> 3      Keystrokes-> 99
oly  <--->  only
Editing correct, ' only ' on line # 84 character position 13
Line befor editing--> 'two was the oly   '
Edited line read--> ' two was the only   '
Edited line  80  lines below opening text window.
v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v
 v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v > > > > > > > > > .
> IC n Quit
UP = 0          DOWN = 83     LEFT = 0       RIGHT = 13


----------------------------------------------------------------
 39
Subjt->2       Order->2      Chrs/Ln-> 64  WinHt-> 19    Edit Msg-> 21
Tot Tm-> 22   Loc Tm-> 20   Ed Tm-> 2      Keystrokes-> 49
emprtiness  <--->  emptiness
Editing correct, ' emptiness ' on line # 12 character position 30
Line befor editing--> 'top-secret aircraft.  In the emprtiness of the desert, pilots    '
Edited line read--> ' top-secret aircraft.  In the emptiness of the desert, pilots    '
Edited line within opening text window.
v v v v v v v v v v v v v . > . . > . . > . . > ^ . > > > > > > > > > > > . . > . > > > . . .
DC Quit
UP = 2          DOWN = 13     LEFT = 0       RIGHT = 32
```

Figure 6. Example of printed output for each edited message.

EXPERIMENTAL DESIGN

Model

A 3 by 3 by 4 completely within-subjects analysis of variance (ANOVA) design was used, with each subject being exposed to each combination of line length (16, 32, or 64 characters per line), window height (1, 4, 8, or 19 lines per page), and edit location within the text (beginning, middle, or end). Presentation order of messages, window heights, and line lengths was counterbalanced. Figure 7 shows the experimental design.

Window Height (lines per page)	Edit Location: Beginning			Middle			End		
1	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9
4	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9
8	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9
19	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9	S1 to S9
	16	32	64	16	32	64	16	32	64
	Line Length			Line Length			Line Length		

(characters per line)

Figure 7. Experimental design.

Independent Variables

Independent variables for the study were line length (16, 32, and 64 characters per line), window height (1, 4, 8, and 19 lines per page), and text edit location (beginning, middle, or end of message).

Dependent Variables

To determine a sensitive measure of the effects of the experimental treatments, a number of measures were analyzed. These included edit field locating time, edit time, total time, edit errors, and scroll errors (scroll reversals).

RESULTS AND DISCUSSION

For this pilot study, an approximate analysis was completed in which a univariate analysis of the repeated-measures design was obtained for each independent variable by treating subjects as a random effect. The model is called a mixed-effects model, and the resulting analysis is a mixed-model analysis of a repeated-measures design. The following dependent measures were analyzed for each of the independent variables:

- total editing time
- edit field location time
- edit performance time
- editing correctness
- vertical scroll reversals (scrolls up)

The results of these ANOVAs are presented in Tables 1 through 5. Vertical scroll reversals were analyzed by reviewing the keystroke sequences data for each subject for each message edited. It appeared that subjects frequently "missed" the edit string and had to scroll up to find it.

As shown in the ANOVA tables, line length significantly influenced both edit field location time and total time, $F(2, 16) = 28.04$, $p<.001$ and $F(2, 16) = 14.46$, $p<.001$. Line length did not significantly affect edit performance time or editing correctness. As expected, edit location significantly influenced edit field location time and total time, $F(2, 16) = 126.74$, $p<.001$ and $F(2, 16) = 59.67$, $p<.001$. There were no significant interaction effects for total time, edit performance time, edit field location time, or editing correctness. Vertical scroll reversals were significantly influenced by line length, edit location, and by a line length by edit location interaction, $F(2, 16) = 9.19$, $p<.005$, $F(2, 16) = 11.96$, $p<.001$, and $F(4, 32) = 6.48$, $p<.001$. Interestingly, horizontal scroll reversals were not significantly influenced by any main effects or interactions.

Figures 8 to 12 graphically depict the above findings. Figure 13 presents mean times to locate text for all combinations of line length, window height, and edit location. Figure 14 presents means for vertical scroll reversals.

Two-tailed Bonferroni t statistics, using $\alpha = .05$ as the error rate per family of comparisons, were computed for the measures of location time and vertical scroll reversals and for the independent variables of line length and location of edit field in text. The number of comparisons (k) for each family was three (for example, 16 with 32, 16 with 64, and 32 with 64 for the line length family of comparisons). The error term for each factor (line length and place in text) and each measure (location time and vertical scroll reversals) was the within-subjects error term used in the calculation of the F statistics. Significant contrasts (mean differences criteria) for each of the above were computed to be as follows:

Location time as dependent variable (DV)
Line length differences between means: 2.38 seconds
Place differences between means: 3.37 seconds

Vertical scroll reversals as DV
Line length differences between means: 0.34 reversal
Place differences between means: 0.47 reversal

Table 1

Analysis of Variance With Total Time as Dependent Variable

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	*F* Ratio
S	8	5615.90	701.98	
LL	2	2231.15	1115.57	14.46*
LL x S	16	1234.56	77.16	
WH	3	293.53	97.84	0.37
WH x S	24	6346.32	264.43	
EL	2	25520.59	12760.30	59.67*
EL x S	16	3421.62	213.85	
LL x WH	6	653.81	108.97	0.87
LL x WH x S	48	6011.13	125.23	
LL x EL	4	2951.87	737.97	2.29
LL x EL x S	32	10290.75	321.58	
WH x EL	6	4285.46	714.24	0.86
WH x EL x S	48	39799.63	829.16	
LL x WH x EL	12	51916.72	4326.39	1.14
LL x WH x EL x S	96	363585.60	3787.35	
TOTAL	323	524158.64		

*$p<.001$

KEY

S = Subjects
LL = Line length
WH = Window height
EL = Edit location

Table 2

Analysis of Variance With Time to Locate as Dependent Variable

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	*F* Ratio
S	8	3423.52	427.93	
LL	2	2400.73	1200.37	28.04*
LL x S	16	685.04	42.81	
WH	3	49.65	16.55	0.16
WH x S	24	2416.45	100.68	
EL	2	23077.50	11538.75	126.74*
EL x S	16	1456.61	91.04	
LL x WH	6	284.93	47.49	0.49
LL x WH x S	48	4694.62	97.80	
LL x EL	4	2320.06	580.02	1.97
LL x EL x S	32	9402.82	293.83	
WH x EL	6	2972.41	495.40	0.80
WH x EL x S	48	29558.16	615.79	
LL x WH x EL	12	41516.78	4326.39	1.22
LL x WH x EL x S	96	271154.60	2824.53	
TOTAL	323	395413.88		

*p<.001

KEY

S = Subjects
LL = Line length
WH = Window height
EL = Edit location

Table 3

Analysis of Variance With Time to Edit as Dependent Variable

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
S	8	599.58	74.94	
LL	2	92.59	46.30	1.15
LL x S	16	646.54	40.40	
WH	3	156.15	52.05	0.71
WH x S	24	1757.26	73.21	
EL	2	62.04	31.02	0.41
EL x S	16	1187.85	74.24	
LL x WH	6	540.98	90.16	1.75
LL x WH x S	48	2470.19	51.46	
LL x EL	4	112.61	28.15	0.50
LL x EL x S	32	1803.84	56.37	
WH x EL	6	665.53	110.92	2.01
WH x EL x S	48	2641.46	55.03	
LL x WH x EL	12	1731.07	144.26	1.22
LL x WH x EL x S	96	11301.37	117.72	
TOTAL	323	25769.06		

KEY

S = Subjects
LL = Line length
WH = Window height
EL = Edit location

Table 4

Analysis of Variance With Editing Correctness as Dependent Variable
(SS and MS x 100)

Source of Variation	Degrees of Freedom	Sum of Squares (SS)	Mean Square (MS)	F Ratio
S	8	88.88	11.11	
LL	2	12.96	6.48	1.27
LL x S	16	81.48	5.09	
WH	3	13.27	4.42	2.69
WH x S	24	39.50	1.64	
EL	2	1.85	0.926	1.60
EL x S	16	9.26	0.578	
LL x WH	6	4.32	0.72	0.34
LL x WH x S	48	101.24	2.10	
LL x EL	4	1.85	0.46	0.0109
LL x EL x S	32	1353.71	42.30	
WH x EL	6	408.02	68.00	0.66
WH x EL x S	48	4914.20	102.37	
LL x WH x EL	12	5188.28	432.35	1.16
LL x WH x EL x S	96	35681.17	371.67	
TOTAL	323	47899.99		

KEY

S = Subjects
LL = Line length
WH = Window height
EL = Edit location

Table 5

Analysis of Variance With Vertical Scroll Reversals as Dependent Variable

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
S	8	37.33	4.66	
LL	2	16.12	8.06	9.19*
LL x S	16	14.04	0.87	
WH	3	0.18	0.06	0.03
WH x S	24	43.01	1.79	
EL	2	40.05	20.03	11.96**
EL x S	16	26.77	1.67	
LL x WH	6	4.07	0.68	0.42
LL x WH x S	48	77.32	1.61	
LL x EL	4	36.09	9.02	6.48**
LL x EL x S	32	44.57	1.39	
WH x EL	6	14.43	2.41	1.06
WH x EL x S	48	108.28	2.26	
LL x WH x EL	12	68.45	5.70	1.53
LL x WH x EL x S	96	358.24	3.73	
TOTAL	323	888.95		

*$p < .005$
**$p < .001$

KEY

S = Subjects
LL = Line length
WH = Window height
EL = Edit location

Considering these values and the data presented in Figures 8 through 14, the following summarizes statistical significance between pairs of means:

- for the line length factor and location time dependent variable, significant differences exist between 16 characters per line and 32 and 64 characters per line (mean differences 5.7 and 5.8 seconds), while contrasting 32 and 64 characters per line was not significant (mean difference = 0.01 second).

- for the place in text factor and location time dependent variable, all contrasts are significant (beginning - middle = 14.3 seconds, beginning - end = 20.4 seconds, and middle - end = 6.1 seconds).

- for the line length factor and vertical scroll reversal dependent variable, a significant difference exists between 16 and 64 characters per line (mean difference 0.42 reversal). Contrarily, 32 and 64 characters per line and 16 and 32 characters per line contrasts were not significant (mean differences 0.11 and 0.31 reversals).

- for the place in text factor and vertical scroll reversal dependent variable, a significant difference exists between the beginning and middle positions and the beginning and end positions (0.67 and 0.66 reversals). Contrarily, middle and position mean difference was significant (0.01 reversal).

Figures 8 to 12 show these differences clearly.

It is expected that the results of the main study, which will use a larger and more representative population sample, will be similar to the results obtained in this pilot study. If this assumption is true, then specific screen design guides can be identified for systems requiring similar user tasks that are restrained by screen size. Most interesting of these is the task-based trade-off of required response time (to locate a field) versus allowable error rate (scroll reversals, which suggests visual scanning and target location were affected by window definition). Where response time constraints exist, a line length of 32 or more characters would facilitate rapid location. On the other hand, where low error rates (detection/location failures) are required, shorter lines of text would better support the user. Therefore, the design guidance to be provided would have to be based on the response limitations imposed on the user.

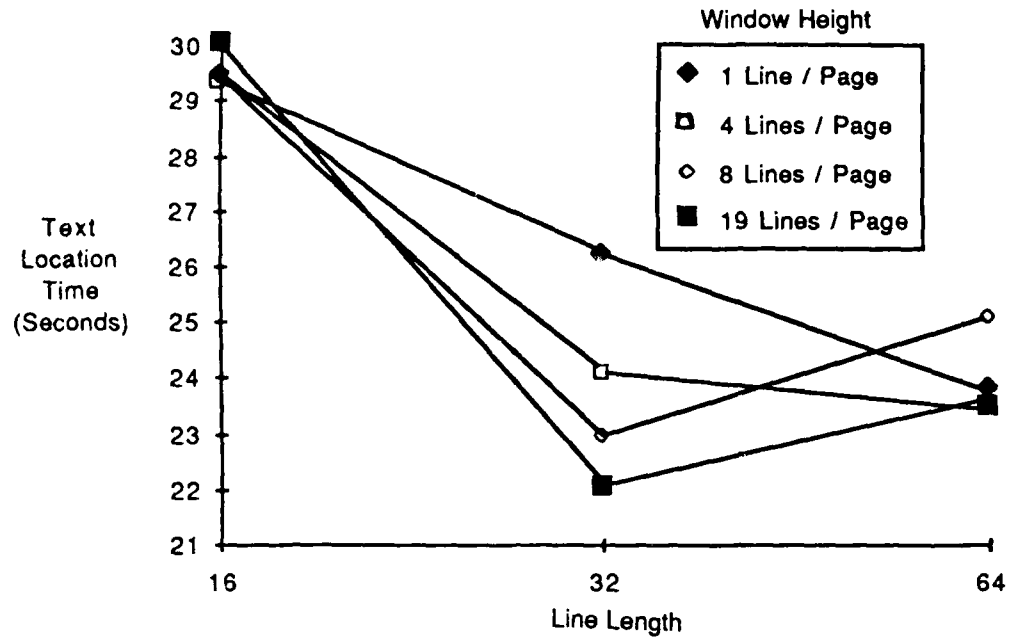

Figure 8. Mean times to locate edit field as a function of line length and window height.

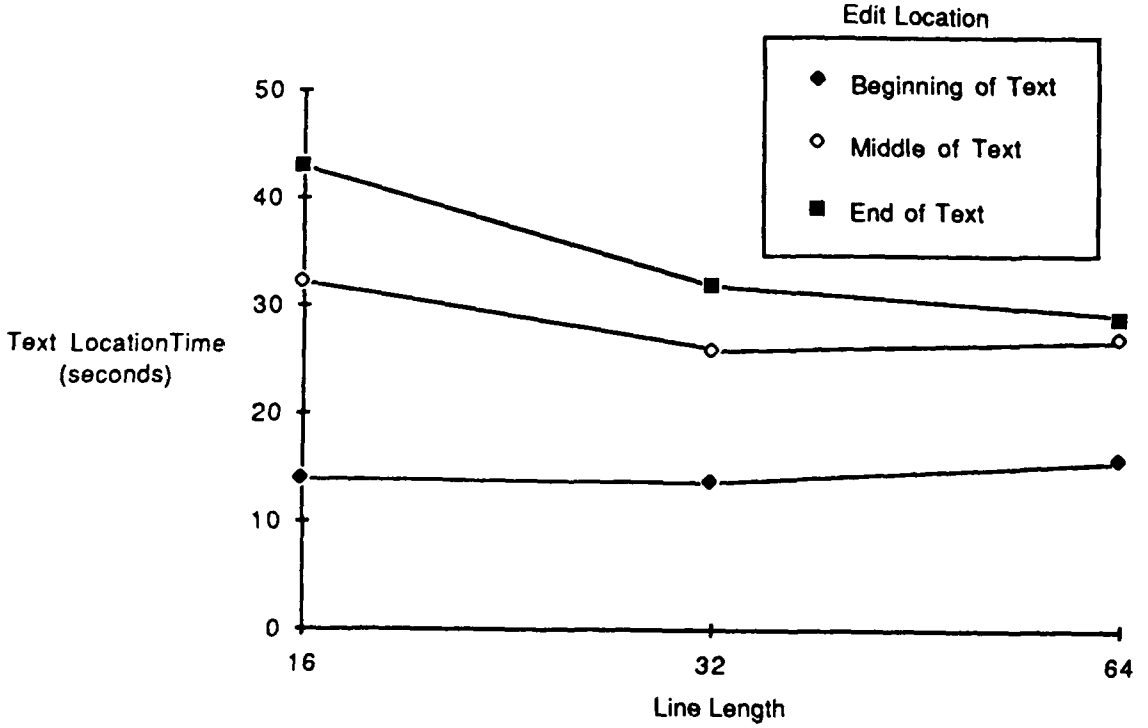

Figure 9. Mean times to locate edit field as a function of line length and edit field location in text.

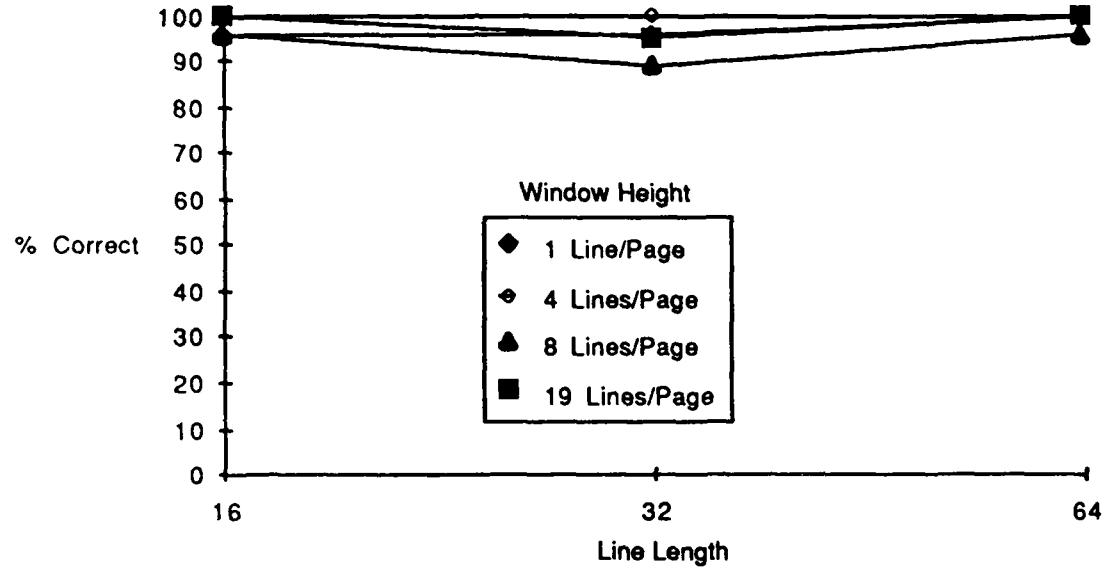

Figure 10. Mean percentage of correct editing as a function of line length and window height.

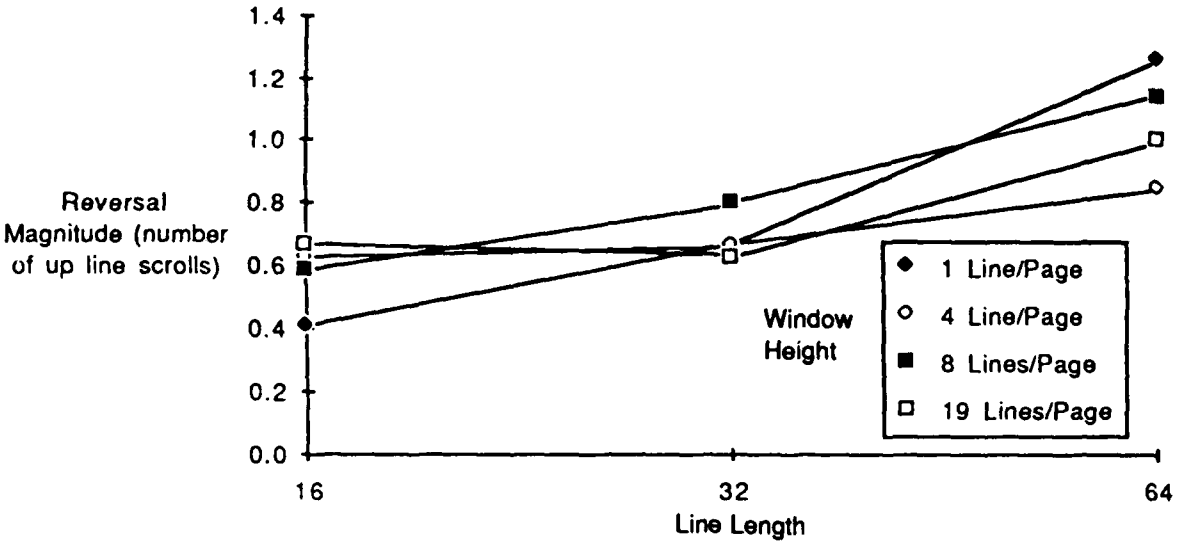

Figure 11. Vertical scroll reversals as a function of line length and window height.

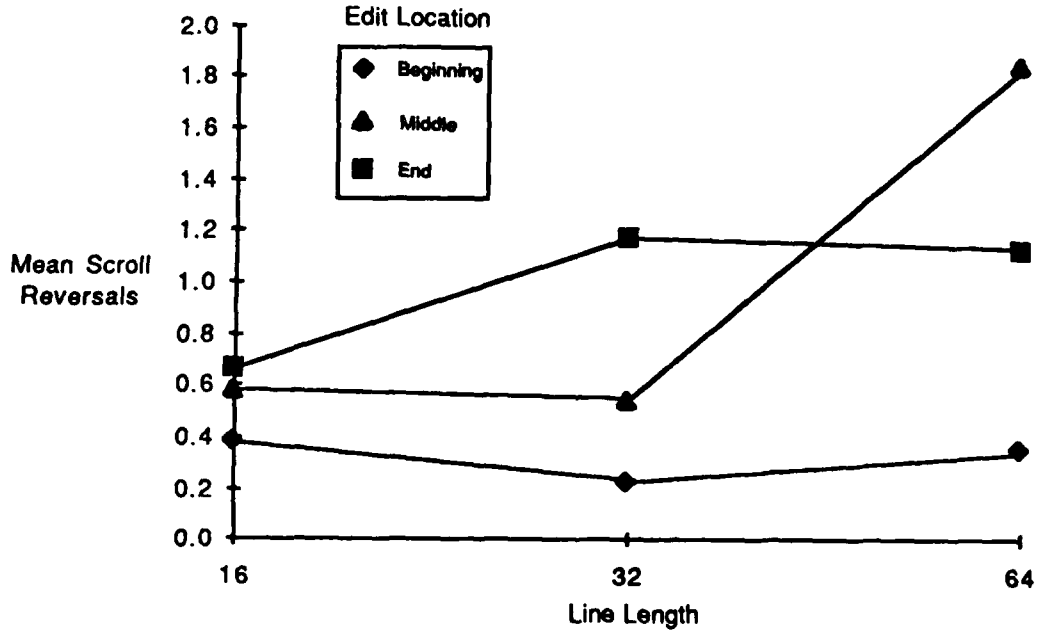

Figure 12. Vertical scroll reversals as a function of line length and edit field location.

Line Length

Edit Location	16	32	64	Mean
Beginning	13.6	13.7	16.0	14.4
Middle	33.1	27.5	25.6	28.7
End	42.7	32.4	29.0	34.8
Mean	29.7	23.9	24.0	**25.9**

Window Height

Line Length	1	4	8	19	Mean
16	29.4	29.4	30.5	29.5	29.7
32	26.3	23.0	22.1	24.1	23.9
64	23.8	25.8	25.5	23.4	24.0
Mean	26.5	25.8	25.4	25.7	**25.9**

Figure 13. Mean times to locate edit strings as a function of line length, window height, and edit location.

Line Length

Edit Location	16	32	64	Mean
Beginning	0.38	0.23	0.35	0.32
Middle	0.58	0.54	1.84	0.99
End	0.66	1.17	1.12	0.98
Mean	0.58	0.69	1.00	**0.76**

Window Height

Line Length	1	4	8	19	Mean
16	0.41	0.63	0.59	0.67	0.58
32	0.67	0.67	0.80	0.63	0.69
64	1.26	0.85	1.15	1.00	1.00
Mean	0.78	0.72	0.74	0.77	**0.76**

Figure 14. Mean vertical scroll reversals as a function of line length, window height, and edit location.

RECOMMENDATIONS

Based on the findings of the pilot study, the following recommendations are proposed for the main study:

1. Because it was found that the dependent measures of edit performance time and edit correctness were not significant, the two dependent measures to collect data should be edit field location time and vertical scroll reversals.

2. A completely within-subjects design will properly investigate the issue and will reduce the number of subjects required.

3. Because multiple dependent measures are being collected, a multivariate analysis of variance (MANOVA) should be performed on the data.

4. About 21 to 30 subjects should provide adequate power. The number used should be evenly divisible by 3 so that each message order is experienced equally. If a significant characters per line by edit location interaction exists using time to locate as a measure, it should be detectable with this number of subjects.

REFERENCES

Kirk, R. E. (1968). Experimental design: Procedures for the behavioral sciences. Belmont, CA: Wadsworth Publishing Company.

Larkin, M. M. (1987). Text-editing performance on a visual display screen as a function of window height and message length. (Technical Memorandum 1-87). Aberdeen Proving Ground, MD: Human Engineering Laboratory.

Myers, J. L. (1979). Fundamentals of experimental design. Boston: Allyn and Bacon.

Winer, B. J. (1971). Statistical principles in experimental design. New York: McGraw-Hill.

APPENDIX

INSTRUCTIONS TO SUBJECTS

(WELCOME)

WELCOME AND THANK YOU FOR COMING TODAY! This study will investigate people's abilities to use computer screens and keyboards. We are interested in understanding how people interact with computer screens. I will show you how to change information on the screen and then you will make changes to information on the screen. The information you see on the screen will also be printed on sheets of paper. These sheets will show you what changes you are to make by using the keyboard.

Your responses on the computer screen will be kept confidential. The entire test session will last about 1 hour. Do you have any questions? If you would like to participate in this study, please read and then sign this consent form. **(Hand the consent form to the person.)**

(TRAINING SESSION)

(Introduction) Now I will show you how to use the test equipment and how to use the test materials. After you feel that you understand how to use the equipment and the materials, you may practice what you have learned by completing some problems that are similar to the problems you will do in the actual test session.

(Training) I will now explain how to use the keyboard to make changes on the screen. **(Enter Subject ID#, select correct condition, and begin Demo session.)**

These are the keys you will use to move to the place on the screen where you want to make a change. The right arrow key moves the cursor to the right on the screen **(demonstrate)**; the left arrow key moves the cursor to the left on the screen **(demonstrate)**; the down arrow moves the cursor down the screen **(demonstrate)**; and the up arrow moves the cursor up the screen. Notice that when you use the right arrow cursor key to move the cursor all the way to the right side of the screen, if you want to then move the cursor down to the next line on the screen you must use the cursor down key **(demonstrate)**. There may be times when the information on the sheets of paper is longer than the amount of information that you can see on the screen. When this happens, you should use the down arrow key to allow the computer to show you the rest of the information. Do you have any questions so far?

This notebook contains the sheets of paper with the changes you will make to the information on the screens by using the keyboard. When I tell you to begin, you will open the notebook, turn to the first page to see what change you should make, and then make the change to the information on the screen. After you have made the change on the screen, you should press this key **(point to the DONE key)**, which is the DONE key. This key tells the computer that you have finished making the change and are ready to see the next sheet of information on the screen.

Now I will explain how to use the keyboard to make changes to information on the screen. This is the OPTION key **(point to key)**. Each time you want to make a change on the screen, you will need to hold down this key AT THE SAME TIME that you press another key. I will explain how to do this in a moment.

There are four kinds of changes that you will be asked to make. These changes are **INSERT CHARACTER, INSERT WORD, DELETE CHARACTER,** and **DELETE WORD.** You can use this cue card **(put out the cue card)** to help you remember which keys to use to make these changes.

(Insert letter demo). I will start by showing you how to insert a letter. If you want to INSERT a letter, or CHARACTER as it is often called, you first use the cursor keys to get to the place on the screen where you want to make the change. You should put the cursor on the character to the right of the place where you want to insert the new character, in other words, the letter will be inserted to the left of the cursor position. Then you hold down the OPTION key while you press the INSERT CHAR key at the same time. The text will separate and this pointer will appear. Then you type in the character that is written on the sheet in the notebook. The character is inserted at the point where the cursor is positioned. Then you press the DONE key.

(Insert word demo). Now I will demonstrate to you how to INSERT a WORD. **(Turn to the next page, explain the hand-written editing comment, and show how to make the change.)** If you want to INSERT a WORD, you first use the cursor keys, just as before, to get to the place on the screen where you want to make the change. You should put the cursor at the point where you want to insert the new word. Then you hold down the OPTION key and press the INSERT WORD key at the same time. Then you type in the word that is written on the sheet in the notebook. The new word will be inserted at the point where the cursor is positioned. Then you press the DONE key.

(Delete word demo). I will now show you how to DELETE a WORD. **(Turn to the next page, explain the hand-written editing comment, and show how to make the change).** If you want to DELETE a WORD, you must first move the cursor to the place on the screen where you want to make the change. You should put the cursor anywhere within the word you want to delete. Then you must hold down the OPTION key and press the DELETE WORD key at the same time. Then you must press the DONE key.

(Delete character demo). I will now demonstrate to you how to DELETE a CHARACTER. **(Turn to the next page, explain the hand-written editing comment, and show how to make the change on the screen.)** If you want to DELETE a CHARACTER, you must first move the cursor to the place on the screen where you want to make the change. You should put the cursor directly on the character that you want to delete. Then you must hold down the OPTION key and press the DELETE CHAR key at the same time. Then you must press the DONE key.

As I mentioned earlier, you can look at this cue card whenever you need help in remembering how to use the keyboard. Also, if you make a mistake in editing, you can correct it as long as you have not hit the DONE key. For example, if you delete the wrong letter, you can reinsert it using INSERT CHARACTER, and then delete the correct letter using DELETE CHARACTER.

Do you have any questions on how to use the keyboard? Do you have any questions on how to use the notebook and the keyboard together to make changes to information you will see on the screen? If not, you are now ready to practice what you have just learned. I'll be here to answer questions during the PRACTICE session but when you do the actual test session you will be left in the room alone. So please feel free to ask as many questions as you like during the practice session. You may now turn to the PRACTICE section of the workbook and work through the practice problems. **(Stay in the room and let the subject work the practice session.)**

(TEST SESSION)

VERY GOOD! Now you are ready to begin the actual test session. Please work at your own speed but be as accurate and quick as you can. When you have finished working through the notebook, please meet me back in the room where we met. You may turn the page of the notebook to the test section and begin. **(Leave the room and go around the corner to watch the printer. Before the person has completed all 36 trials, go back to the room to be ready to meet him or her there.)**

GREAT! You are finished.

Thank you very much for your participation. I have enjoyed having you.

EDIT FUNCTIONS CUE CARD

Cursor Keys (Arrows)	Used to move through the text. Also used to exit edit mode and enter cursor mode.
Option	Used to enter edit mode; used simultaneously with edit function keys (described below).
Option-Delete Char	Used to delete a single character. Place cursor directly over character to be deleted, then enter **Option-Delete Char**.
Option-Delete Word	Used to delete a complete word. Place cursor anywhere within word to be deleted, then enter **Option-Delete Word**.
Option-Insert Char	Used to insert a single character. Characters will be inserted to the immediate **left** of cursor position. Enter **Option-Insert Char**, and the insertion symbol will appear, then enter a single character.
Option-Insert Word	Used to insert a single word. Words will be inserted to the immediate **left** of cursor position. Enter **Option-Insert Word**, and the insertion symbol will appear, then enter the word to be inserted.
Done	Used to exit the edit mode and continue on to the next message to be edited.