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A COMPARATIVE ANALYSIS OF METHODS FOR TACTICAL DATA INPUTTING

Alison F. Fields, Richard E. Maisano, and
Charles F. Marshall

BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

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Nearly all information in tactical operations systems is input manually. Two problems that arise when manually inputting data are (a) the introduction of errors in translating information into computer format and (b) the introduction of a bottleneck in total system response time. Therefore, alternative methods of inputting data for accuracy and speed should be evaluated.

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Four methods were examined for speed and accuracy in inputting tactical messages concerning enemy activity into an Army computer format. The methods were (a) typing--the user types the appropriate codes into a message format; (b) typing with an error corrector--the computer automatically attempts to correct common spelling and/or typing errors; (c) menus--the user indicates which of the legal entries is desired from a list; and (d) typing with autocompletion and an English option--the user must type only sufficient characters to uniquely identify the item, using either the appropriate code or its English definition.

Thirty-two enlisted persons representative of the class of military personnel who might serve as input device operators input one of four sets of nine messages using each inputting method.

The use of menus was the most accurate inputting method. For users of limited experience (1 day of inputting), there were no differences in speed among the inputting methods.

Consideration should be given to the adoption of menus in tactical operation systems with a menu override option for experienced users. The use of an error corrector, autocompletion, or an English option is probably not warranted unless operational use shows a specific need for such an aid.

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A COMPARATIVE ANALYSIS OF METHODS FOR TACTICAL DATA INPUTTING

Alison F. Fields, Richard E. Maisano, and
Charles F. Marshall

Edgar M. Johnson, Work Unit Leader

BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

Submitted as complete and technically accurate, by:
Edgar M. Johnson
Technical Area Chief

Approved By:

A.H. Birnbaum, Acting Director
ORGANIZATIONS AND SYSTEMS
RESEARCH LABORATORY

Joseph Zeidner
TECHNICAL DIRECTOR

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

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Tactical Operations System

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FOREWORD

The Battlefield Information Systems Technical Area of the Army Research Institute (ARI) is concerned with the demands of increasingly complex battlefield systems that are used to acquire, transmit, process, disseminate, and utilize information. This increased complexity places greater demands upon the operator interacting with the machine system. Research in this area is focused on human performance problems related to interactions within command and control centers as well as on issues of systems development. Such research is concerned with software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor systems integration and utilization.

An issue of special concern within the area of user-oriented systems is the improvement of manual data input procedures, especially in the Tactical Operations System (TOS). The main source of information for tactical data systems is manual data entry--a slow, error-prone process. The capability of tactical data systems such as TOS to support command staff actions with accurate, complete, and timely information is dependent on the performance of the person who must manually enter information into the system. Previous ARI research on data entry has resulted in simplified message formats, improved reference codes, and aids for on-line preparation and verification of message entries. Although progress has been made, data entry remains a major system bottleneck. The research reported here compared alternative inputting methods with four levels of system aiding and prompting and has produced specific design recommendations for improving the speed of data entry and error rates.

Research in user-oriented systems is conducted as an in-house effort augmented through contracts. This report resulted fron an in-house research effort responsive to requirements of Army Project 2Q763743A774 and to special requirements of the U.S. Army Combined Arms Combat Development Activity, Fort Leavenworth, Kans. Special requirements are contained in Human Resource Need 76-162 (77-295), "Processor Aided Retrieval and Storage."

JOSEPH ZEIDNER
Technical Director

A COMPARATIVE ANALYSIS OF METHODS FOR TACTICAL DATA INPUTTING

BRIEF

Requirement:

Nearly all information in tactical operations systems is input manually. Two problems that arise when manually inputting data are (a) the introduction of errors in translating information into computer format and (b) the introduction of a bottleneck in total system response time. Therefore, alternative methods of inputting data for accuracy and speed should be evaluated.

Procedure:

Four methods were examined for speed accuracy when inputting tactical messages concerning enemy activity into an Army computer format. The methods were (a) typing--the user types the appropriate codes into a message format; (b) typing with an error corrector--the computer automatically attempts to correct common spelling and/or typing errors; (c) menus--the user indicates which of the legal entries is desired from a list; and (d) typing with autocompletion and an English option--the user must type only sufficient characters to uniquely identify the item, using either the appropriate code or its English definition.

Thirty-two enlisted persons, representative of the class of military personnel who might serve as input device operators, input one of four sets of nine messages using each inputting method.

Findings:

The use of menus was the most accurate inputting method. For users of limited experience (1 day of inputting), there were no differences in speed among the inputting methods.

Utilization of Findings:

Consideration should be given to the adoption of menus in tactical operation systems with a menu override option for experienced users. The use of an error corrector, autocompletion, or an English option is probably not warranted unless operational use shows a specific need for such an aid.

A COMPARATIVE ANALYSIS OF METHODS FOR TACTICAL DATA INPUTTING

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A COMPARATIVE ANALYSIS OF METHODS FOR TACTICAL DATA INPUTTING

INTRODUCTION

Despite the long-term possibility of direct-sensor to computer-data transfer, the main source of information for tactical operations systems is manual data inputting. Two problems arise when data are entered into the system manually: (a) the introduction of errors in translating information into computer format and (b) the introduction of a bottleneck in total system response time.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been engaged in research to improve performance of data inputting at the man-machine interface (see Alderman (1976) for a discussion of previous research). Earlier research sought to improve human performance by individualized training techniques (Gade, Fields, & Alderman, 1978), by computer prompting and instruction (Strub, 1975), and by using on-line inputting with verification (Strub, 1971).

The earlier research, however, did not focus on actual inputting procedures. To learn how the method of inputting affects speed and accuracy, four different methods for entering intelligence data into a Tactical Operating System (TOS) format were examined. The fastest method could be used to alleviate the bottleneck at the man-machine interface. The problem of introduction of error has two parts: (a) the operator must form a correct concept of the information (from reading a message, hearing a telephone message, viewing a radar scope, etc.) and (b) the operator must input properly formatted information based on a correct concept. In other words, an error could arise if the operator misunderstood the information or incorrectly input the information. Although it is difficult to separate the two sources of error, the method of inputting affects inputting errors rather than concept formation errors.

The first of the four methods chosen for testing was typing in which the user types the appropriate codes into a message format. Typing is a common method of inputting and is used in most versions of the Army's developing Tactical Operations System and previous ARI research.

The second inputting method was also typing, except that a computer automatically attempted to correct common spelling and typing errors. The computer should be able to make corrections faster than the human user and thus speed up the rate of inputting.

A third inputting method used menus, in which the user indicates which of the legal entries listed is desired. A track ball moving a cursor was used to indicate the entry. This method is a common alternative to typing; it requires less training and the user cannot make spelling errors. Also, because the use of menus places a smaller cognitive load on the user (requiring recognition memory rather than recall memory),[1] there is also the possibility that fewer errors will occur.

The fourth method of inputting was aimed especially at speeding up the rate of inputting. This method, which used typing as its base, required that the user type only enough characters to identify a member of the table of legal entries for that item of the format. The computer would fill in the rest of the entry, thus saving typing time. Because research has shown that typing English is faster than typing codes, the user of this method was allowed to use either the code or its English definition. In either case, the participant was to use only the minimum number of characters needed to identify the code or definition.

The different operating characteristics of the four methods provide a basis for predicting relative inputting performance. Thus, compared with normal typing, typing with an error corrector should result in fewer errors as well as a time savings. Similarly, the use of menus should result in fewer errors and possibly a time savings. However, the fastest and most accurate inputting method should be autocompletion.

OBJECTIVE

The purpose of this research was to evaluate alternative methods of inputting enemy situation data for speed, accuracy, and ease of use.

METHOD

Subjects

Thirty-two enlisted men and women were randomly assigned to four groups for the experiment. Participants possessed a GT score of 105 or above, vision correctable to 20/20, and were representative of the class of military personnel who might be trained to serve as input device operators. Although 26 of the 32 participants claimed some typing skill, and several had had limited exposure to computers, none had used the inputting techniques being evaluated in the experiment.

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[1] References to this phenomenon are common. For examples, see Loftus & Loftus, 1976, pp. 56-91, or Baddeley, 1976, pp. 285-286.

Task

The participants acted as intelligence staff members entering information about the enemy into a computerized data base. They received free text messages describing enemy actions. An example appears in Figure 1. Their job was to extract the necessary information and enter the appropriate codes into a variation of the Enemy Situation Data Add (ESDA) format of the TOS system (see Figure 2).

Experimental Station

The experiment was conducted in an area containing a table and chair for the participant. Two cathode ray tube (CRT) displays sat on the table, one showing the format into which the participant would enter data and the other containing the menus for the menu-selection inputting method. A track ball for the menu-selection method was placed in front of that CRT. A keyboard was placed in front of the format CRT. A dictionary was available that contained the valid codes and their English definitions cross-indexed to the items in the format. An intercom was provided for calling the experimenter.

Inputting Methods

Four different inputting methods were investigated in this experiment. Each method used automatic tabbing; that is, after the completion of an entry, the computer automatically moved the cursor to the next entry item in the format. The computer did not accept invalid codes[2] for an entry and gave the user an error message to that effect.

I. Typing. In this method, the message format appeared on the screen with the cursor placed at the first item. The users then filled in the appropriate codes (including blanks) for each item, referring to the dictionary of valid codes and their definitions as needed. The computer rejected any input that was not a legal entry and would not allow the user to continue until a valid code was entered. Participants could backspace and type over their answers. The cursor automatically moved to the next item in the message format when a valid entry had been typed.

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[2] An invalid code is one that does not appear in the valid code list for an entry. The terms "valid" and "legal" are used interchangeably. A valid code may be incorrect if it appears in the valid code list but does not correctly describe the information in the free text message.

SPOT REPORT

PRECEDENCE: FLASH - IMMEDIATE - PRIORITY - ROUTINE

DISPOSITION: GI G3OPS G4 G5 FSE TASE

MIC G2OPS

ENGR G2EXT 1BDE 2BDE 3BDE

FROM: 1st Brigade, Ground Surveillance Section

REPORT TIME: 1745

EVENT TIME: 1630

CLASSIFICATION: U C S TS

DESCRIPTION: Convoy moving SW along Route #15
7 tanks, 22 trucks, 52 APC's
picked up by unattended ground sensors
vic. XT437262

MESSAGE NUMBER - 45618

Figure 1. Typical free text message describing enemy actions.

```
ENEMY SITUATION DATA ADD - ESDA

ORIG/NO:[     /    ] SCTY[  ] PRES[  ] RESTR[  ]

RECD-FR[      ] REPT-ID [            ] REL-TO[    ]

AGENCY[       ] SOURCE-ID[     ]

EVENT-TIME[             ] NATION[  ]

EN-UNIT[      /    / / ]EN-PARENT[     /   / / ]

--SUBJ---ACTV---QUANT-DESCRIPTION--------LOCATION-

1(       /     /     /                  /        )

2(       /     /     /                  /        )

3(       /     /     /                  /        )

4(       /     /     /                  /        )

5(       /     /     /                  /        )

REMARKS[                                         ]

DISTR[    ,    ,    ,    ,    ] INTEREST[ ]
```

Figure 2. Format for entering data.

II. Typing with Error Correction. This method was the same as Method I except that an aid had been added--a typing error corrector. When the user typed an invalid entry, the system assumed that a typing error had been made and attempted to correct the error. The typing error corrector dealt with four kinds of errors: transposition of two adjacent letters, insertion of an extra letter, deletion of one letter, or substitution of one incorrect letter. When the typed item was an invalid entry, the typing corrector tried to form a hypothesis of what the entry should be. For each of the four kinds of errors, the typing corrector found a list of all the members of the valid list that were either the same length as the invalid entry, one character shorter, or one character longer, depending on which of the four types of typing errors was being tested. Then it went through one of four processes:

1. The typing corrector scanned the target word and the entry from the left for mismatches. At the first mismatch, it transposed the mismatched letter in the entry with the letter to the right. If the new word matched the target word, the target word was the hypothesis. If there was no match, the typing corrector went on to the next target word.

2. The typing corrector scanned the target word and the entry from the left for mismatches. It deleted the mismatched letter in the entry and checked for a match. If there was no match, the typing corrector went on to the next target word.

3. The typing corrector scanned from the left for mismatches and deleted the mismatched letter from the target word and checked for a match. If there was no match, it went on to the next target word.

4. The typing corrector scanned from the left for mismatches. At the first mismatch, it skipped the mismatched letters in both words and checked the rest for a match. If there was no match, the typing corrector went on to the next target word.

The first hypothesis formed when the typing corrector found a match printed out on the screen with an error message. If it was the entry the user actually wanted, the user hit a key to signal acceptance; otherwise the user could hit a key to signal a retyping of the entry. If the typing corrector could not form a hypothesis, an error message appeared on the screen and the user had to retype the entry.

III. Menus. In this input method, typing was used for entering three types of items in the message format: map coordinates, dates, and cardinal numbers. All other data had to be entered by selecting the appropriate item from an alphabetically or logically ordered menu; data could not be typed in. The message format appeared on the right CRT with a cursor at the first item. The menu of legal entries for the first item appeared on the left CRT in their uncoded form (i.e., English definitions from the dictionary). If a blank was a valid entry, it was included in the menu. When an item was chosen, its code was filled into the message format by the computer and the cursor moved to the next item. If an item had to be typed rather than chosen from a menu (e.g., map coordinate string), instructions to type the item would be displayed where the menu would normally appear. In these cases, invalid entries (e.g., insufficient characters in the coordinate string) were rejected and the next item could not be entered until a valid entry had been typed in, as in Method I.

IV. Typing with Autocompletion and English Option. This method was the same as Method I, but with two additions. First, the participant could enter the English definition from the dictionary in place of the code, as desired. Second, when the participant felt that enough characters had been typed to identify a member of the valid entry list (either code or English), he would push the send button, causing the autocompletion program to take over. If indeed the program could match the characters with the beginning of one, and only one, member of the valid entry list, it would automatically finish the entry for the participant and move the cursor to the next entry. If a unique match could not be made, the program asked for more characters. The participant could invoke the autocompletion program at any time and as often as wished until a unique match was made.

Dependent Variables

The primary dependent variables were format completion time and accuracy in terms of number of errors per format. Typing errors as well as errors of interpretation and errors specific to a particular inputting method were included in evaluating the number of errors per format.

Other data collected included the number of times the typing corrector was used, the number of times the typing corrector correctly identified the target code, the number of times autocompletion was used, the number of times English definitions were used in place of codes, the number of times the participant corrected an entry by backspacing and typing over before entering the item, and the participant's stated preferences among the input methods. All the participants' entries and the entry times were recorded as well.

PROCEDURE

Thirty-six free text messages describing enemy actions were divided into four sets of nine messages with each message set (M) balanced for types of subjects, sources, restrictions, unit identifications, and difficulty during the pilot testing. For each message set, the first message was always a practice message, and the other eight messages made up the experimental set. In addition to these 36 messages, 2 other messages were initially presented as practice messages.

RESULTS

Analysis of variance summary tables and means for the dependent variables in this experiment can be found in the appendix. Only major findings are given here.

Accuracy

Accuracy of an inputting method may be considered from two perspectives: (a) mean errors per message and (b) the number of participants who had the fewest errors using a particular method. For both measures, the rank order of inputting methods was the same (see Table 2).

Table 2

Accuracy Ranking of Inputting Methods

Method	Mean number of errors per message	Participants who made the fewest errors using this method
Menus	2.64	17
Typing with error corrector	3.36	8.5[a]
Typing	3.77	3.5[a]
Typing with autocompletion	4.39	3

[a]Includes one tie between typing and typing with error corrector.

An analysis of variance of the mean error data indicates that the differences among the inputting methods are significant ($F = 13.98$, $df = 3,84$, $p < .001$). There were no statistically significant residual interactions between inputting methods and message set, sessions, or groups. The analysis of variance table (Table A-1) and a discussion of other significant findings is provided in the appendix.

Time

The mean time per message using each of the four inputting methods and number of participants who had their fastest scores using a given inputting method are shown in Table 3.

Table 3

Time Ranking of Inputting Methods

Method	Mean time per message (in seconds)	Number of participants who averaged the fastest time using this method
Typing with autocompletion	413.13	13
Typing with error corrector	397.01	9
Typing	396.05	7
Menus	396.52	3

Although scoring by number of participants (who averaged their best times over the eight messages using a given inputting method) is consistent with the original predictions (see the discussion of inputting methods in the Introduction), the mean time ranking is almost the exact reverse. An analysis of variance perfoımed on both the raw time scores and the logs of the time scores (used because of skew in the time scores) showed that the differences among inputting methods in mean times were statistically insignificant. (The analysis of variance summary tables can be found in Tables A-2 and A-3 of the appendix.) The most significant factor in the analysis of variance of the time data was Sessions. The more practice a participant had, the shorter the inputting time became ($p < .001$). This can be seen in the mean times across all inputting methods for each session, shown in Table 4.

Table 4

Time Data for Sessions

Session	Mean time (in seconds)
1	531.11
2	387.12
3	360.21
4	324.27

Preferences

As the participants were debriefed, they were asked about their preferences among inputting methods. It was hypothesized that people would prefer a method with which they had performed well--either in making the fewest errors or in averaging the fastest time. The preference results can be seen in Tables 5 and 6. A coefficient of agreement[3] (κ) and an approximation of the standard error ($\sigma\kappa$) were determined for each table. (See Cohen, 1960, for a discussion of κ.) Contrary to expectations, there is chance agreement or, at best, a slight negative agreement between preference and best performance. For fewest errors, $\kappa = -.108$ and $\sigma\kappa = .149$. For fastest time, $\kappa = -.128$ and $\sigma\kappa = .057$.

Use of Computer Aids

Backspacing. Whenever a participant was typing an entry, the backspacing option was available. This option allowed the subject to back up and type over an answer to change it. The use of the backspace option allowed the participant to catch and correct mistakes before the computer

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[3] κ, the coefficient of agreement, is a measure of the agreement between two variables measured by nominal scales (in this case, best performance and preference). Like the Pearson product-moment correlation coefficient, r, κ can take on values only between -1 and +1. A score of +1 would indicate total agreement between performance and preference, and a score of -1 would indicate that users never preferred the inputting method they did best on. A score of 0 would indicate no predictive linear relationship between preference and performance.

Table 5

Agreement Table Between Preferences and Fewest Errors, by Inputting Method

Fewest errors	Preference: Typing	Error corrector	Menus	Autocompletion	Total
Typing	0	0	2	0	2
Error corrector	2	0	5	1	8
Menus	1	3	10	3	17
Autocompletion	1	0	1	0	2
Total	4	3	18	4	29[a]

[a]Three subjects did not express preferences.

Table 6

Agreement Table Between Preferences and Best Time, by Inputting Method

Best time	Preference: Typing	Error corrector	Menus	Autocompletion	Total
Typing	0	0	5	0	5
Error corrector	1	1	5	2	9
Menus	0	2	0	1	3
Autocompletion	3	0	8	1	12
Total	4	3	18	4	29[a]

[a]Three subjects did not express preferences.

would catch them. This option was frequently used by the participant, as shown in Table 7. The backspacing option could be used with three results: (a) a correct entry, (b) a valid (correctly spelled) entry that was not the correct entry for the message, or (c) an invalid entry.

Error Corrector. Table 8 shows the use of the error corrector. The error corrector could change an invalid entry to a valid and correct entry, and could change an invalid entry to a valid and correct entry but the participant could reject that correct answer. In about a third of the cases the error corrector could not arrive at a valid entry.

Autocompletion with English Option. Table 9 shows the use made of the autocompletion option and the English option. There were six forms these options could take. The subject could use the full English definition, and that definition could be either correct or incorrect. The subject could use autocompletion on either the code or the English definition and these autocompleted entries could be either correct or incorrect.

DISCUSSION

Menus

Menus appear to be more error-free than the other inputting methods examined (see Table 2). Indeed, there is a 40% decrease in error with menus from the worst case, typing with autocompletion. Menus are popular; 18 out of 29 participants expressed a preference for them. Finally, menus do not have higher mean times than the other inputting methods. Therefore it would seem reasonable to suggest that the use of menus be seriously considered for adoption for use in tactical data inputting.

This study considered menu selection with a track ball. However, the track ball method of menu selection does not seem to be a good method of inputting. It is slow and cumbersome to use. There are several other methods of a menu selection (e.g., lightpen, touch-sensitive panels, a typed index code or letter) that should be considered. Each method has advantages and disadvantages; the results of this research do not suggest which one would be the best for the tactical data inputting task.

None of the menus in this research was particularly long. Most fit on one screen (i.e., they were less than 40 items long). The longer menus (e.g., "subject") were divided into sections (e.g., "personnel," "vehicle," etc.). The first screen shown to the participant was a list of sections from which the subject could select a screen-sized menu. Even with the relatively fast speed of the experimental displays and the relatively short length of the menus, participants still had to wait for a menu to be printed out so that they could respond. With slower equipment, longer menus, or more experienced users, delays due

Table 7

Use of Backspacing

Inputting method	Number of times backspacing was used to correct entry	Average per subject	Number of times backspacing was used to correct spelling of an incorrect entry	Average per subject	Number of times back-spacing was used on in-valid entry	Average per subject
Typing	204	6.38	15	.469	60	1.87
Typing with error corrector	259	8.09	12	.375	40	1.25
Menus	105	3.28	5	.156	17	.53
Typing with autocompletion	165	5.16	19	.594	45	1.41
Total	733	22.91	51	1.59	162	5.06

Table 8

Use of Error Corrector

Number of times error corrector was correctly accepted	Average per subject	Number of times error corrector was incorrectly rejected	Average per subject	Number of times error corrector could not arrive at an entry	Average per subject
104	3.25	10	0.31	37	2.59

Table 9

Autocompletion and English Option[a]

	Correct use of full English	Incorrect use of full English	Correct autocompletion of code	Incorrect autocompletion of code	Correct autocompletion of English	Incorrect auto-completion of English
Frequency	46	15	1,809	76	135	14
Average per subject	1.44	.47	56.53	2.38	4.22	.44

[a] On the average, each subject had 106 opportunities to use these options.

to either paging through a menu or waiting until the menu was printed out could be a serious defect. Therefore, either a menu override option should be made available for experienced users, or careful consideration should be given to the design of an operational menu system taking these points into account. Otherwise a poorly designed menu system could negate the benefits found in this research.

Time Data

The time data from this experiment suggest that the participants never reached a plateau where practice effects no longer affected performance. If such a plateau had been reached, perhaps time differences among the inputting groups would have emerged.

Would autocompletion, for example, have been faster if the subjects had had more experience? It is impossible to say. Autocompletion was the fastest inputting method for 40% of the participants, or 13 people.

An a priori estimate assuming no differences among inputting methods would lead us to expect each inputting method to be fastest for 25% of the participants. The mean time of those 13 people, 308.23 seconds, however, was faster than any other group, and their use of the autocompletion option was higher than the total group average. This mean inputting time was also faster than the average for any of the four sessions. Recall that the analysis of variance on sessions produced the most significant results, indicating a training effect (the fastest session was the last one, the fourth, and the mean was 324.27).

Many subjects complained that autocompletion was confusing and difficult to understand. This confusion may have led to the high error score and wide variance seen in the autocompletion data. It would seem that autocompletion is a useful tool only for a sophisticated user.

Error Corrector

The computer spelling error corrector was impressive to watch in action; it came up with correct hypotheses in most cases (i.e., a hypothesis acceptable to the user) and decreased errors by 11% from typing without the error corrector. Yet the practical value (less than .5 fewer mistakes per message) does not seem valuable. The error corrector should probably be considered only if operational use of a tactical inputting system shows a disturbingly large number of typing and spelling errors.

English Option

The option to use English was not as popular as the option to use codes (see Table 9). The English option was used most often where the code and English definition were most dissimilar. In inputting the precedence codes (R = Routine, P = Priority, I = Immediate, and Z = Flash) for example, F with autocompletion was often used rather than Z. This unpopularity may be because the English required many more characters to be typed, on the average, than the code and also required more characters to uniquely identify the item. An English option is probably not very useful, particularly with well-designed, user-oriented codes.

CONCLUSIONS

Menus are recommended for use in inputting tactical data because they appear to cause fewer inputting errors without noticeably affecting input rate than the other methods examined in this research. However, to maximize the benefits of the menus, special attention should be given to the design of an operational menu-based inputting system--particularly the length of menus, the speed with which they can be displayed, and the manner in which items are selected from a menu.

Spelling correctors or autocompletion should be considered only for experienced users and in operational settings that specifically require such aids.

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APPENDIX

STATISTICAL SUMMARY TABLES

Table A-1 contains the analysis of variance summary table for the error data; Table A-4 contains the means and error data for each of the four variables and for each cell.

Table A-2 contains a summary of the analysis of variance for time data. Several outliers were found in the data (e.g., some subjects had never used a typewriter keyboard before and literally had to "hunt and peck" for each key). Because the presence of outliers can unduly influence an analysis of variance, a second analysis of variance was run using logs of the time score. The results of the second analysis are summarized in Table A-3. Table A-5 contains the means and time data for each of the four variables and for each cell.

DISCUSSION

Error Data

Message sets (M) are a significant source of variance as can be seen in Tables A-1 and A-4. Groups (G) and sessions (S) are also somewhat different. However, since the residual (or interaction) term is not significant and since the experimental design is a Greco-Latin square with within-subject measures, these factors do not affect the main conclusion concerning inputting methods.

Time Data

Use of the log transform to reduce the skew in the time data reduced the size of the residual term (Tables A-2 and A-3). However, the ordering of the other terms remained approximately the same. In both analyses, inputting methods (I) are not significant and sessions (S) are very significant ($p < .001$).

A mistake in numbering two messages put a short message from set 4 into set 3 and a long message from set 3 into set 4. Therefore, message set 3 is about eight items too short and message set 4 is eight items too long. This probably accounts for the difference in means between them (see Table A-5).

Table A-1

Analysis of Variance Table for Error Data (32 Subjects)

Source of variation	SS	df	MS	F
Between subjects		31		
Groups (G)	114.38	3	38.13	3.79*
Subjects/groups = e_1	281.51	28	10.05	
Within subjects		96		
Message sets (M)	34.20	3	11.40	9.34***
Inputting methods (I)	51.18	3	17.06	13.98***
Sessions (S)	13.09	3	4.36	3.57*
Residual	1.76	3	0.59	0.48
Subjects/groups = e_2	102.09	84	1.22	
Total	598.21	127		

* $p < .05$.
***$p < .001$.

Table A-2

Analysis of Variance Table for Time Data (32 Subjects)

Source of variation	SS	df	MS	F
Between subjects		31		
Groups (G)	314557.95	3	104852.65	4.86**
Subjects/groups = e_1	603568.31	28	21556.01	
Within subjects		96		
Message sets (M)	87759.42	3	29253.14	12.23***
Inputting methods (I)	6631.30	3	2210.43	.92
Sessions	789543.52	3	263181.17	109.92***
Residual	41975.21	3	13991.74	5.85**
Subjects/groups = e_2	200989.96	84	2392.74	
Total	2045025.66	127		

** $p < .01$.
***$p < .001$.

Table A-3

Analysis of Variance Table for Logs of Time Data (32 Subjects)

Source of variation	SS	df	MS	F
Between subjects		31		
Groups (G)	313915.66	3	104638.55	4.22*
Subjects/groups = e_1	694914.81	28	24818.39	
Within subjects		96		
Message sets (M)	64248.09	3	21416.03	10.01***
Inputting methods (I)	1440.03	3	480.01	.22
Sessions (S)	781955.53	3	260651.84	121.81***
Residual	23799.95	3	7933.32	3.71*
Subjects/groups = e_2	179741.9	84	2139.8	
Total	2060015.97	127		

* $p < .05$.
***$p < .001$.

Table A-4

Means and Error Data for Four Variables and for Each Cell

Groups (G)	Sessions (S) 1	2	3	4	Mean time	Inputting method (I)	Mean	Message set (M)	Mean
A	X = 5.29	X = 4.03	X = 4.64	X = 6.46	$\bar{X}$ = 5.1	Typing	3.77	1	3.12
	1,1[a]	2,3	3,4	4,2					
B	X = 3.93	X = 2.95	X = 3.01	X = 1.75	$\bar{X}$ = 2.91	Typing with error corrector	3.36	2	4.16
	2,2	1,4	4,3	3,1					
C	X = 1.53	X = 2.79	X = 3.59	X = 2.85		Menus	2.64	3	2.95
	3,3	4,1	1,2	2,4	$\bar{X}$ = 2.69				
D	X = 5.29	X = 2.68	X = 2.64	X = 3.24		Typing with autocompletion	4.39	4	3.93
	4,4	2,2	2,1	1,3	$\bar{X}$ = 3.41				
Mean time	$\bar{X}$ = 4.01	$\bar{X}$ = 3.11	$\bar{X}$ = 3.47	$\bar{X}$ = 3.58					

[a]The first number is the inputting method (I): 1 = typing, 2 = typing with error corrector, 3 = menus, and 4 = typing with autocompletion. The second number is the message set (M).

Table A-5

Means and Time Data (in Seconds) for Four Variables and for Each Cell

Groups (G)	Sessions (S) 1	2	3	4	Mean time	Inputting method (I)	Mean	Message set (M)	Mean
A	X = 547.24	X = 379.31	X = 407.45	X = 326.66	$\bar{X}$ = 415.17	Typing	369.05	1	400.73
	1,1[a]	2,3	3,4	4,2					
B	X = 493.8	X = 347.3	X = 299.15	X = 300.06	$\bar{X}$ = 360.08	Typing with error corrector	397.01	2	405.24
	2,2	1,4	4,3	3,1					
C	X = 410.01	X = 353.31	X = 331.94	X = 312.6	$\bar{X}$ = 351.97	Menus	396.52	3	361.55
	3,3	4,1	1,2	2,4					
D	X = 673.4	X = 468.56	X = 402.31	X = 357.74	$\bar{X}$ = 475.50	Typing with autocompletion	413.13	4	435.19
	4,4	2,2	2,1	1,3					
Mean time	$\bar{X}$ = 4.01	$\bar{X}$ = 3.11	$\bar{X}$ = 3.47	$\bar{X}$ - 3.58					

[a]The first number is the inputting method (I): 1 = typing, 2 - typing with error corrector, 3 = menus, and 4 = typing with autocompletion. The second number is the message set (M).

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