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GRAPHIC VERSUS TOTE DISPLAY OF INFORMATION IN A SIMULATED TACTICAL OPERATIONS SYSTEM

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Army Research Institute for the Behavioral and Social Sciences
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SYSTEMS INTEGRATION & COMMAND/CONTROL TECHNICAL AREA

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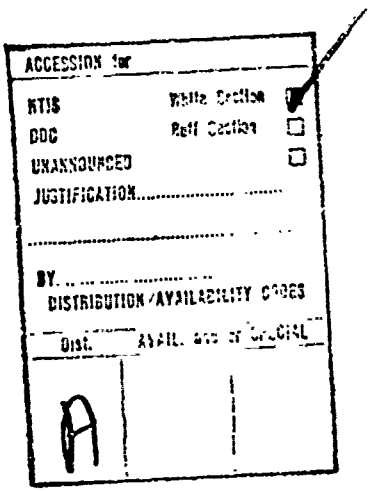

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13. ABSTRACT

To assist commanders in making tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and displayed in the most efficient way possible. To meet this need, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and great amounts of military data, studying at the same time the most effective interaction of these computer information systems with human abilities. As part of this continuing study, the Command and Control Work Unit Area of the Army Research Institute compared the effects of graphic and tote display modes on the speed and quality of decisions based on the displayed information.

In the context of ARI's Simulated Tactical Operations System (SIMTOS), 36 officers, divided into two groups, were presented a command decision task. For one group, information requested by the officers from the data base was presented in graphic format emphasizing spatial and symbolic coding of the data. For the other group, the data were presented in tote form emphasizing tabular arrangement and alpha-numeric coding. Evaluation of the two display modes was in terms of speed and accuracy of the final decision and the number of non-redundant facts accessed by the subject.

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13. ABSTRACT - continued

The two groups did not differ significantly, in accuracy of decision, speed of decision, or number of facts accessed. Therefore, the more economical tote form of displays should be used wherever feasible. Where graphic displays are used, the complexity and density of information presented can be considerably reduced by conversion to a form suitable for CRT or printout.

Technical Research Note 243

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FORWORD

Technological advancements have led to increased speed, mobility, and destructive power of military operations. To permit commanders to make tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and used more effectively than ever before. To meet this need, the Army is developing automated systems for receipt processing, storage, retrieval, and display of different types and vast amounts of military data. There is a concomitant requirement for research to determine how human abilities can be utilized to enable the command information processing systems to function with maximum effectiveness.

The research reported here was accomplished by the Systems Integration & Command/Control Technical Area, Organizations & Systems Research Laboratory of the U. S. Army Research Institute for the Behavioral and Social Sciences. The Institute, established 1 October 1972 as replacement for the U. S. Army Manpower Resources Research and Development Center, unifies in one enlarged organization all OCRD activities in the behavioral and social sciences area, including those conducted by the former Behavior and Systems Laboratory (BESRL) and the Motivation and Training Laboratory (MTL).

The Command & Control Work Unit Area of the Army Research Institute is concerned with problems of information presentation, processing, and utilization in computerized systems. Specific aspects of information processing systems are examined with respect to the human users of the system. The present publication reports on a comparison of graphic displays and tote displays as modes of presentation for information called from the data base.

The entire research effort is responsive to requirements of RDTE Project 2Q062106A723, "Human Performance in Military Systems," FY 1973 Work Program, and to special requirements of the Assistant Chief of Staff for Force Development, the Assistant Chief of Staff for Intelligence, the U. S. Army Combat Developments Command, and the U. S. Army Computer Systems Command.

J. E. UHLANER
Technical Director

GRAPHIC VERSUS TOTE DISPLAY OF INFORMATION IN A SIMULATED TACTICAL OPERATIONS SYSTEM

BRIEF

Requirement:

To compare graphic and tote display modes as used in computer-aided tactical information processing systems in terms of the speed and quality of the decisions reached on the basis of the information displayed.

Procedure:

In the context of ARI's Simulated Tactical Operations System (SIMTOS), two groups of officers (N = 14 in each group) were presented a command decision task. For one group, information requested by the officers from the data base was presented in graphic format emphasizing spatial and symbolic coding of the date. For the other group, the data were presented in tote form emphasizing tabular arrangement and alpha-numeric coding.

Evaluation of the two display modes was in terms of speed and accuracy of the final decision and number of non-redundant facts accessed by the subject.

Findings:

Groups using the graphic and tote displays did not differ significantly in accuracy of decision, speed of decision, or number of facts accessed.

Utilization of Findings:

In the absence of definitive findings, for the present it would be more economical to use the tote form of displays wherever feasible.

There was indication that, where graphic displays are to be used, the complexity and density of the information presented can be considerably reduced by conversion to a form suitable for CRT or printout.

GRAPHICS VERSUS TOTE DISPLAY OF INFORMATION IN A SIMULATED TACTICAL OPERATIONS SYSTEM

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GRAPHIC VERSUS TOTE DISPLAY OF INFORMATION IN A SIMULATED TACTICAL OPERATIONS SYSTEM

INTRODUCTION

Computer-aided command systems for a tactical operations center (TOC) are being developed by the Army. A key factor in the design of such systems is the selection of displays that will enhance overall system performance. Since system performance in a TOC is often evaluated in terms of the quality and speed of the commander's decisions, it is necessary to determine what display methods and procedures will best facilitate information assimilation by the commander and his staff, thereby optimizing decision making.

Two forms of display are now used to transmit information to the commander and staff of a TOC. In tote displays, information is presented by alpha-numeric characters in a tabular arrangement. Graphic displays are vector-drawn displays employing symbolic characteristics. A list of unit locations by numerical designators and coordinates is an example of a tote display. The same data depicted by standard military flag symbols on a situation map is an example of a graphic display. Table 1 illustrates the distinction.

Currently, the bulk of information transmitted to a tactical commander and staff is in tote form, but much of this information is converted to graphic form for presentation. The assumption in this translation process is that command and staff decision quality is improved by a graphic presentation of information. This assumption appears to rest on intuitive rather than empirical grounds. Indeed, the scant empirical evidence available suggests that, at least in abstracted tasks, no facilitation of performance is attributable to the graphic display of information[1] [2].

With the advent of the computer, it has become possible to transmit information directly to the staff and commander in tote form. However, present technological advances have made relatively sophisticated graphic display devices available for automated systems[3]. The availability of

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[1] Vicino, F. L., and S. Ringel. Decision making with updated graphic vs alpha-numeric information. ARI Technical Research Note 178. November 1966. (AD 647 623)

[2] Nawrocki, L. H. Alpha-numeric versus graphic displays in a problem-solving task. ARI Technical Research Note 227. September 1972. (AD 748 799)

[3] Miller, I. M. Computer graphics for decision making. Harvard Business Review, November-December 1969, 47(6), 121-132.

Table 1

CONTENT AND FORMAT OF SLIDES FOR GRAPHIC AND TOTE DISPLAYS

Content	Number of Slides	Graphic Format	Tote Format
Full color work map	(1)	Slide of map	Wall map
Enemy order of battle	(4)	Flow chart with flag symbols	Tabular list of units
Friendly task organization	(12)	Flow chart with flag symbols	Tabular list of units
Enemy unit location	(1)	Map with flag symbols	Coordinate list
Friendly unit location	(2)	Map with flag symbols	Coordinate list
Area of operations	(2)	Boundary trace on map	Coordinate points
Enemy attack formations	(3)	Two dimension flag symbol chart	Verbal description
Fords, key terrain, avenues of approach	(1)	Map with trace of relevant information	Overlay provided upon request
Weapon ranges	(1)	Histogram of ranges	Numeric listing
Personnel effective	(1)	Histogram of percents	Percent listing
Offensive and defensive supply	(1)	Histogram of tonnage	Tonnage list

these devices permits the designer to consider the direct graphic display of information as an alternative to presenting the same information in a tote display. That this possibility is being considered by the Army is evidenced by Combat Development Command's recently proposed set of requirements for the implementation of a tactical automated graphic display device[4]. The cost of such graphic displays is considerably greater than comparable tote displays and likely to remain so[5]. If acted upon, then, the assumption that graphic displays are superior to tote for command decisions could be a costly one, should it prove to be incorrect. The purpose of the present research was to provide additional empirical evaluation of the impact of graphic displays on command decisions.

As was noted previously, comparison of the two display modes has been restricted to tasks that represent only a portion of the total system. Thus, while color, brightness level, symbol orientation, and other factors can be manipulated to enhance an individual's ability to extract and assimilate information, the impact of these factors on total system output has not yet been ascertained[6] [7]. The present research is a comparison of graphic and tote displays of tactical information under conditions which simulate those in a computer-aided TOC. Evaluation of the two displays focused on two components of systems output, the speed and accuracy of the final decision.

A secondary objective was to determine the difficulties (if any) that might be encountered in implementing graphic displays in a computer-aided tactical information processing system.

METHOD

Subjects

The subjects were 28 field grade officers with Command and General Staff College and G-3 staff experience. All participants served on a volunteer basis for one 3-4 hour session. Fourteen subjects were randomly assigned to each of two conditions.

4/ Combat Development Command. Proposed revision of Qualitative Materiel Development Objective for a tactical group display. Combat Development Objective Guide. 1971. Paragraph 812b(9).

5/ Machover, C. Family of computer-controlled CRT graphic displays. Information Display, July-August 1966, 3(4), 43-46.

6/ Kuehn, R. L. Display requirements assessment for command and control systems. Information Display, November-December 1966, 3(6), 43-46.

7/ McKendry, J. M., D. J. Mace, and J. D. Baker. Implications of BESRL research for displays in tactical information processing. ARI Technical Research Report 1156. January 1969. (AD 688 581)

Task

Each subject assumed the role of a G-3 operations officer for an American Mechanized Division opposed by portions of an Aggressor Combined Arms Army. His task was to complete the following three phases of defensive planning:

1. Allocation of combat power to the echelons of defense
2. Task organization
3. Missions for subordinate units

The scenario for the task represented a European mid-intensity conflict. The environment simulated a computerized TOC. The Simulated Tactical Operations System (SIMTOS) developed by ARI as a research vehicle provided both the data base and the operations environment. The SIMTOS permits evaluation of performance in a command decision task approximating conditions that would exist in a computerized TOC. A detailed description of the task instructions, and basic equipment is available in previous documents[8] [9].

Stimulus Materials

Previous to the present research, the bulk of the tactical information available to subjects in the SIMTOS was presented in tote form via cathode ray tube (CRT). Certain additional information was provided by maps and overlays upon request.

For the present experiment, the SIMTOS scenario was reviewed by the experimenter and a compilation was made of data that were judged feasible for a graphic/symbolic format. These data were then transferred from the CRT to 70 mm color slides. The slides were back projected via POLAKOTE screen[10]. Since the subject was free to move about in the test cubicle, viewing distance could vary from a few inches to several feet, at the discretion of the subject. Data that were judged not feasible for conversion to graphic form remained available to the subject on the CRT.

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[8] Krumm, R. L., J. E. Robins, and T. G. Ryan. Studies of tactical military decision making: III. Predictor variables and criterion measures. ARI Technical Research Note 229. March 1973.

[9] Robins, J. E., L. Buffardi, and T. G. Ryan. Research on tactical military decision making: application of a decision prediction concept in a SIMTOS environment. ARI Technical Research Note 246 (in press).

[10] Use of commercial designations is in the interest of precise reporting only, and does not constitute indorsement by ARI or by the Army.

The SIMTOS program was modified to allow the subject access to either CRT or slide presentation of information, depending on which of these contained the requested information. This arrangement of information was called the graphic display condition.

For comparison, the slide material available in graphic form was duplicated in the form of totes. Minor programming modifications would have permitted the tote displays to be shown via the CRT. However, to avoid confounding methods of display with differences in the physical characteristics that may be inherent in slide and CRT presentation, the tote displays were presented in the same manner as the graphic displays. This display arrangement was labeled the tote display condition. Table 1 provides a brief description of the slide content for the two conditions. In the present experiment it is possible that portions of the data remaining on the CRT in either experimental condition could provide information critical to system performance. However, an experiment by Strub[11] indicated that this occurrence is unlikely. Strub employed the SIMTOS to determine the information categories most consistently and frequently requested by subjects. The information supplied by these critical categories is virtually identical with that available in the slides in the present experiment.

Variables

The independent variable, then, was display method-graphic or tote. The graphic display condition emphasizes the spatial arrangement and symbolic coding of data. The tote display condition emphasizes the tabular arrangement and alpha-numeric coding of data.

Subjects were scored on three major objective performance criteria:

Accuracy. Total number of points given for a solution on the basis of a Command and General Staff College scoring procedure. The maximum number of points obtainable was 78. (A detailed description of the scoring procedure is documented elsewhere.[12]) Accuracy as measured here is intended to reflect the quality component of system performance.

[11] Strub, M. H. Tactical planning (offensive and defensive)--Minimum essential information requirements. ARI Technical Research Note (in preparation).

[12] Robins, J. E., L. Buffardi, and T. G. Ryan. Research on tactical decision making; application of a decision prediction concept in a SIMTOS environment. ARI Technical Research Note 246 (in press).

Total Time. Total number of minutes a subject took to complete the task. This measure reflects the speed component of system performance.

Facts. Total number of non-redundant facts accessed by each subject during the experiment. A detailed explanation of a fact is available in the report cited in footnote 12[13]. In general, a fact represents one specific item of information from the data base. A single slide or CRT frame might contain several facts. The tote and graphic slides contained identical facts. They differed only in the format and code used to display a fact.

RESULTS

Five items from a personal history questionnaire administered to the subjects following the experimental session were examined to determine if the two groups could be assumed to have equivalent task relevant experience. Student's t'tests revealed no significant difference between the two groups on any of the five items (Table 2).

The t-values obtained for each of the three criterion measures failed to reach a statistically significant level. Table 3 shows the group means and respective t-values for each of the three performance measures.

To determine if display method affected the selection of particular categories of information, data were obtained on the number of subjects who accessed each category at least once during the experiment. Each slide represented one such category. The slide access frequency between groups cannot be meaningfully assessed by statistical means. However, Table 4 indicates no major differences between the two groups across the major slide categories.

In addition to the preceding objective measures, the subject's written comments concerning the experiment were obtained. Each subject was provided with a response sheet and requested to comment on any difficulties encountered during the experiment--display quality, for example. These comments were sorted into four major classes as they related to procedure, data base, organization of the data base, and display mode. Table 5 presents the frequency of responses in each class. These frequencies reveal no major difference between the two groups of subjects. Comments on procedure were predominantly suggestions that subjects be permitted to review task relevant material prior to the experiment and perhaps have a warm-up period with the equipment itself.

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[13] Robins, J. E., L. Buffardi, and T. G. Ryan. Research on tactical decision making; application of a decision prediction concept in a SIMTOS environment. ARI Technical Research Note 246 (in press).

Table 2

MEANS AND t-values [a] FOR 5 ITEMS ON PERSONAL HISTORY QUESTIONNAIRE

	Years College Education	Years Since CGSC	Months Combat Experience	Years in Military	CGSC Percentile
Graphic	5.7	5.6	13.4	19.2	52.5
Tote	5.3	4.2	17.7	16.7	58.5
t	.73	1.14	.93	1.60	.67
σ	.55	1.23	4.60	1.56	8.92

[a] t(.01,27) = 2.47
t(.05,27) = 1.70
t(.10,27) = 1.31

Table 3

MEANS AND t-VALUES[a] FOR THREE PERFORMANCE MEASURES

	Accuracy	Total Time	Number of Facts
Graphic	32.6 points	165.9 min.	88.1
tote	29.9 points	178.6 min.	105.6
t	.78 points	.91 min.	.54
σ	3.45 points	13.90 min.	32.14

[a] $t(.01,27) = 2.47$
$t(.05,27) = 1.70$
$t(.10,27) = 1.31$

However, review and practice prior to the experiment would have contaminated the results, since it would be difficult to equate subjects for degree of practice, and partial presentation of the stimuli prior to testing could not have been avoided. Comments on the data base content were generally related to minor typographic errors or the wording of information statements. Also, some felt that the data were too detailed. Regarding data base organization, 17 of the subjects felt that task organization information was spread across too many separate slides. (While use of a single task organization chart had been considered by the experimenters, the number of units in friendly and aggressor forces, combined with size limitations of the display, precluded use of a single chart.)

Only two comments were directly related to the display mode itself. Two officers commented that the graphic map displays were somewhat difficult to read. The remaining comments were generally recommendations for minor changes in experimental procedure, data base organization, and data base content.

IMPLICATIONS OF THE RESEARCH

The results indicate that the display variable has no significant effect on either the objective performance measures or the subjective evaluations employed in the experiment. Several comments are relevant at this point.

Table 4

NUMBER OF SUBJECTS ACCESSING SLIDE CATEGORIES

Slide category	Access Frequency Graphic	Tote
Work Map	14	a
Area of Operations Map	14	a
Friendly Task Organization	14	14
Friendly Unit Location	9	9
Enemy Order of Battle	4	9
Enemy Unit Location	1	1
Enemy Attack Formations	2	1
Weapon Range	9	9
Personnel Effective	10	7
Supply Availability	2	3
Terrain Information	11	13

[a]Maps were wall mounted and no access rate may be determined, although availability may be assumed to mean always accessed.

Table 5

FREQUENCY OF COMMENTS CLASSIFIED BY CONTENT

Response Classification	Response Frequency Graphic	Tote
Procedure	7	10
Data Base Content	6	7
Organization of Data Base	9	8
Display Mode	2	0

The results must be interpreted with caution in view of the small sample. However, there is additional evidence supportive of the results obtained. At least three previous research efforts using more restricted tasks have shown no differences between graphic and tote display of information[14] [15] [16]. Taken together, these findings and those of the present experiment would indicate that for a variety of tasks and measures there is little if any system performance advantage to be gained by graphic displays, All the information displayed on the tote slides could have been shown on the CRT screen with little difficulty. This was not done in the present experiment for reasons of experimental control previously discussed under Method.

If there is little advantage to be gained from graphic presentation, and since totes may be displayed on a CRT, then it is likely that a substantial number of the requirements for a graphic display as listed in the recent Qualitative Material Development Objective (QMDO) could be eliminated. This elimination could be accomplished by presenting as much information as possible via the CRTs presently available (and being used) in such developmental systems as the Tactical Operations System (TOS).

This procedure would not necessarily eliminate the need for computer-driven graphic displays. By definition, there exists no method of constructing a nongraphic map! Nor is there satisfactory empirical evidence as yet regarding the impact of graphic/symbolic displays in a dynamic combat environment. Rather, the results suggest that the complexity and density of information being considered for inclusion on graphic displays (50-60 items) may be considerably reduced by conversion to a form suitable for CRT or printout. Such a decrease in the information load for graphic displays is likely to facilitate implementation of these devices.

Relative to the secondary objective of the experiment--determining potential difficulties with graphic displays--several interesting observations may be made concerning the graphic display of maps, based on the subject's comments and on difficulties that occurred in stimulus construction. Although only two subjects complained of difficulty in

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[14] Mayfield, C.E. Empirical human factors investigation of display design. Franklin Institute Research Laboratories. Philadelphia, Pa. April 1967. (AD 653 470)

[15] Vicino, F. L., and S. Ringel. Decision making with updated graphic vs alpha-numeric information. ARI Technical Research Note 178. November 1966. (AD 647 623)

[16] Nawrocki, L. H. Alpha-numeric versus graphic displays in a problem-solving task. ARI Technical Research Note 227. September 1972. (AD 748 799)

reading the back-projected map displays, it is possible that many subjects had difficulty but did not criticize map readability since they were able to carry out the task. On any similar method of display (back-projected slides), two major difficulties are encountered: First, there is the problem of the slide itself. Photographing a map calls for a considerable reduction in size from the surface area of the map to that of the slide[17]. Considerable detail is lost in this reduction--a loss which becomes apparent when the slide is later projected. Second, even in a relatively fixed environment there will be some jitter in the projected image due to vibration from both the equipment itself and from external sources. Such jitter is likely to increase considerably in a mobile field environment, resulting in even poorer visual quality.

Both problems could be minimized if the map slide were not required to contain the level of detail and code system existing on present standard military maps. For example, the requirement for multi-color maps means loss of clarity in the display, as the color photograph process produces greater loss of resolution than does the equivalent black-and-white process.

An additional problem reported by some subjects was that of relating location information between maps of different scales. For example, geographic disorientation was experienced in transferring from a 1:250,000-scale operations map to 1:50,000 blow-ups of segments of the operations map, and vice versa. This problem suggests that split-screen, multiple-screen, expansion, blinking lights, or a variety of other techniques may be necessary to aid the user in orienting himself from one map to a map of different scale. The selection of the best alternative is, of course, a matter requiring empirical verification.

CONCLUSIONS

Within the constraints imposed by research thus far accomplished, there is no empirical evidence of improved performance due to graphic displays.

Several technological difficulties remain to be surmounted if a decision is made to implement sophisticated graphic displays. In the absence of additional findings, it would appear for the moment more economical and technologically feasible to use alpha-numeric/tote displays as much as possible.

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[17] The author wishes to express his appreciation for the considerable efforts of the U. S. Army Topographic Command (particularly to Mr. Green and Mr. Hunsicker) in producing the highest possible slide quality now obtainable.

A direct comparison of tote and graphic displays may well be a moot point because of the nearly infinite combinations of display and task. Clearly, some information seems inherently suited to display by alpha-numeric/totes (such as numerical listings) and some to symbolic/graphics (such as movement). At this point, it appears that the primary/research effort should be directed toward determining command information requirements, followed by experimentation to identify the most advantageous means for displaying the information which satisfies these requirements. Such research would provide a more adequate basis for evaluating the need for graphic displays and determining their most appropriate use.

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