Technical Report 428

LEVEL II

A COMPARISON OF ALTERNATE FORMATS FOR THE PORTRAYAL OF TERRAIN RELIEF ON MILITARY MAPS

John P. Farrell and Lawrence M. Potash

HUMAN FACTORS TECHNICAL AREA

U. S. Army
Research Institute for the Behavioral and Social Sciences

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Two experiments evaluated the effectiveness of relief shading and layer tints as supplements to contour lines for solving eight types of military map-use problems. The addition of layer tints was found to increase the speed of solving most problems with no loss in accuracy. The addition of shaded relief increased the time required to solve problems requiring detailed information but may be valuable in providing a quick general impression. Personnel experienced in using military maps solved map problems

20. more accurately but no faster, on the whole. Also, solving military map use problems in the classroom appears to correlate with performance in the field.

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FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with the demands of the future battlefield for increased man-machine complexity to acquire, transmit, process, disseminate, and utilize information. The research is focused on the interface problems and interactions within command and control centers and is concerned with such areas as topographic products and procedures, tactical symbology, information management, user-oriented systems, staff operations and procedures, and sensor systems integration and utilization.

One area of special interest is that of human factors problems in the design of topographic products and procedures. This publication evaluates the effectiveness for solving military map problems of supplementing current, standard relief formats with either shaded relief or layer tints. Findings can aid in the design of cost-effective special purpose Army maps and in the objective evaluation of cartographic products.

Research on the design of topographic products and procedures is conducted as an in-house effort augmented by contracts with organizations selected for their specialized capabilities and facilities. These efforts are responsive to the general requirements of Army Project 2Q763743A774 and to special requirements of the USA Engineering Topographic Laboratory. Special requirements are contained in Human Research Need 79-230 "Topographic Product Design and Test Methodology."

This research effort was made possible through the assistance of Alex Pearson of the USA Engineering Topographic Laboratory and through the cooperation of Combat Developments Experimentation Command, Fort Ord, California.

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A COMPARISON OF ALTERNATE FORMATS FOR THE PORTRAYAL OF TERRAIN RELIEF ON MILITARY MAPS

BRIEF

Requirement:

To evaluate techniques designed to enhance the display of terrain information on military maps, and compare the effectiveness of these techniques with standard U.S. Army contour line maps.

Procedure:

In two experiments, the standard U.S. Army contour line maps were compared with innovative map formats consisting of contour lines supplemented with (a) relief shading, and (b) gradient (layer) tints. The effectiveness of the maps was evaluated by measuring the accuracy and speed with which topographic information was extracted from the map products. A field trial was also conducted to compare the performance criteria used in Experiments I and II with performance on map-use tasks in the field, i.e., finding checkpoints and reporting target locations.

Findings:

The addition of layer tints to maps increases the speed with which information can be extracted from maps with no loss in accuracy.

The addition of relief shading increases the amount of time required to extract the topographic information needed in the map-use tasks of most Army personnel, although relief shading has some value for visualizing terrain.

Experienced personnel solve map tasks more accurately, but not necessarily faster than less experienced personnel.

Utilization of Findings:

Layer tints are a valuable supplement on special purpose maps for fast and accurate solutions to terrain information problems, especially if the problems involve elevation. Shaded relief does not aid in the solution of map tasks that require detailed and specific terrain information.

Measurement of the accuracy and speed of extraction of information from a map product was found to be a valuable technique for evaluation of experimental map products and a valuable alternative to user surveys and field tests.

A COMPARISON OF ALTERNATE FORMATS FOR THE PORTRAYAL OF TERRAIN RELIEF ON MILITARY MAPS

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A COMPARISON OF ALTERNATE FORMATS FOR THE PORTRAYAL OF TERRAIN RELIEF ON MILITARY MAPS

INTRODUCTION

Maps and map reading are essential components of most military operations, and their role has become increasingly important with the emphasis on combined arms tactics in the modern U.S. Army. Actions of infantry, artillery, aviation, and armor must be closely coordinated and precise positional information of the interacting units is required. To facilitate accurate positioning it is necessary to have maps which present terrain information in a form that is clear and unequivocal to the user.

In an effort to make the terrain relief information on maps more perceptually accessible to the user, the U.S. Army Engineer Topographic Laboratory has been developing new map formats and has requested ARI research support to assess the effectiveness of these experimental map products. This report presents the results of experiments conducted for this evaluation and briefly presents the research methodology which ARI developed for that purpose. A more extensive discussion of the research methodology developed for assessing relief map legibility is presented by Potash, Farrell, and Jeffrey (1978).

Background

Military maps must present information about terrain, such as steepness, shape, and elevation of landforms, on a two-dimensional surface in such a manner that it can be perceived quickly and accurately.

For approximately the last 50 years the means of depicting terrain information on U.S. Army maps has been contour lines, or lines drawn through all points of the same elevation on a given landform with the interval between adjacent lines reflecting the vertical interval on the land. Contour lines replaced other portrayal techniques because they provide the most precise information about terrain. Unfortunately, there are a number of difficulties with contour lines. Some of these difficulties are cartographic: cliffs do not show up well; small terrain features are not represented; and for rough terrain with extremes of relief, such as that found in many parts of the western U.S., there simply may not be enough space on the map sheet for the number of contour lines required (Marsden, 1955). A more serious problem with contour lines, however, is behavioral. Many map users have difficulty visualizing terrain when contour lines are the only guide, and it has been found that many military map users report to hand application of additional material to enhance their perception of the terrain portrayed (Skop, 1958). In addition, in many military tasks, such as helicopter navigiation at low altitudes, there is insufficient time to interpret contour lines accurately.

There are a number of alternatives and supplements to contour lines as a means of portraying terrain relief. These include: (1) hachures, or linear "hash" marks, to indicate the presence of slopes; (2) the Tanaka method, a system of modified contours; (3) digital terrain information, or spot heights in numerical forms; (4) perspective drawing or drawings to give the impression of space or depth; (5) relief shading or the shading of slopes; and (6) layer or gradient tints which color code different altitude zones. After conferring with U.S. Army Engineer Topographic Laboratory personnel, it was concluded that for military map problems it would be undesirable to sacrifice the precision of contour lines, so supplements rather than alternative formats were considered. The particular contour supplements to be evaluated were selected on the basis of both previous research and the availability of cartographic resources for generating materials. For example, the quality of hachures are highly subject to the skill of the cartographic artist applying them, and easily degenerate into "hairy caterpillars" (Robinson and Sale, 1969, p. 175) when very high levels of expertise are not employed. Similarly, the Tanaka method was not chosen for evaluation because the cartographic techniques required are not available on a widespread basis. As a result of these considerations, shaded relief and layer or gradient tints were chosen for evaluation as supplements to contour lines. In Figure 1, examples of unenhanced contour lines and of contour lines supplemented with shaded relief and with layer tints are shown.

In shaded relief, light is presumed to come from one direction, and slopes on the incident side of a hill or given landform are unshaded, while slopes on the opposite side are in the shade. The degree of shading varies, with the steeper slopes being darker. In gradient or layer tints, terrain is color coded to indicate bands of elevation. Several gradations of a single hue may be used or these may be different colors; for example, 500 to 1500 feet may be represented by yellow, 1500 to 2500 feet by tan, and all elevation above 2500 feet by brown. In the current research three to four different colors were used, depending on the range of elevation present in the specific map segments.

In related research on the value of layer tints Kempf and Poock (1969) used 12 tints, varying in both intensity and color, to compare contour lines versus contour lines plus layer tints. Their experiment showed that the addition of layer tints improved performance on determining the altitude of given points, but had a detrimental effect on determining grid coordinates. DeLucia (1972) also found that the addition of relief shading had a detrimental effect on the accessibility of two-dimensional terrain information.

In another experiment, Phillips, DeLucia and Skelton (1975) compared four types of maps: contour line, contour line supplemented with shaded relief, layer tints, and digital or spot height maps. An interesting innovation in this study was the use of two areas of the Atlantic sea

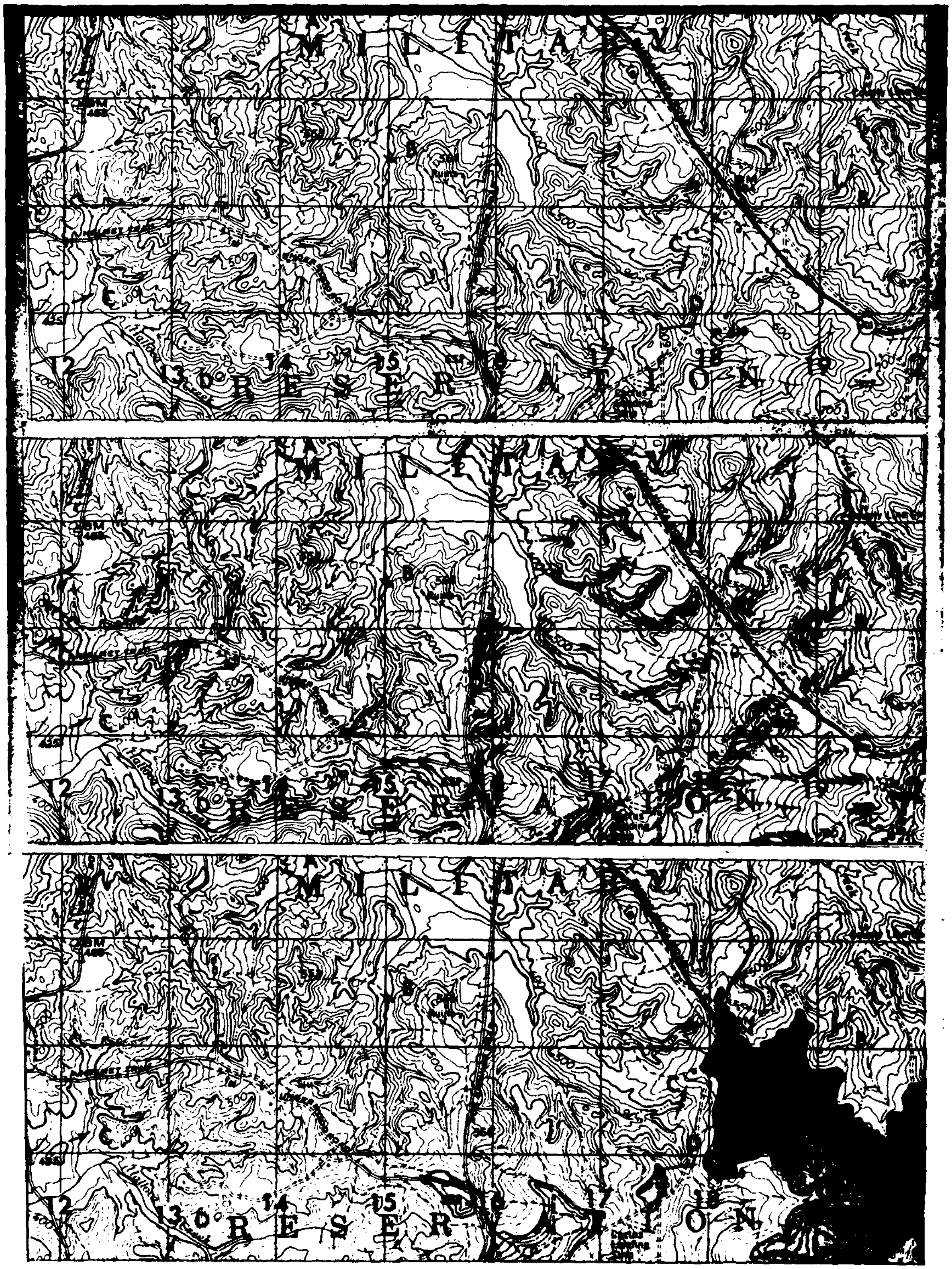


Figure 1. Examples of Three Map Formats; Contour Lines, Shaded Relief, and Layer Tints

floor to produce the maps and thereby control for previous experience with the map or actual terrain as a contaminating variable. In their results, layer tints proved best for judging relative height and visualizing the landscape. Contour lines and contour lines supplemented with relief shading proved to be roughly equal for all tasks. As expected, digital or spot height maps were relatively good for height judgment, but not for other tasks. Phillps et al. used layer tints without contour lines, while in the current research, contour lines were supplemented by layer tints. There were also a number of procedural differences.

The results of previous research suggested that both the maps supplemented with shaded relief and those supplemented with layer tints would be superior to unenhanced contour lines. It was also predicted that the experimental maps would be less advantageous for the more experienced map users who were more familiar with the standard contour line format than for the less experienced map users. The present research sought to test both of these hypotheses.

The Evaluation of Military Maps

The primary goal of the research was to evaluate the effectiveness of the alternate techniques for the portrayal of terrain relief. A secondary goal of the research effort, however, was to develop a research methodology for the evaluation of military maps. Until recently, alternate map formats were evaluated by either surveys of user preference or by field tests. Both of these techniques have inherent problems. While surveys are relatively inexpensive and also provide information on the degree of user acceptance, user preference surveys have questionable predictive validity for performance with maps unless the individuals questioned have actually used the map products under consideration (Wheaton, Zavala, and Van Cott, 1967). One study found that the preference opinions of potential users were useless as predictors of performance under daylight conditions, and only in a night experiment were subjective judgments of preference of any value in predicting user performance (Hill, 1974). The positive results at night were most likely due to the effect of image quality on perception at low levels of illumination. Under daylight conditions, however, judgment was affected by biases due to the esthetic qualities of the map, personal preferences due to previous experience, and other contaminating factors.

Field tests present other problems. Objective field testing is expensive in terms of time and dollars, and many extraneous variables which are difficult to control are present. In one study no significant differences were found between map types because of the large number of uncontrolled variables present in the field (MAPPRO II, 1973). If only one terrain is used, the question arises about whether the results are terrain specific or if generalizations can be made to other terrains.

Seasonal effects exist and must be controlled; for example, land navigation is generally easier in the late fall and winter when vegetation does not obscure the shape of landforms or landmarks such as small streams. A more serious contaminating variable is tracks made through grass and other vegetation by the early players. These tracks persist for a considerable length of time and affect the behavior of subsequent players.

In view of these problems with the more traditional approaches to map format evaluation, an approach was developed focused on the information extracted from the map. Somewhat similar approaches were used by Kempf and Poock (1969), who measured time and accuracy in determining elevation and grid coordinates, and by Phillips, DeLucia and Skelton (1975), who required participants to extract 12 types of information from maps. Both the approach of Kempf and Poock (1969) and that of Phillips (1975) have some similarities to the current approach.

Eight types of relief information normally extracted from maps by Army users were identified, based upon consultations with personnel at the U.S. Army Engineer Topographic Laboratory and other representative military users, and developed into subtests. Map segments representing four types of terrain ranging from relatively flat to mountainous were used. Answers were scored for both accuracy and time. Illustrations of each of the eight terrain formation items are described below; however, a more extensive description is provided in Potash, Farrell, and Jeffrey (1978).

Eight Types of Terrain Information

1. Landform Identification. The participants are presented with map segments with arrows overprinted, and shown sketches of various landforms, such as hills, valleys, spurs, saddles, or depressions. The participants are then required to specify which of the representative landforms is portrayed on the map at the tip of each arrow (Figure 2).

2. Ridge-Valley Identification. In this task the participants are presented with map segments that contain overprinted lines. The participants' task is to determine if a line is overprinted on a valley or a ridge, or if it does not fall into either category (Figure 3).

3. Slope Identification. Slopes may be convex, concave or uniform. In this task the participants are presented with map segments with arrows overprinted. The participant is asked which type of slope is indicated and if the arrow runs up or down hill (Figure 4).

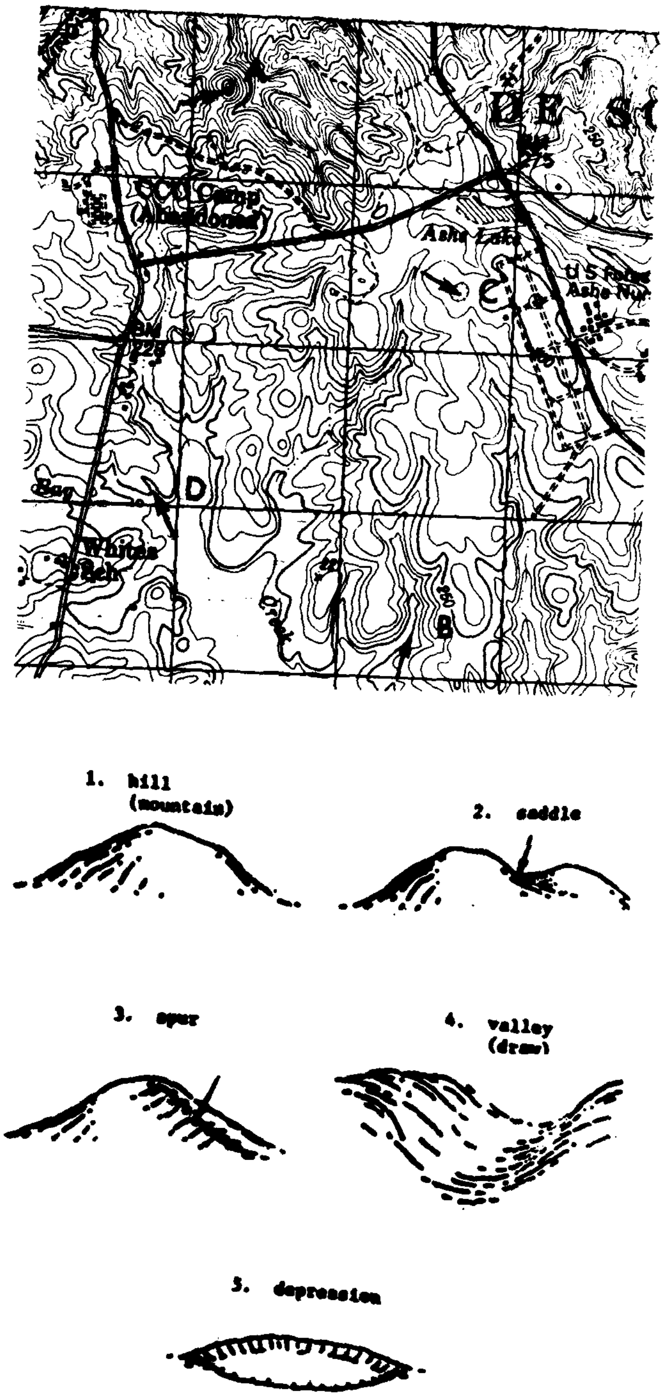


Figure 2. Sample Landform Identification problem. Map segment and landform sketches. Overprinted letters on map segments must be matched with appropriate landform.

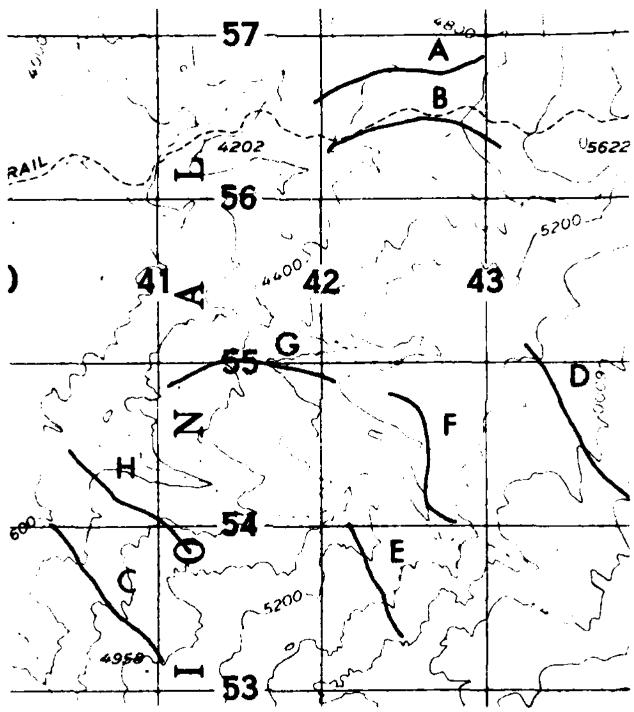


Figure 3. Sample Ridge-Valley problem. Map segment with overprinted lines which are used in ridge-valley identification.

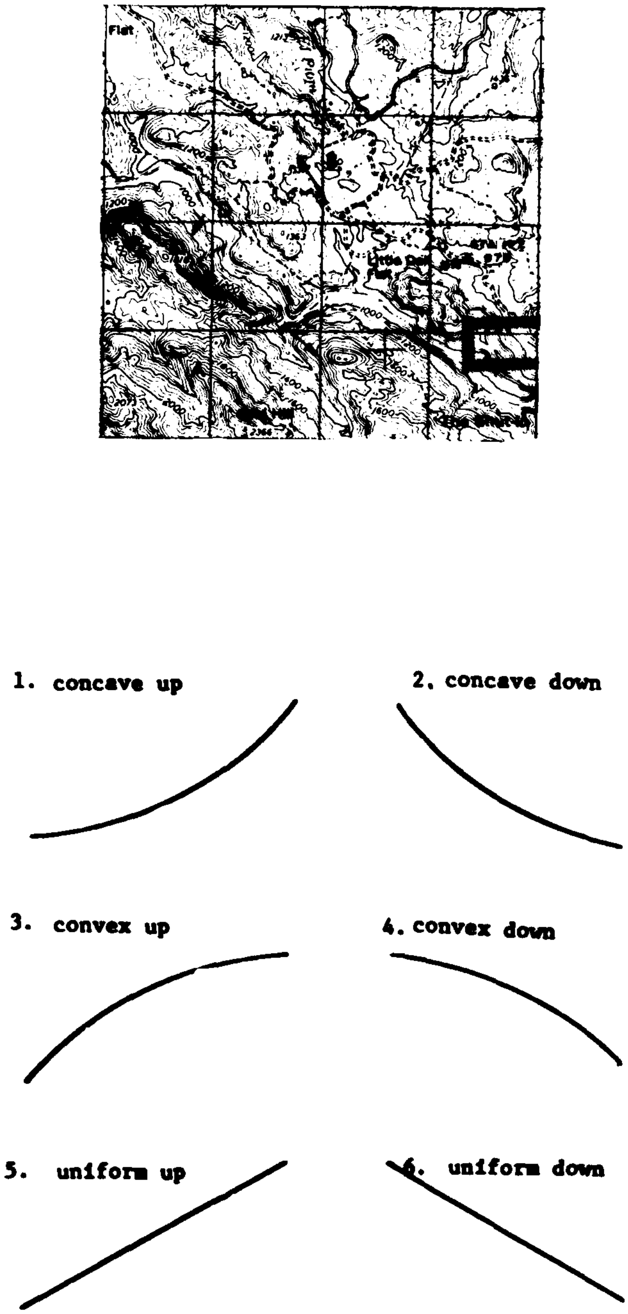


Figure 4. Sample Slope Identification problem. Slopes indicated by overprinted lines must be matched with an illustrated slope type.

4. Identification of High and Low Areas. In this task the participants are presented with map segments divided into 64 grid squares, each of the grid squares representing an area 1000 x 1000 meters. The participants must specify the 4 highest and the 4 lowest grid squares (Figure 5).

5. Spot Elevation Problems. Map segments with several points indicated by letters are presented to the participants, who are required to determine the elevation of each point (Figure 6).

6. Vertical Profile Identification. In this task participants are presented with maps with overprinted lines which indicate slopes. The participant must match the slope indicated on the map with one of three drawings of slope angles (Figure 7).

7. Terrain Visualization. Participants are shown a terrain sketch and map segments with points indicated. The participants must visualize each of the points indicated on the map and determine which best matches the sketch (Figure 8).

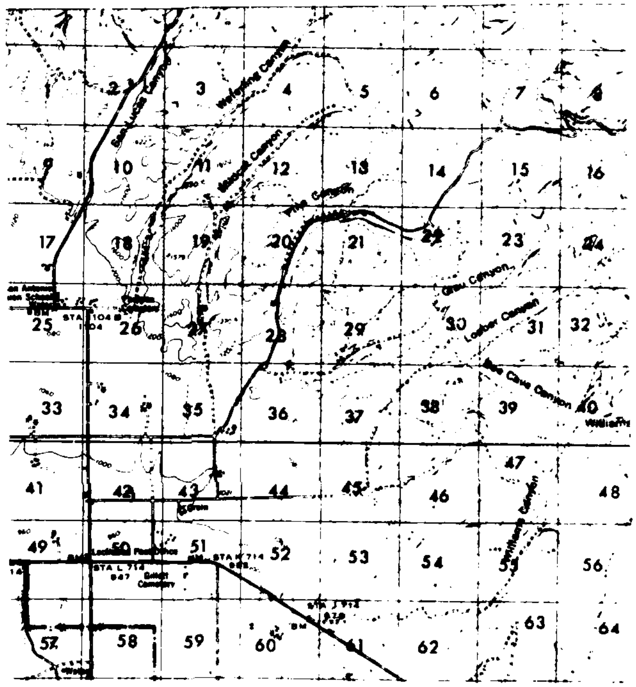
8. Defilade or Intervisibility. Map segments with points indicated by letters are presented to the participants, and the participants are asked to determine if observers located at selected pairs of points are visible to each other (Figure 9).

Since the eight subtests directly measure the accuracy and speed with which terrain information is extracted from maps, these subtests are inherently valid. The basic criteria in performance with a map is the extraction of terrain information. Tests which contain a representative sample of the behavior domain to be tested have content validity (Anastasi, 1976, p. 96-102 and 133-134). The eight subtests represent types of information that Army personnel must extract from maps. Thus these eight subtests are criterion referenced and possess content validity.

Unfortunately, content validity may not insure predictive validity. As stated earlier, performance in the field with a map is a complex multifaceted task, and predictive validity cannot be assumed. Therefore, as part of the research program, performance on the eight subtests was compared with field performance on map use tasks.

Research Approach

In Experiment I a total of 48 Army officers and NCOs were tested for the speed and accuracy with which they solved terrain information problems in each of the eight subtests. While there was a considerable range in the level of previous map experience of the participants, the overall map-use experience of the group was somewhat higher than that of the general U.S. Army population.



contour interval 40 ft.

Figure 5. Sample High-Low Area problem. The four highest and four lowest grids on overprinted map must be identified.

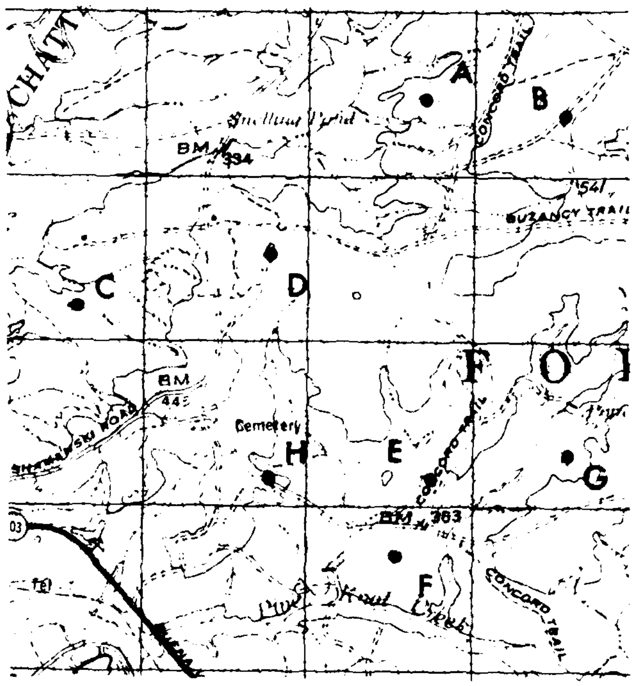


Figure 6. Samplė Spot Elevation problem. Elevation of overprinted points on map segment must identified.

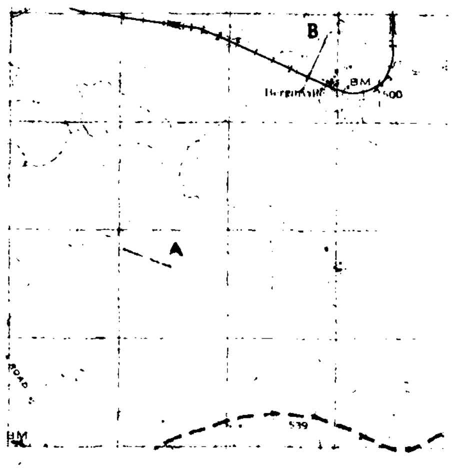
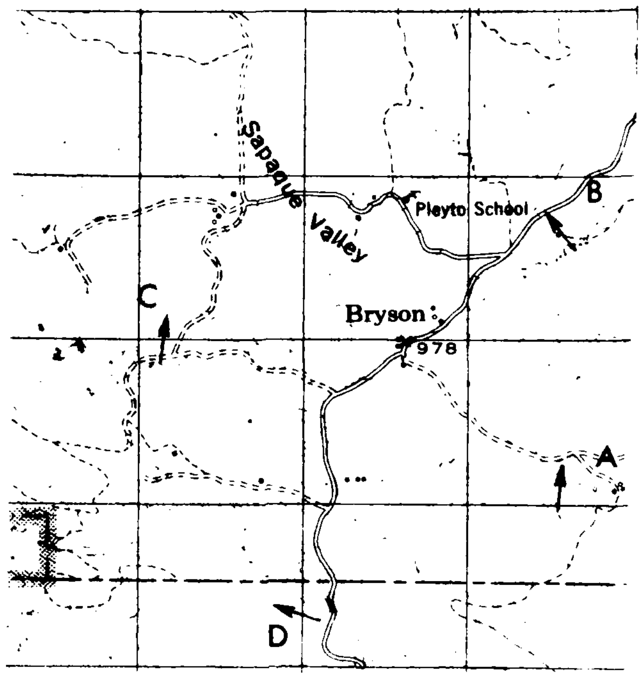


Figure 7. Sample Vertical Profile problem. Profile indicated by overprinted line on map sement must be matched with a line drawing illustrating vertical profiles.



Your approximate angle of vision is enclosed by the dashed lines touching the arrow tip. The length of the thick solid line touching the arrow tip represents the maximum range for your vision.

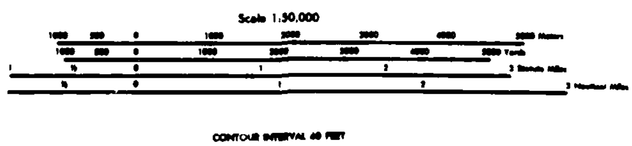


Figure 8. Sample Terrain Visualization problem. Drawing of scene must be matched with overprinted point on map segment.

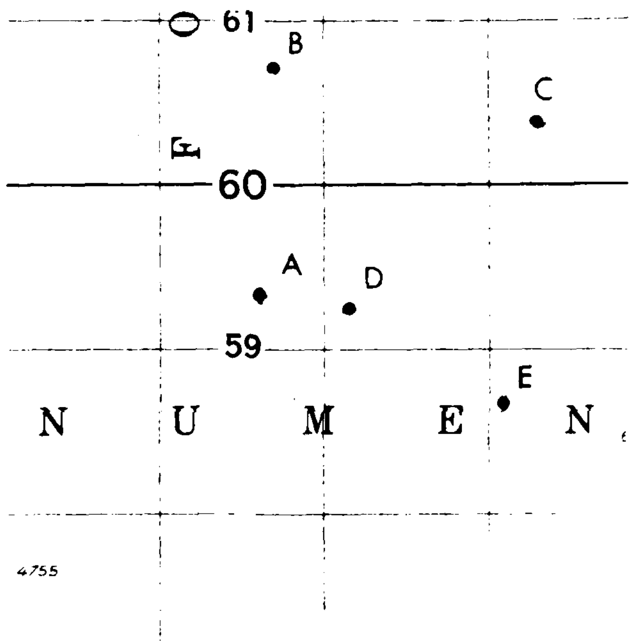


Figure 9. Sample Defilade problem. Intervisibility between points overprinted on map sement must be identified.

Experiment II was essentially a replication of Experiment I, but the overall map user experience level was lower. The participants in Experiment II generally had been in the Army less time and had less map experience than the participants in Experiment I. The participants in Experiment II were chosen so that results of the research effort could be generalized to a much larger portion of the Army population. The characteristics of the participants and the research procedure are presented in greater detail in the Method section.

A field validation was also conducted to insure that results of the measures used in Experiments I and II would generalize to performance in the field. In this experiment only the standard contour line map was evaluated and the performance of participants on the assessment test was compared with performance on field criteria.

Research Objectives

(1) To evaluate two experimental map formats, using shaded relief and layer tints as supplements to contour lines, and compare them to standard U.S. Army maps.

(2) To assess the effects of user experience with each type of map, and determine if alternate map formats are preferable with less experienced personnel.

(3) To determine the effectiveness of a method of evaluating map products by measuring the speed and accuracy with which information is extracted from the map.

METHOD

Experiment I

Participants. A total of 48 male Army officers and NCOs ranging in rank from sergeant through major participated in this experiment. Although the level of experience in use of the standard Army contour line map varied, the overall level of experience was somewhat higher than the general Army population. Participants were obtained from the Second Armored Division. This particular unit uses maps for land navigation more often than many other units. Approximately two-thirds of the participants were Ranger qualified and had received advanced instruction in map use and land navigation. Those participants who were Ranger qualified and had used maps in exercises regularly within the last two years were considered highly experienced; those participants who had Ranger training but had not used maps in exercises within two years were considerd moderate in experience; and those who had not received Ranger training and had not used maps in field exercises in two years were considered low in experience. Fourteen participants were in the low category, 19 in the moderate, and 15 in the highly experienced category.

Performance Measures. A test containing eight subtests was created, corresponding to the eight critical types of relief information discussed earlier, to measure the extraction of information from each map format. The eight types are: landform identification, ridge-valley identification, identification of slopes, identification of high and low ground, determination of elevation of spots, vertical profile identification, terrain visualization, and intervisibility or defilade. Each subtest was scored on both speed and accuracy. Map segments representing 4000 meter by 4000 meter grid squares accompany questions, except for the "identification of high-low area" problem which uses 8000-meter grid squares. The map segments are taken from the standard scale or 1:50,000 map, and four terrain contour intervals were used: 10, 20, 40, and 80 feet.

Procedure. Participants were tested in small groups of either six or eight in a large room with widely spaced tables and one participant per table. Participants were randomly assigned to seats, and the format placed at a given seat was varied on a daily basis. Participants were instructed to work as quickly and as accurately as possible. They were instructed to take a rest break if they became fatigued, but to take the break only at the end of a problem. Stopwatches were given to each participant to determine the amount of time required to solve each problem, and they were instructed to indicate the time required to solve each problem with the answers on their answer sheet. Each participant worked with only one problem at a time.

Experiment II

Participants. A total of 30 participants were used in Experiment II. The participants were obtained from initial entry officer candidate students. Overall experience level was somewhat lower than that of the general Army population, although five participants did have extensive prior experience.

Procedure. Ten different participants were tested each day in a large room for three consecutive days. The map formats placed at the seats were altered each day and seats were assigned to obtain the required number of participants in each particular experimental condition.

RESULTS

Overview

In this section, results for the major variables, map format and user experience, are summarized in terms of both accuracy and time scores for both Experiments I and II (Tables 1 through 4). Appendixes A-D contain the results in greater detail, with mean accuracy and median time scores for each experience level as well as analysis of variance tables. Results from the field validation experiment to assess the predictive validity of the subtests are presented in Appendix E.

Experiment I

Since there was no overall performance score, separate two-way analyses of variance (Map Format x Experience Level) were conducted for each of the eight subtests for both accuracy and time scores. Therefore, there are 16 two-way analyses of variance. Of the two major variables, map format and user experience, map format is the more important.

Results on the map format variable are summarized for accuracy scores in Table 1 and for time scores in Table 2. In Table 1, statistically significant effects for map format can be seen on the landform identification, the ridge-valley identification and the spot elevation subtests. On these three subtests, the map format using layer tints was superior on two: ridge-valley identification and spot elevation. Inspection of Table 1 shows that the accuracy scores on the contour line and layer tint formats are relatively close to each other, and that on all eight subtests, the map format using shaded relief was poorest.

Table 2 is a summary of the results using time required to solve the problem as the scoring criterion. Inspection of Table 2 indicates that with layer tint format the shortest time was required to solve the problem for seven of the eight subtests, the only exception being terrain visualization. On only two of the subtests, however, was the effect statistically significant: ridge-valley identification, and identification of high and low areas.

The other major variable, user experience level, concerned two significant issues, (1) main effect due to experience and (2) interaction effects between map format and experience levels. The results regarding experience are presented in Table 3.

Experience level of the user produced a significant main effect on all eight subtests when accuracy scores were used as a criterion for performance. Using time scores as a criterion, however, produced only three significant effects. There were no statistically significant interaction effects between experience level of user and map format in any of the 16 two-way analyses of variance in Experiment I.

Experiment II

In the data on Experiment II, within-cell variance was higher than in Experiment I and fewer statistically significant effects were found.

TABLE 1

Experiment I: Summary of Significant Effects on Map Format for Mean Accuracy Scores

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	13.64	12.4	13.12*
2. Ridge-Valley Ident	23.86	20.67	25.19**
3. Slope Ident	12.14	10.28	11.69
4. Ident of High-Low Areas	47.6	46.8	48.44
5. Spot Elevation	23.14	16.56	22.56**
6. Vertical Profile	8.5	6.78	7.69
7. Visualization	9.5	8.34	9.13
8. Defilade	20.86	19.44	19.69

* $p<.05$
** $p<.01$

TABLE 2

Experiment I: Summary of Significant Effects on Map Format for Median Time Scores

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	1.02	1.04	.76
2. Ridge-Valley Ident	2.36	2.37	1.71*
3. Slope Ident	1.34	1.36	1.19
4. Ident of High-Low Areas	4.23	3.13	2.51**
5. Spot Elevation	4.51	4.14	3.34
6. Vertical Profile	1.87	1.7	1.57
7. Visualization	.88	.78	1.0
8. Defilade	2.68	2.46	1.9

* $p<.05$
**$p<.01$

Table 3

Experiment I: Statistically Significant Effects From User Experience Levels

Subtest	Accuracy Scores: Main Effect	Accuracy Scores: Interaction With Format	Time Scores: Main Effect	Time Scores: Interaction With Format
1. Landform Ident	.01	NS	NS	NS
2. Ridge-Valley Ident	.01	NS	NS	NS
3. Slope Ident	.05	NS	.05	NS
4. Ident of High-Low Areas	.01	NS	NS	NS
5. Spot Elevation	.01	NS	.05	NS
6. Vertical Profile	.01	NS	.05	NS
7. Visualization	.05	NS	NS	NS
8. Defilade	.01	NS	NS	NS

In the accuracy scores of Experiment II, no statistically significant effects were found from either the map format or the user experience level variables. Trends were similar to Experiment I in that the shaded relief format produced the lowest mean score on seven of the eight subtests with the low experience groups, and the lowest mean scores on all eight subtests in the higher experience group. Although these effects were not statistically significant, such consistent trends should not be ignored. These trends may be seen by inspecting tables in Appendix C.

Statistically significant effects were found in the time scores for both the map format and user experience level variables. In map format, the landform identification and the terrain visualization subtests produced significant effects. A summary of the effects obtained with time scores in Experiment II is presented in Table 4.

For the low experience group, shaded relief was the poorest format, except on the terrain visualization subtest. Shaded relief was somewhat better for the higher experience group, as can be seen in greater detail in Appendix D, Tables D-1 and D-2.

The experience variable produced significant effects on the landform identification and the ridge-valley identification subtests in time scores. In the landform identification time score results, a significant interaction occurred between map format and experience ($p<.01$). In the total of 31 tests for interactions between map format and experience in Experiments I and II this was the only significant interaction.

DISCUSSION

Overview

In providing an interpretation of the data acquired in Experiments I and II, three major issues must be considered: (1) effect of map format; (2) effect of user experience; and (3) interaction effects between map format and experience. Several aspects of each of these variables must be considered. If a particular map format is superior for some subtests but not for others, this will affect the generalizations that can be made about that particular format. Effects of experience, and interactions between map format and experience, must also be discussed. Interactions are particularly important because a large number of significant interactions would indicate that a particular map format was more effective at some experience levels than others, and this would also affect the generalizations that could be made from the data. Two remaining issues must be addressed in discussing the experimental results: (1) implications of the research for map design and (2) implications for evaluating cartographic products. This last issue is discussed in Appendix E, where the predictive validity of the eight subtests is addressed.

TABLE 4

Experiment II: Summary of Significant Effects on Map Format for Time Scores

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	1.24	1.13	.95**
2. Ridge-Valley Ident	1.74	2.18	1.76
3. Slope Ident	1.01	1.46	1.13
4. Ident of High-Low Areas	2.48	2.83	2.31
5. Spot Elevation[a]	Insufficient data on This Subtest		
6. Vertical Profile	2.42	1.51	2.45
7. Visualization	.73	.61	1.0**
8. Defilade	2.26	1.93	2.02

[a]The spot elevation of 32 points must be determined on this subtest, and due to the generally low experience level of the participants in this experiment, many of them were unable to complete enough items to obtain meaningful time scores on this subtest.

**p<.01

Effects of Map Format on Accuracy in Experiments I and II

In Experiments I and II the most important issue is the effect of map format--whether or not the supplements of shaded relief or layer tints to standard U.S. Army contour line maps result in superior performance. In Experiment I, using accuracy scores as criteria, statistically significant effects were found on three subtests: landform identification, ridge-valley identification, and spot evaluation. On each of these subtests the difference was small between the map format using layer tints as a supplement and the standard contour line map. Both of these formats, however, were superior to the format using shaded relief as a supplement. A general trend in this direction is also evident on the remaining five subtests; however, the effects did not reach statistically significant levels. These general effects occurred for all experience levels in Experiment I.

Experiment II was rather similar to Experiment I but was conducted on a population with a generally lower experience level. It was thought that the relatively poor performance found with the shaded relief supplement might have been due to the fact that participants in Experiment I were somewhat more experienced in using maps than were the general U.S. Army population. This greater experience with the standard U.S. Army contour line map might have created a bias in favor of the standard map, so participants with an experience level somewhat lower than that of the general U.S. Army population were used in Experiment II. However, using accuracy scores as criteria, no statistically significant effects were found on map format. Mean scores on the layer tint format were consistently higher (although not statistically significant) than on shaded relief format on seven of the eight subtests in Experiment II. Such a consistent trend should not be ignored. These results with accuracy scores in Experiment II reflect the same trend found in Experiment I. For most Army map use problems involving specific terrain relief information, layer tints appear superior to shaded relief as a supplement to contour lines. This replication of the effect found in Experiment I with a different overall experience level among the participants suggests that the effect is a general one.

Effects of Map Format on Time Scores in Experiments I and II

In the time data for Experiments I and II, results were generally similar to the accuracy data, but the map format using layer tints to supplement contour lines was superior to both shaded relief or unenhanced contour lines. In Experiment I, significant effects occurred only in ridge-valley identification and identification of high and low areas. In both of these subtests, layer tints resulted in faster problem solving time. In the subtests of Experiment I, layer tints required the shortest solution time on at least six of the eight subtests regardless of the experience group. In Experiment II, the results using time data were somewhat less clear. For the low experience groups, layer tints and standard contour lines were better than shaded relief on landform identification, but for the higher experience group the standard contour line map was poorest.

A statisticallly significant effect in the time scores favored shaded relief on the visualization task. This effect cannot be considered a sampling error or a fluke. Examination of the visualization subtests results in Experiment I (Tables 1 and 2) indicates a slight effect favoring shaded relief when both time and accuracy are used as criteria. Once again, a trend is evident. The visualization subtest differs from the others in that the participant is required to visualize an area rather than answer questions concerning precise detail as in the other seven subtests.

Effects of User Experience Level

User experience level had a more powerful effect on accuracy than on time in Experiment I. This effect was not replicated in Experiment II because of the high-within cell variance on accuracy scores from the relatively less experienced participants. The effect in Experiment I, however, demonstrated that greater levels f experience resulted in more accurate, but not necessarily faster, solutions of terrain relief problems. An important implication of this finding is that speed of solving map tasks may be less sensitive than accuracy as a measure of human performance with maps.

Interactions Between Map Format and User Experience Level

In the combined results of Experiments I and II, there were 31 statistical tests for interaction between the two main effects, map format and user experience level. Only one statistically significant interaction occurred in the 31 tests. The lack of strong interaction effects suggests that while the less experienced participants have lower performance levels than the more experienced, the same relative patterns occur for different experience levels. This result suggests that special purpose maps are not necessary for terrain problems with less experienced participants.

Implications for the Design of Maps

These results have several implications for the design and evaluation of military and commercial maps. In general, the use of layer tints to enhance contour lines made relief information the most perceptually accessible to users. This was true for most of the measures which involved extracting highly detailed information typical of Army map tasks. The use of shaded relief increased the amount of time required to solve problems with no increase in accuracy, except on the terrain visualization measure. This suggests that relief shading has some value in giving a fast general impression of the terrain characteristics in a given area, but not for questions involving more precise terrain information.

One important result is that when contour lines were supplemented with shaded relief, which was intended to enhance the perception of terrain relief, there was an increase in the time required to solve the problems with no corresponding increase in accuracy for most of the subtests. This unexpected finding, consistent with the work of other investigators such as Hill (1974), suggests that new cartographic products require objective evaluation. It is likely that shaded relief impeded performance because of a cluttering effect, and since such effects often cannot be foreseen, empirical testing of new military map products is advisable.

SUMMARY

The primary goal of this research effort was to evaluate two experimental map formats designed to enhance the perceptual accessibility of terrain relief information. The two experimental map formats supplemented contour lines with either shaded relief or layer tints. The first experiment involved participants who had relatively more experience with maps than most U.S. Army personnel. To insure that the results of research would generalize to the entire U.S. Army population, a group with less experience was used in a second experiment.

For most of the eight types of terrain information that subjects were required to extract from maps, the map format using layer tints to supplement contour lines resulted in faster problem solving with no loss in accuracy. The use of shaded relief did not increase the map reading speed and sometimes resulted in a decrease in accuracy of extracting the specific terrain information typical of most U.S. Army map use problems. Shaded relief was of some value, however, for giving a general impression of the topography of a given area. More experienced personnel solved map problems more accurately but not necessarily faster than inexperienced personnel. In 31 tests for interactions between map format and experience, only one significant interaction occurred. A map format that is effective at one experience level is also effective at another, and special purpose maps for map users with low experience do not appear necessary.

A secondary goal of the research effort was to further develop the research methodology for evaluating map formats. Traditional techniques for map evaluation--user surveys and field tests--have limitations. Therefore, a technique was developed which measures the speed and accuracy with which information is extracted from a map product. This technique was found to be a useful method for evaluating the effectiveness of experimental maps.

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APPENDIX A

ACCURACY EFFECTS IN EXPERIMENT I

Table A-1

Mean Accuracy Scores in Experiment I, Low Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	11.75	10.25	12.5
2. Ridge-Valley Ident	18.25	13.50	21.8
3. Slope Ident	10.25	7.5	11.0
4. Ident of High-Low Areas	44.0	40.5	47.5**
5. Spot Elevation	20.75	8.75	19.3
6. Vertical Profile	6.5	4.75	5.83
7. Visualization	6.0	7.0	8.3*
8. Defilade	20.0	16.25	18.17**

* $p<.05$ level
** $p<.01$

TABLE A-2

Mean Accuracy Scores in Experiment I, Moderate Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	14.3	12.0	13.14
2. Ridge-Valley Ident	26.17	21.83	26.0
3. Slope Ident	13.0	10.3	11.29**
4. Ident of High-Low Areas	48.3	46.5	47.7
5. Spot Elevation	25.67	19.17	23.57
6. Vertical Profile	10.0	7.17	8.0
7. Visualization	10.10	8.67	9.43*
8. Defilade	20.3	20.17	20.0**

* $p<.05$
**$p<.01$

TABLE A-3

Mean Accuracy Scores In Experiment I, High Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	14.5	13.88	14.33
2. Ridge-Valley Ident	26.0	23.39	30.67
3. Slope Ident	12.75	11.87	14.0*
4. Ident of High-Low Areas	50.0	50.3	52.0
5. Spot Elevation	21.75	18.5	26.67
6. Vertical Profile	8.25	7.5	10.67
7. Visualization	12.25	8.88	10.0*
8. Defilade	22.5	20.5	22.0**

* $p<.05$
** $p<.01$

TABLE A-4

Analysis of Variance for Accuracy, Experiment I
Landform Identification

Source	df	MS	F	P<
Map Format	2	9.47	3.31	.05
Experience	2	27.71	9.67	.01
A x B	4	2.02	.70	NS
Within cells	39	2.86		
Total	47			

TABLE A-5

Analysis of Variance for Accuracy, Experiment I
Ridge - Valley Identification

Source	df	MS	F	P<
Map Format	2	155.51	6.93	.01
Experience	2	320.03	14.26	.01
A X B	4	9.40	.42	NS
Within cells	39	22.45		
Total	47			

TABLE A-6

Analysis of Variance for Accuracy, Experiment I
Slope Identification

Source	df	MS	F	P<
Map Format	2	26.01	2.78	NS
Experience	2	44.36	4.74	.05
A X B	4	5.20	.56	NS
Within cells	39	9.36		
Total	47			

TABLE A-7

Analysis of Variance for Accuracy, Experiment I
Identification of High and Low Areas

Source	df	MS	F	P<
Map Format	2	40.23	1.35	.NS
Experience	2	166.23	5.60	.01
A X B	4	14.66	.49	NS
Within cells	39	29.70		
Total	47			

TABLE A-8

Analysis of Variance for Accuracy, Experiment I
Slope Identification

Source	df	MS	F	P<
Map Format	2	273.12	13.65	.01
Experience	2	192.38	9.62	.01
A X B	4	35.83	1.79	NS
Within cells	39	20.0		
Total	47			

TABLE A-9

Analysis of Variance for Accuracy, Experiment I
Vertical Profile

Source	df	MS	F	P<
Map Format	2	14.68	1.95	NS
Experience	2	41.60	5.54	.01
A X B	4	6.37	.85	NS
Within cells	39	7.51		
Total	47			

TABLE A-10

Analysis of Variance for Accuracy, Experiment I
Terrain Visualization

Source	df	MS	F	P<
Map Format	2	6.58	.79	NS
Experience	2	40.73	4.87	.05
A X B	4	8.31	.99	NS
Within cells	39	8.36		
Total	47			

TABLE A-11

Analysis of Variance for Accuracy, Experiment I
Defilade

Source	df	MS	F	P<
Map Format	2	14.23	1.98	NS
Experience	2	45.72	6.35	.01
A X B	4	4.13	.57	NS
Within cells	39	7.20		
Total	47			

TABLE A-12

Summary of Significant Accuracy
Effects in Experiment I

Subtest	Main Effects		Interaction
	Map Format	Experience	
1. Landform Ident	NS	.05	NS
2. Ridge-Valley Ident	NS	.01	NS
3. Slope Ident	.01	.01	NS
4. Ident of High-Low Areas	NS	.01	NS
5. Spot Elevation	NS	.05	NS
6. Vertical Profile	NS	NS	NS
7. Visualization	.05	.01	NS
8. Defilade	.01	.01	NS

APPENDIX B

MEDIAN TIME EFFECTS IN EXPERIMENT I

TABLE B-1

Median Time Scores in Experiment I, Low Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	1.42	.86	.92
2. Ridge-Valley Ident	3.01	2.16	1.96*
3. Slope Ident	1.72	1.72	1.29
4. Ident of High-Low Areas	4.78	2.67	2.9**
5. Spot Elevation	6.32	4.18	4.12
6. Vertical Profile	1.25	.77	1.38
7. Visualization	.68	.86	1.2
8. Defilade	2.57	1.88	1.75

*$p < .05$ level
**$p < .01$

TABLE B-2

Median Time Scores in Experiment I, Moderate Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	.84	1.32	.68
2. Ridge-Valley Ident	2.23	2.99	1.58*
3. Slope Ident	1.17	1.64	1.17
4. Ident of High-Low Areas	3.54	4.1	2.18**
5. Spot Elevation	3.59	5.1	2.99
6. Vertical Profile	2.13	2.0	1.4
7. Visualization	.89	.81	.89
8. Defilade	2.49	3.08	1.86

*$p < .05$ level
**$p < .01$

TABLE B-3

Median Time Scores in Experiment I, High Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tints
1. Landform Ident	.89	.92	.61
2. Ridge-Valley Ident	1.9	2.0	1.51*
3. Slope Ident	1.24	.98	1.03
4. Ident of High-Low Areas	4.72	2.63	2.48**
5. Spot Elevation	4.09	3.39	2.89
6. Vertical Profile	2.11	1.95	2.35
7. Visualization	1.08	.71	.87
8. Defilade	3.14	2.28	2.29

*$p < .05$ level
**$p < .01$

TABLE B-4

Analysis of Variance for Median Times, Experiment I,
Landform Identification

Source	df	MS	F	P<
Map Format	2	.44	2.37	NS
Experience	2	.24	1.29	NS
A X B	4	.35	1.86	NS
Within cells	39	.9		
Total	47			

TABLE B-5

Analysis of Variance for Median Times, Experiment I, Ridge-Valley Identification

Source	df	MS	F	P<
Map Format	2	2.32	3.36	.05
Experience	2	1.28	1.86	NS
A X B	4	.95	1.38	NS
Within cells	39	.69		
Total	47			

TABLE B-6

Analysis of Variance for Median Times, Experiment I, Slope Identification

Source	df	MS	F	P<
Map Format	2	.31	1.29	NS
Experience	2	.89	3.66	.05
A X B	4	.22	.89	NS
Within cells	39	.24		
Total	47			

TABLE B-7

Analysis of Variance for Median Times, Experiment I, High and Low Areas

Source	df	MS	F	P<
Map Format	2	12.61	10.01	.01
Experience	2	.15	.12	NS
A X B	4	3.13	2.49	NS
Within cells	39	1.26		
Total	47			

TABLE B-8

Analysis of Variance for Median Times, Experiment I, Spot Elevation

Source	df	MS	F	P<
Map Format	2	6.73	3.20	NS
Experience	2	7.68	3.64	.05
A X B	4	4.20	1.99	NS
Within cells	39	2.11		
Total	47			

TABLE B-9

Analysis of Variance for Median Times, Experiment I, Vertical Profile

Source	df	MS	F	P<
Map Format	2	.24	.26	NS
Experience	2	3.87	4.12	.05
A X B	4	.60	.63	NS
Within cells	39	.94		
Total	47			

TABLE B-10

Analysis of Variance for Median Times, Experiment I, Terrain Visualization

Source	df	MS	F	P<
Map Format	2	.14	.83	NS
Experience	2	.01	.06	NS
A X B	4	.19	1.15	NS
Within cells	39	.17		
Total	47			

TABLE B-11

Analysis of Variance for Median Times, Experiment I, Defilade

Source	df	MS	F	P<
Map Format	2	2.09	1.91	NS
Experience	2	1.02	.93	NS
A X B	4	.93	.84	NS
Within cells	39	1.10		
Total	47			

TABLE B-12

Summary of Significant Time Effects in Experiment I

Subtest	Main Effects		Interaction
	Map Format	Experience	
1. Landform Ident	NS	NS	NS
2. Ridge-Valley Ident	.05	NS	NS
3. Slope Ident	NS	.05	NS
4. Ident of High-Low Areas	.01	NS	NS
5. Spot Elevation	NS	.05	NS
6. Vertical Profile	NS	.05	NS
7. Visualization	NS	NS	NS
8. Defilade	NS	NS	NS

APPENDIX C

ACCURACY EFFECTS IN EXPERIMENT II

TABLE C-1

Mean Accuracy Scores in Experiment II, Low Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tint
1. Landform Ident	12.44	12.12	13.25
2. Ridge-Valley Ident	23.3	20.5	25.25
3. Slope Ident	12.44	11.0	11.87
4. Ident of High-Low Areas	41.66	46.0	48.37
5. Spot Elevation	21.2	18.75	20.75
6. Vertical Profile	9.2	8.43	7.62
7. Visualization	8.3	6.67	9.12
8. Defilade	19.3	16.5	20.5

TABLE C-2

Mean Accuracy Scores in Experiment II, High Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tint
1. Landform Ident	16.0	11.0	13.5
2. Ridge-Valley Ident	32.0	22.0	29.0
3. Slope Ident	14.0	8.0	15.5
4. Ident of High-Low Areas	49.0	43.0	53.5
5. Spot Elevation	25.0	16.5	24.0
6. Vertical Profile	9.0	6.0	12.5
7. Visualization	13.0	7.0	10.0
8. Defilade	22.0	20.0	20.5

TABLE C-3

Analysis of Variance for Accuracy Data Experiment II, Landform Identification

Source	df	MS	F	P<
Map Format	2	9.38	2.71	NS
Experience	1	3.04	.88	NS
A X B	2	7.35	2.12	NS
Within cells	24	3.46		
Total	29			

TABLE C-4

Analysis of Variance for Accuracy Data Experiment II, Ridge-Valley Identification

Source	df	MS	F	P<
Map Format	2	64.36	1.81	NS
Experience	1	82.03	2.31	NS
A X B	2	17.07	.48	NS
Within cells	24	35.48		
Total	29			

TABLE C-5

Analysis of Variance for Accuracy Data Experiment II, Slope Identification

Source	df	MS	F	P<
Map Format	2	26.77	3.19	NS
Experience	1	2.01	.24	NS
A X B	2	14.60	1.74	NS
Within cells	24	8.40		
Total	29			

TABLE C-6

Analysis of Variance for Accuracy Data Experiment II, High-Low Area Identification

Source	df	MS	F	P<
Map Format	2	62.29	.82	NS
Experience	1	37.89	.50	NS
A X B	2	37.62	.49	NS
Within cells	24	76.18		
Total	29			

TABLE C-7

Analysis of Variance for Accuracy Data Experiment II, Spot Elevation

Source	df	MS	F	P<
Map Format	2	45.07	1.15	NS
Experience	1	9.67	.25	NS
A X B	2	14.16	.36	NS
Within cells	24	39.21		
Total	29			

TABLE C-8

Analysis of Variance for Accuracy Data Experiment II, Vertical Profile Identification

Source	df	MS	F	P<
Map Format	2	10.61	1.15	NS
Experience	1	2.08	.23	NS
A X B	2	17.70	1.92	NS
Within cells	23	9.20		
Total	28			

TABLE C-9

Analysis of Variance for Accuracy Data Experiment II, Terrain Visualization

Source	df	MS	F	P<
Map Format	2	19.45	2.16	NS
Experience	1	14.36	1.59	NS
A X B	2	6.96	.77	NS
Within cells	22	9.01		
Total	27			

TABLE C-10

Analysis of Variance for Accuracy Data Experiment II, Defilade

Source	df	MS	F	P<
Map Format	2	9.10	.75	NS
Experience	1	15.83	1.31	NS
A X B	2	4.17	.35	NS
Within cells	22	12.09		
Total	27			

TABLE C-11

Summary of Significant Accuracy Effects in Experiment II

Subtest	Main Effects		Interaction
	Map Format	Experience	
1. Landform Ident	NS	NS	NS
2. Ridge-Valley Ident	NS	NS	NS
3. Slope Ident	NS	NS	NS
4. Ident of High-Low Areas	NS	NS	NS
5. Spot Elevation	NS	NS	NS
6. Vertical Profile	NS	NS	NS
7. Visualization	NS	NS	NS
8. Defilade	NS	NS	NS

APPENDIX D

MEDIAN TIME EFFECTS IN EXPERIMENT II

TABLE D-1

Median Time Scores in Experiment II, Low Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tint
1. Landform Ident	.81	1.15	.83**
2. Ridge-Valley Ident	1.81	2.27	1.57
3. Slope Ident	1.06	1.58	1.10
4. Ident of High-Low Areas	2.44	3.13	1.99
5. Spot Elevation[a]	Incomplete data on this subtest		
6. Vertical Profile	2.39	1.16	2.69
7. Visualization	.72	.68	.92**
8. Defilade	2.39	1.99	1.93

[a] Many of the participants were unable to complete enough items to obtain meaningful time scores on this subtest.

*$p < .05$
**$p < .01$

TABLE D-2

Median Time Scores in Experiment II, High Experience Group

Subtest	Contour Lines	Shaded Relief	Layer Tint
1. Landform Ident	5.08	1.01	1.45**
2. Ridge-Valley Ident	1.08	1.80	2.52
3. Slope Ident	.59	.94	1.25
4. Ident of High-Low Areas	2.83	1.63	3.58
5. Spot Elevation[a]	Incomplete data on this subtest		
6. Vertical Profile	2.67	1.17	4.03
7. Visualization	.87	.38	1.35**
8. Defilade	1.06	1.72	2.37

[a] Many of the participants were unable to complete enough items to obtain meaningful time scores on this subtest.

**$p < .01$

TABLE D-3

Analysis of Variance for Median Time, Experiment II, Landform Identification

Source	df	MS	F	P<
Map Format	2	5.69	71.83	.01
Experience	1	9.59	121.03	.01
A X B	2	7.05	89.05	.01
Within cells	24	.08		
Total	29			

TABLE D-4

Analysis of Variance for Median Time, Experiment II, Ridge-Valley Identification

Source	df	MS	F	P<
Map Format	2	.60	.92	NS
Experience	1	.03	.04	.05
A X B	2	1.04	1.58	NS
Within cells	24	.65		
Total	29			

TABLE D-5

Analysis of Variance for Median Time, Experiment II, Slope Identification

Source	df	MS	F	P<
Map Format	2	.27	1.21	NS
Fxperience	1	.39	1.72	NS
A X B	2	.22	.92	NS
Within cells	24	.23		
Total	29			

TABLE D-6

Analysis of Variance for Median Time, Experiment II, High-Low Area Identification

Source	df	MS	F	P<
Map Format	2	.22	.15	NS
Experience	1	.10	.07	NS
A X B	2	3.07	2.18	NS
Within cells	24	1.41		
Total	29			

TABLE D-7

Analysis of Variance for Median Time, Experiment II, Vertical Profile

Source	df	MS	F	P<
Map Format	2	4.95	2.20	NS
Experience	1	.61	.27	NS
A X B	2	1.01	.45	NS
Within cells	23	2.25		
Total	28			

TABLE D-8

Analysis of Variance for Median Time, Experiment II, Terrain Visualization

Source	df	MS	F	P<
Map Format	2	.46	8.14	.01
Experience	1	.03	.62	NS
A X B	2	.17	2.99	NS
Within cells	22	.06		
Total	27			

TABLE D-9

Analysis of Variance for Median Time, Experiment II, Defilade

Source	df	MS	F	P<
Map Format	2	.24	.30	NS
Experience	1	.56	.70	NS
A X B	2	.99	1.24	NS
Within cells	22	.80		
Total	27			

TABLE D-10

Summary of Significant Time Effects in Experiment II

Subtest	Main Effects		Interaction
	Map Format	Experience	
1. Landform Ident	.01	.01	.01
2. Ridge-Valley Ident	NS	.05	NS
3. Slope Ident	NS	NS	NS
4. Ident of High-Low Areas	NS	NS	NS
5. Spot Elevation	NS	NS	NS
6. Vertical Profile	NS	NS	NS
7. Visualization	.01	NS	NS
8. Defilade	NS	NS	NS

APPENDIX E

FIELD VALIDATION OF EIGHT SUBTESTS OF INFORMATION EXTRACTION FROM MAP PRODUCTS

Introduction

A secondary purpose of this research effort was the development of a research methodology for work in this problem area. Traditionally, new products are evaluated by opinion surveys from user groups or by field tests. There are problems with both of these methods. Surveys are inexpensive and do provide data on user acceptance. However, if the users have not actually used the map under consideration their opinions have little predictive validity (Hill, 1974; Wheaton, Zavala, and Van Cott, 1967). Field tests of map products also present problems. Field tasks involving a map are complex and involve additional skills beyond simply extracting information from a map. In addition a large number of variables are present in field trials which are expensive and time consuming to control. If only one terrain is used the results may be terrain specific and may not generalize to other terrains. Seasonal factors are involved, and results may not be the same at different times of the year since land navigation is easier in the late fall and winter when vegetation does not obscure terrain features. Many other contaminating factors exist; for example, early participants make tracks through vegetation which influence the behavior of later participants. While field trials can produce valuable data when these factors are controlled, it would be desirable to develop an alternate method for assessing the effectiveness of new map formats.

After extensive consultations with cartographers at the U.S. Army Engineer Topographic Laboratory it was determined that measuring the speed and accuracy with which terrain information could be extracted from a map would be a valuable addition to user surveys and field tests as a method for evaluating cartographic products. Extensive discussions were held with military map users at the U.S. Army Infantry School to determine what types of information must be extracted from maps in Army tasks. It was found that U.S. Army users extract eight types of information from maps, and a subtest was developed for each type. These eight types are: landform identification; ridge-valley identification; slope identification; identification of high and low areas; spot elevation; vertical profile; terrain visualization; and defilade or intervisibility. These are described in greater detail in the Introduction to this report.

In the development of behavioral measures, validity is an issue that must be addressed. Since the eight subtests are based on performance on a map use task, the test is inherently valid in terms of construct validity and content validity. If a test contains a representative sample of the behavior domain to be tested, it has content validity (Anastasi, 1976, pp. 133-134).

Predictive validity, however, must be demonstrated when a classroom type of test, such as the eight subtests, is developed. The classroom test must be compared to a criterion where performance is measured, and correlation must be demonstrated. Since map use tasks in the field are complex and contain skills other than map reading, it would be unreasonable to expect extremely high correlations. However, performance in the field on a map task should correlate with a field criterion. For determining the predictive validity of these subtests, field tasks of checkpoint location and target location were chosen.

Method

Participants. A total of 16 participants were used. These participants were a stratified random sample chosen to represent the varying degrees of experience in the Army population at large. Participants were obtained from installations other than where the experiment was being conducted. No participants had prior experience on the terrain used in the experiment.

Location. The field test portion of the experiment was conducted in the Gabilan Valey area of Hunter-Liggett Military Reservation in California. The U.S. Army Combat Development Experimentation Command (CDEC) was conducting field research in this location, and the experiment was supported by CDEC as a portion of their research effort. The area is approximately 30 percent flat-to-rolling terrain and 70 percent rolling-to-rough terrain. The floor of the Gabilan Valley averages 1200 feet above sea level and is sparsely vegetated with oak trees and shrub. The surrounding hills and mountains of the Coast Range are heavily vegetated with oak, chaparral, and shrub. The area permits cross country vehicle traffic in dry weather. Almost all of the rainfall in the region occurs during the winter months, and the experiment took place in April and May when conditions were dry.

Apparatus. Apparatus consisted of: 1/4 ton trucks; a radar-based range measurement system (RMS) which used triangulation in conjunction with a DEC-1061 computer system to determine accurate position location information; a voice recording system; two-way radios; the map performance measures, standard Army contour maps of the area, and various forms.

Procedure. The experiment included of both classroom and field tests. After an introductory briefing participants were given the eight map use subtests. These subtests were administered in a large room with widely spaced tables in a single session. The field portion of the experiment was conducted over the next five weeks.

Participants were given training in map use for land navigation and safety before the field portion of the experiment. Numerous safety problems are inherent with single participants navigating in relatively isolated terrain: they may become lost, injured in accidents, etc. Therefore, for safety, participants were tested singly using light 1/4 ton trucks with drivers. The participant acted as a navigator and directed the driver. Drivers were trained to avoid giving cues and restricted to speeds of less than 15 miles per hour.

In the field tests, participants were given two types of land navigation tasks, checkpoint identification and target location. Four routes were used with six checkpoints on each route and an observation post at the end of each route. Thus, each participant had to locate 24 checkpoints. Routes were approximately 6 to 7 kilometers long and the checkpoints varied from 1/2 to 2 kilometers apart. The order of the routes for each participant was counterbalanced, and to avoid the problem of tracks through vegetation becoming a cue for subsequent participants, vehicles were driven through the area between trials.

Participants were issued maps, paper, and protractor. For each trial or route they were given a map with a set of instructions and the eight-digit coordinates of the start point, and six checkpoints. They were directed to make a thorough map reconnaissance and plot their planned routes. For the checkpoint identification task, they were taken to a known start point and directed to find the six checkpoints and the observation post. When the participants believed that they had arrived at a checkpoint the position was noted. The exact location was determined with the RMS. The participants were informed of their actual position at each checkpoint so that they would always proceed from a known position and previous errors would not be compounded in locating the next checkpoint. Checkpoint location scores were determined by noting the radial error or the direct line distance between reported location of the checkpoint and the actual location. Direction of errors was not recorded.

For the target location task, participants were directed to find an observation post at the end of their checkpoint identification route. If they were in error they were directed to the true location of the last checkpoint. All participants were given their location in eight-digit coordinates, and allowed use of binoculars, compass, and protractor as well as their map. The targets were 12-foot-square panels of wood located at distances varying between 1000 and 6000 meters from the observation post. Radial errors between the reported location and the actual location of targets were calculated with the RMS system.

Two series of nine targets were used. Participants were allowed to use any procedures they preferred to locate targets in the first series. For the second series of targets, participants were directed to use the procedures outlined in FM 21-26, the Army Field Manual on Map Reading, to report target locations. Therefore, two sets of target location scores were obtained, the first using unspecified procedures and the second using specified procedures.

Results

On the three field tasks, the mean radial error between actual location and reported location was determined. These scores were correlated with the map subtest scores using Spearman-Rho correlations, which are more appropriate than the Pearson Product Moment correlation considering the number of participants involved. These correlations are presented in Table E-1.

TABLE E-1

Correlations of Map Performance Task with Field Criteria

Subtest	Checkpoint Location	Target Location Unspecified Procedure	Target Location Specified Procedure
1. Landform Ident	-.30	-.10	-.34
2. Ridge-Valley Ident	-.14	-.18	-.27
3. Slope Ident	-.32	-.13	-.20
4. Ident of High-Low Areas	-.26	-.49*	-.30
5. Spot Elevation	-.28	-.47*	-.22
6. Vertical Profile	-.04	-.20	+.33
7. Visualization	-.24	-.29	-.63**
8. Defilade	-.31	+.005	-.31

*p< .05
**p< .01

In the first field task, checkpoint location, all eight correlations are negative, which was the expected direction, since the field performance was measured by an error score. In the second field performance task, target location with unspecified procedures, all correlations are in the expected direction with the exception of defilade. Two correlations are significant at the .05 level: identification of high and low areas, and spot elevation. In the third field task, target location with specified procedures, all correlations were in the expected direction with the exception of the vertical profile. The correlation on terrain visualization was significant at the .01 level.

Discussion

Compared to previous techniques for evaluating maps, the techniques used in this research may provide a valuable alternative for assessing the effectiveness of map products. The results of the field validation, summarized in Table E-1, suggest that the subtests have predictive validity. Of the 24 correlation coefficients obtained, all but 2 were in the correct direction, which is negative because the field performance score was an error score, correlated with the subtests.

Only 3 of the 24 correlations obtained were statistically significant at conventional levels of confidence, .05 and .01. However, a number of considerations must be kept in mind in interpreting the data. The number of participants (16) was rather low, due to the expense of field tests and logistical considerations; high correlations rarely occur with a sample size of this magnitude. The field criteria also must be considered. A large number of variables are always present in the field, and many of these cannot be controlled. In addition, map use tasks in the field are complex and a number of skills are involved in addition to extracting information from a map product. In considering the impact of these factors, the fact that 22 of 24 correlations were in the correct direction and that three of the correlations were significant supports the predictive validity of the subtests.

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