Technical Report 1015

Predicting Land Navigation Performance in the Special Forces Qualification Course

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U.S. Army Research Institute

October 1994

United States Army Research Institute for the Behavioral and Social Sciences

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Accesion For	
NTIS CRA&I	☒
DTIC TAB	☐
Unannounced	☐
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Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1994, October	Final Aug 91 - Mar 94

4. TITLE AND SUBTITLE
Predicting Land Navigation Performance in the Special Forces Qualification Course

5. FUNDING NUMBERS
63007A
792
1223H
879300

6. AUTHOR(S)
Busciglio, Henry H.; and Teplitzky, Martha L.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-RS
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

8. PERFORMING ORGANIZATION REPORT NUMBER
ARI Technical Report 1015

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
--

11. SUPPLEMENTARY NOTES
--

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE
--

13. ABSTRACT *(Maximum 200 words)*

This research examined performance on the land navigation field test administered in the Special Forces Qualification Course (SFQC) as a function of three sets of possible predictors: (a) Project A paper and pencil tests of spatial ability (Map, Maze, and Orientation), (b) performance on the military orienteering events in the Special Forces Assessment and Selection program (SFAS), and (c) measures of intelligence and physical fitness obtained in SFAS. Our multivariate analyses showed that SFQC trainees who passed the land navigation test on the first try had significantly higher scores on the Map test than those who did not. We also found that those who failed land navigation had significantly lower ratings on orienteering Event IV (the last and longest event in SFAS) than did those who passed land navigation either on their first try or on a retest.

Analyses of hypothetical cut-scores on the Map test were examined to provide information on the potential utility of this measure as a screening tool. The benefits (i.e., higher success rates when the cut-offs were used) were marginal because even very lenient cut-offs would exclude many students with the potential

(Continued)

14. SUBJECT TERMS
Special Forces training
Land navigation
Spatial aptitude
Map reading

15. NUMBER OF PAGES

16. PRICE CODE
--

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

13. ABSTRACT (Continued)

to pass land navigation. The Map test and military orienteering scores might, however, be useful as diagnostic tools. Students with low scores could be advised that they are likely to be at a disadvantage in the SFQC and instructed to improve their map reading and navigation skills before attending. For purposes of selection screening, we are planning research with another Project A spatial test, Assembling Objects, that has shown great promise in previous settings.

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Predicting Land Navigation Performance in the Special Forces Qualification Course

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Office, Deputy Chief of Staff for Personnel
Department of the Army

October 1994

Army Project Number
2Q263007A792

Manpower and Personnel

FOREWORD

The increase in the variety and complexity of Special Forces missions throughout the world has created a need for systematic, comprehensive procedures for assessing Special Forces candidates. In response to this need, the U.S. Army John F. Kennedy Special Warfare Center and School (USAJFKSWCS) started the Special Forces Assessment and Selection (SFAS) program in June of 1988 to identify candidates with a high potential for success in the Special Forces Qualification Course (SFQC). At the same time, the Special Warfare Center asked the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to collaborate on research designed to examine and fine-tune the Special Forces (SF) selection process. ARI has a commitment, confirmed in the June 1991 Memorandum of Agreement with the U.S. Army Special Operations Command, to support Special Operations Forces through research on the skills and aptitudes required in our elite forces.

This particular project examines spatial ability tests, SFAS military orienteering scores, and other measures as predictors of performance on the Q Course land navigation field exam. The spatial ability measures were paper-and-pencil tests developed and validated by ARI's Selection and Assignment Research Unit as part of Project A. The military orienteering and land navigation events were designed and administered to SF candidates by the Special Warfare Center during the normal course of their assessment and training programs. Research in this area is important because land navigation is critical in special operations and these skills are difficult and costly to teach.

The research was a collaborative effort by ARI and USAJFKSWCS, sponsored by the Chief Psychologist of the Special Warfare Center and completed under the Selection and Assignment Research Unit's research program on Special Screening Tests for Critical MOS. The results have been briefed to the sponsor and were found to be useful because they not only highlight the importance of abstract spatial abilities but they also provide the first empirical examination of the relationship between SFAS military orienteering events and land navigation. Further research should allow us to fine-tune diagnostic and selection instruments and ultimately enhance the effectiveness of SF assessment and training.

EDGAR M. JOHNSON
Director

ACKNOWLEDGMENTS

We would like to express our appreciation to the following individuals for their valuable assistance:

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

U.S. Army John F. Kennedy Special Warfare Center and School
COL Travis Griffin
LTC David McCracken
MAJ Juan Orama

Special thanks also to Michael Rumsey, Selection and Assignment Research Unit Chief, and to Paul Gade and Fred Mael for their astute and constructive comments on earlier drafts of this paper.

PREDICTING LAND NAVIGATION PERFORMANCE IN THE SPECIAL FORCES QUALIFICATION COURSE

EXECUTIVE SUMMARY

Research Requirement:

The land navigation phase of the Special Forces Qualification Course (SFQC) is comprehensive and difficult. Inability to pass the 18-kilometer go/no-go land navigation field exam is the single largest cause of failure in the field phase of SF training. The primary purpose of this research was to assess the utility of three new Project A spatial ability tests and six Special Forces Assessment and Selection (SFAS) military orienteering events as predictors of performance on this critical exam. We hypothesized that spatial ability and skill in military orienteering (i.e., navigating over unfamiliar territory from a drop-off point to a prescribed destination) would be positively related to land navigation performance.

Procedure:

Candidates entering two SFAS classes took the Project A Map, Maze, and Orientation tests, along with tests of general cognitive ability (the Wonderlic Personnel Test), and physical fitness (the Army Physical Fitness Test, or APFT). Scores on the six SFAS military orienteering events were obtained at the end of the program. About half of all SFAS candidates were selected for the SFQC, and these are the soldiers for whom we obtained the criterion measure--performance on the land navigation field exam. Univariate and multivariate analyses were conducted along with analyses designed to illustrate the potential utility of various hypothetical cut-off scores.

Findings:

The major results of our analyses were as follows:

1. In general, the spatial scores were more useful for predicting land navigation performance than were the orienteering, fitness, or intelligence test (Wonderlic) scores.

2. The Map test was the only predictor to account for unique variance in whether or not students passed land navigation on their first try.

3. Students with very low scores on the Map test had considerably lower first time pass rates (48%) on the land navigation field exam than other students (76%).

Utilization of Findings:

Land navigation performance in the SFQC appears to be a function of both spatial aptitude and orienteering skills and techniques acquired through experience. The modest effect sizes for the spatial measures in this research do not allow us, at this point, to recommend the use of the Map, Orientation, or Maze tests as selection criteria for SF training. The results do, however, suggest that spatial aptitude is a factor in training and performance and that additional research in this area is warranted. Future analyses, for example, might focus on determining the extent to which general intelligence can compensate for the lack of spatial aptitude. In the interim, the Map test might be used as an efficient, low-cost way of providing prospective Special Forces trainees with feedback about their prospects for success in land navigation training. Such feedback might encourage self-selection out of the program or personal efforts to improve skills through study and practice. For purposes of selection screening, we are planning research with another Project A spatial test, Assembling Objects, that has shown great promise in previous settings.

PREDICTING LAND NAVIGATION PERFORMANCE IN THE SPECIAL FORCES QUALIFICATION COURSE

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Introduction

Background

Land navigation is a critical skill in Special Forces (SF). In the performance of their missions, SF soldiers are frequently called upon to navigate through unfamiliar territory, often over difficult terrain, under the cover of darkness. Consequently, there is a strong emphasis on land navigation in SF training. In fact, the Special Forces Qualification Course (SFQC or Q Course) includes the most comprehensive land navigation program taught by any Army school (Fricke, 1990). In a week-long block of instruction, students learn to identify terrain features, find their positions on a map, measure ground distance, and navigate cross-country using a map and a compass (Fricke, 1990).

Historically, land navigation has been one of the most difficult components of the Q Course, with failures on the final field exam accounting for a large proportion of the attrition from training (Pleban et al., 1988). Dissatisfaction with the high Q Course attrition rate (40% to 50%) was one of the factors that led to the development and implementation of the Special Forces Assessment and Selection (SFAS) program in 1988. SFAS is designed to identify candidates who are well suited for SF and to screen out volunteers who lack the qualities and potential to complete SF training. Successful completion of the program has been a prerequisite for the Q Course since June of 1988.

SFAS has been successful in reducing Q Course attrition; however, the land navigation portion of the training is still problematic. For example, records maintained by the Special Warfare Center and School show that in classes 2-90 to 5-90 the percentage of soldiers who failed the land navigation exam on their first try ranged from 23% to 46%. Although well over half of these students passed the re-test exam (second try pass rates ranged from 52% to 85%), land navigation is still difficult for many SF trainees.

The primary purpose of this research is to examine the relationship between three measures of spatial ability and performance on the SFQC land navigation field exam. This research builds on earlier work showing the relationship between spatial ability and performance on military orienteering events in SFAS (Busciglio, Teplitzky & Welborn, 1991). The analyses are designed to provide decision makers with data on the potential

[1]A shorter version of this report was presented at the 1993 Military Testing Association conference. Although a slightly different sample was used, our overall findings and conclusions are the same.

utility of the spatial tests as screening criteria and diagnostic instruments.

Land Navigation Research

In 1986, ARI researchers (Pleban et al., 1988) conducted a preliminary examination of factors related to success in the four week field training portion (Phase I) of the SFQC. Graded events in this phase included map reading written exam, land navigation field exercise, confidence course, patrolling written exam, patrolling field exercise, and performance as a patrol member. The sample for the research consisted of the 338 soldiers attending the Q Course at Fort Bragg, North Carolina, between September 1986 and January 1987. Out of this group, 67% passed Phase I. Of those who did not pass Phase I, 84% were dropped because they failed the land navigation portion of the course.

Analyses in the Pleban et al. (1988) study focused on identifying differences between successful and unsuccessful Phase I trainees in four areas: aptitude scores from the Armed Services Vocational Aptitude Battery (ASVAB), intelligence (measured by the Wonderlic Personnel Test), physical fitness, and personality (Myers-Briggs Type Indicator). Because land navigation failures accounted for nearly all the academic attrition in the sample, the analyses can be interpreted as providing information on the factors related to successful performance in land navigation.

Results showed that general aptitude was the most promising predictor of Phase I success for active duty soldiers. Among the active component soldiers, successful trainees had significantly higher scores (one half to one full standard deviation) than unsuccessful trainees on five ASVAB composites (general maintenance, combat, field artillery, operators and food, and skilled technical). For reservists, on the other hand, ASVAB scores were almost identical for successful and unsuccessful trainees.

The most general measure of intelligence, the Wonderlic test, was not related to success for either active or reserve component soldiers (total sample $\underline{r}$ = .13, ns). Army Physical Fitness Test (APFT) scores and the personality measures also did not differentiate successful and unsuccessful Phase I trainees.

In a second study, Pleban, Allentoff, and Thompson (1989) examined predictor relationships with scores on the six Phase I graded events, as well as the final pass/fail outcome. Although ASVAB scores were not available for these analyses, other predictors were similar, including Wonderlic scores, background characteristics, and personality measures (Jackson Personality Inventory). The sample consisted of the 293 students from the November 1987 SFQC class, 62% of whom successfully completed Phase I. Of those who did not pass, 61% failed either the map reading written exam (11%) or the land navigation field exam (50%).

In contrast to their earlier results (Pleban et al., 1988), Pleban et al. (1989) found a significant correlation (r=.29) between Wonderlic scores and pass/fail status in Phase I. The correlation between the Wonderlic and go/no-go status on the land navigation field exam was about the same magnitude (r=.28). There was also a strong correlation between the Wonderlic and scores on the map reading written exam (r=.52).

The Pleban et al. (1989) analyses also identified prior training as a factor in land navigation performance. Ranger qualified students, for example, had markedly higher Phase I pass rates (84%) than the class as a whole (62%). It is possible that soldiers who volunteer for Ranger school have more aptitude for SF than the average soldier. A simpler explanation, however, is that Rangers do better in SF training because of their prior training and experience in relevant skill areas (e.g., land navigation, patrolling).

The importance of prior experience in land navigation was also shown in Peters, Bleda, and Fineberg's (1979) research. In a small (n=30) sample of Infantrymen, Peters et al. (1979) examined background characteristics, Armed Forces Qualification Test (AFQT) scores, perceptual style (field dependence), and self-ratings of general sense of direction as predictors of performance on a dead reckoning task. Only one variable, the number of times the soldier had participated in land navigation exercises previously, was significantly related to performance. Furthermore, poor navigators demonstrated obvious deficiencies in basic compass, map reading, and pace counting skills, supporting the authors' conclusion that insufficient training or experience could explain performance problems.

A more recent study using a field performance criterion was conducted by the present authors (Busciglio, Teplitzky, & Welborn, 1991) in an assessment setting. The sample included almost 500 candidates in the Special Forces Assessment and Selection (SFAS) program. Predictors included Wonderlic and physical fitness test scores, in addition to three measures of spatial ability, ARI's Map, Maze, and Orientation tests. Dependent variables included times and ratings on six military orienteering events, plus composite measures of performance.

Results showed that two of the spatial tests (the Map test, and to a lesser extent, the Orientation test) were positively related to military orienteering performance. Correlations of Map and Orientation test scores with orienteering times and ratings ranged from .20 to .27 for five of the six events. Correlations with a composite measure of performance (based on ratings) were .33 for the Map test and .30 for the Orientation test. Despite the considerable overlap between the two tests (Map/Orientation: r=.50), both also explained unique variance in the composite measure when all three test scores were included as predictors in a regression equation. In combination, the Map and Orientation tests explained 13% of the variance in the rating composite. The Maze test did not enter the regression as a significant independent predictor.

The spatial test/military orienteering correlations are intriguing because they show that short paper and pencil tests have the potential to predict performance on a very different criterion - the time it takes a soldier to make his way from a starting point to a landmark several kilometers away. Despite the variety of factors likely to affect both orienteering times (e.g., physical endurance, motivation, night vision) and paper and pencil test scores (e.g., reading level, effort, fatigue) spatial tests and orienteering do appear to have certain cognitive requirements in common.

Hunt (1991) reached a similar conclusion based on research with civilian orienteering enthusiasts. Hunt found that expert orienteerers performed better than moderately experienced orienteerers, who in turn performed better than novices, on two abstract measures of spatial ability: two and three dimensional spatial rotation tasks, and a spatial orientation test requiring perspective taking.

On the basis of these and other performance differences, Hunt (1991) concluded that "Orienteering skill is not limited to being able to get around in the woods. It seems to be an ability to build up abstract spatial models of large-space from superior observation of salient visual cues" (p. 25). An experienced Ranger instructor put it more simply, noting that "tactical land navigation requires... the ability to see this flat piece of paper [the map] as a three dimensional picture" (Johnston, 1991).

The research reviewed above suggests that both general intelligence and spatial abilities affect how well, or how quickly individuals can navigate in real-world, natural environments. Simpler criteria, like performance on map-reading tests or direction pointing tasks have also been predicted by cognitive and/or spatial ability measures. This research, reviewed below, suggests that spatial abilities may affect overall land navigation performance by facilitating performance on several different components of the larger task.

<u>Spatial Abilities Research</u>

In the 1970's, Kozlowski and Bryant (1977) showed that people are often good judges of their ability to orient themselves in the real world. Individuals who reported that they had a "good sense of direction" consistently outperformed "poor sense of direction" subjects on location and direction pointing tasks. Scholl (1988), among others, built on this work, and found that "good sense of direction" subjects outperformed "poor sense of direction" subjects primarily on location pointing tasks that required individuals to mentally shift their perspective or rotate their frame of reference. In other words, people with a good sense of direction were better able to imagine they were in a different position relative to their actual location. Scholl interpreted this as evidence that spatial-visual abilities underlie performance differences on orientation, or direction finding tasks.

Simutis and Barsam (1983) found a relationship between spatial ability and another skill required for successful navigation - the ability to identify terrain features from a contour relief map. The sample consisted of 60 soldiers, trichotomized into high, medium, and low spatial ability groups based on composite scores on three spatial subtests from the Kit of Factor-Referenced Cognitive Tests (Eckstrom, French, Harman, & Derman, 1976). Researchers trained and then tested the soldiers on a difficult computerized terrain visualization and identification exercise. The high ability group performed substantially better than the other two groups on the post-training test.

Thorndyke and his colleagues (Thorndyke & Stasz, 1980; Stasz & Thorndyke, 1980) investigated spatial abilities and the different strategies people use to learn locations and recall maps. First they showed that individuals high in spatial-visualization ability, as measured by a test of visual memory and the Group Embedded Figures Test (Oltman, Raskin, & Witkin, 1971), are better able to recall the spatial attributes of map elements. Next, they asked subjects to describe how they approached the map recall task. Results showed that high spatial-visual ability subjects tended to use map learning strategies that involved encoding spatial configurations (e.g., forming mental images, recognizing and using spatial patterns and relationships), as opposed to verbal/associative strategies. The use of these spatially oriented strategies was clearly related to superior performance on map learning tasks.

Weitzman (1979) got similar results when he examined differences in the strategies good and poor orientation subjects used to process spatial information. Individuals skilled in orientation tasks (i.e., better able to accurately point to the location of familiar landmarks out of their field of vision) were more likely to use spatial-visual strategies to represent and recall geographic information than their less skilled counterparts.

Taken together, the land navigation and spatial ability studies lend strong support to the hypothesis that spatial test scores will be related to performance on the SFQC land navigation field exam. More general cognitive ability measures, however, are also likely to be related to land navigation performance (Busciglio et al., 1991; Pleban et al., 1988; 1989). Methodologically this is problematic because spatial ability measures and scores on general cognitive ability, or intelligence tests tend to be highly correlated. Busciglio et al. (1991), for example, found a correlation of .65 between scores on the Wonderlic and scores on the Map test, the best of the three spatial predictors. This was higher than the correlation the Map test displayed with the other two spatial tests (Map/Orientation $\underline{r}$=.50; Map/Maze $\underline{r}$=.42). Scholl and Egeth (1982) also found high correlations (ranging from .47 to .66) between standard intelligence measures (verbal and math tests) and spatial ability (orientation and visualization) measures.

In the present research, multivariate analyses will be used to determine if any of the three spatial tests explain variance in the criterion when a measure of general intelligence (Wonderlic) is also included. Military orienteering scores from SFAS are also examined in relation to the criterion. In an unrestricted sample one would expect a strong relationship between military orienteering performance and success on a land navigation exam. In this case, however, the relationship should be attenuated by the fact that military orienteering events are used as selection criteria in SFAS.

The present analyses include not only an examination of correlations and differences across groups, but also exploratory analyses designed to estimate the impact of establishing a screening cut-off score on these tests. From an applied perspective, results based on a real world sample of SFQC students provide the best assessment of the practical utility of the spatial tests for screening or diagnostic purposes. From a theoretical perspective, however, the sample is less than optimal because it represents a unique, pre-selected population. First, only soldiers who score above the Army average on the General Technical (GT) composite of the ASVAB are even eligible for SFAS. Second, SFAS candidates who fail three or more of the six military orienteering events in SFAS are unlikely to be selected for the SFQC.

In light of the strong relationship between general aptitude and spatial abilities, and the weaker, but significant relationship between spatial tests and military orienteering performance, spatial ability scores are also likely to be higher than one would find in the Army or the population at large. The restricted range of scores on all three predictors (spatial tests, general aptitude, and military orienteering events) means that correlations between these measures and the criterion are likely to underestimate the relationships one would find in a less restricted sample. In other words, we are only likely to find a relationship between spatial abilities and land navigation performance in this sample if the relationship is substantial across the full range of spatial ability levels.

Method

Sample

A total of 297 candidates successfully completed one of the two SFAS classes (3/89 and 4/89) in which we administered the spatial ability tests. SFQC data (i.e., land navigation scores) were gotten by matching the social security numbers of the SFAS graduates with social security numbers from the FY89-92 SFQC Longitudinal Database (see Zazanis, Diana, & Teplitzky, 1994). The 232 soldiers we found in the SFQC database made up the sample for this research.

Measures

Project A Spatial Tests. A researcher employed by the Special Warfare Center administered the three paper-and-pencil spatial tests (Map, Maze, and Orientation) to candidates in the 3/89 and 4/89 SFAS classes (spring 1989) during the in-processing and preliminary testing phase of the program. Candidates were told that the instruments were for research purposes only, and would not be used for evaluation purposes.

All three spatial tests were originally developed in Project A, ARI's effort to develop and validate a comprehensive battery of personnel tests (see Campbell & Zook, 1991). The spatial tests were designed to measure cognitive ability domains not covered by the Armed Services Vocational Aptitude Battery (ASVAB), the instrument now used by the Army for its entry-level enlisted selection and classification decisions (Peterson, 1987). Literature reviews and surveys of subject matter experts were used to isolate the constructs that appeared to be most promising for this purpose.

The Map and Orientation tests were developed to measure a construct called Spatial Orientation - the ability to "maintain one's bearings with respect to points on a compass and to maintain appreciation of one's location relative to landmarks in the environment" (Peterson, 1987, p. 3-29). On the Map test, the examinee works with a schematic map that contains familiar landmarks (e.g., forest, lake). Given the direction of one landmark to another, the examinee must figure out the direction from a given third landmark to a specific fourth one. The Map test consists of 20 items and has a 12 minute time limit.

The Orientation test contains 24 items with a 10-minute time limit. Each item contains a picture within a circular or rectangular frame. The bottom of the frame has a circle with a dot inside it. The picture or scene, said to be immovable, is not in an upright position. The task is to mentally rotate the frame so that the bottom of the frame is positioned at the bottom of the picture. After doing so, the subject must then pick where the dot will appear in the circle, among five alternative answers.

The Maze test was developed to measure Spatial Visualization - Scanning. Spatial visualization is the ability to "mentally manipulate components of two- and three-dimensional figures into other arrangements." Scanning is the ability to "visually survey a complex field to find a particular configuration representing a pathway through the field" (Peterson, 1987, p. 3-5). Each item is a maze with several entrances and exits. Subjects must determine which one of the entrances will lead to an exit. Examinees have 5 1/2 minutes to complete the 24 item test.

A number of authors have reported data on the reliability of these three tests (cf. Campbell & Zook, 1991, 1992). In general, the results support the assertion that all measures have adequate internal consistency and test-retest reliability. Several factor analytic and correlational studies have also been conducted, primarily to determine whether or not the spatial tests were redundant with more general measures of cognitive ability (see Appendix A for a detailed description of this research). The results of these studies suggest that (a) all three tests measure important aspects of general spatial ability; (b) the influence of general cognitive skills is strongest on the Map test and weakest on the Maze test; (c) Map and Orientation are power tests while Maze is a speeded test; and (d) Map and Orientation do, in fact, converge on an "Orientation" construct.

SFAS Military Orienteering Scores. Four of the 21 days of the SFAS program are devoted to military orienteering. Only a basic (skill level I) familiarity with land navigation concepts is required for these events. However, to simulate the operational environment, candidates are given little feedback on their performance and must carry a heavy rucksack as they navigate their way from one point to the next. SFAS cadre observe that physical endurance, motivation and the ability to operate comfortably at night appear to be important to success in SFAS military orienteering.

The military orienteering events take place between the seventh and tenth days of SFAS, immediately before the end of Phase I. On the seventh and eighth days, daytime events (I Day and II Day) are followed by nighttime events (I Night and II Night). The third (III) and fourth (IV) events take place on the ninth and tenth days, respectively. The last event (IV) is the longest and most similar to the SFQC land navigation exam. An important difference between the SFAS and SFQC events, however, is that in SFAS, candidates can navigate along roads, whereas in the SFQC, students must navigate through fields and woods. Candidates normally receive two scores on each of the six military orienteering exercises: a time score (recoded into minutes for the analyses) and a summary performance rating (3=Outstanding; 2=Satisfactory; 1=Unsatisfactory) based on the time score.[2]

Intelligence and Physical Fitness Scores. Basic intelligence was measured by the Wonderlic Personnel test and fitness was measured by scores on the standard Army Physical Fitness Test (APFT). Both measures were obtained during SFAS in-processing. These measures were included in several analyses in an attempt to replicate results of earlier Q Course research (Pleban et al., 1988; 1989).

SFQC Land Navigation Scores. The criterion measure is performance on the final land navigation field examination. Fricke (1990), former commander of Phase I training, describes the exam as "a go/no-go practical exercise over varying terrain in which the student must navigate a course 18 kilometers long and find four points in nine hours. The course begins at 2 a.m., forcing the student to navigate part of the course in darkness. Students who fail the exam will take remedial training and re-test 15 days later" (p. 5). Students who fail the re-test are either dropped from the Q Course or recycled into another class.

Analyses

Correlational and mean difference analyses were conducted to determine which variables were significantly related to land navigation performance. Multivariate discriminant analyses were also conducted to identify predictors that explained unique variance in land navigation performance.

For most analyses the criterion was a dichotomous pass/fail criterion coded "1" if the student passed the land navigation field exam on the first try, and "2" if the student did not pass the exam on the first try. We also conducted exploratory analyses in which students who failed on the first try were divided into two final outcome groups: those who later passed a re-test (during the same or a later course) and those who failed all re-tests. The purpose of creating the three outcome criterion was to capture more of the real criterion variance. Results based on this grouping should be interpreted with caution, however, because of the small sample sizes and the

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[2] In some cases, however, candidates fail to complete an event (e.g., they get lost, give up, or exceed the maximum time and are picked up). When this occurs, the individual receives an unsatisfactory rating for the event and no time score is recorded. In order to make the analyses of time scores comparable to those of the ratings, we attempted to use the same sample with each. Thus, individuals who failed to complete an event were assigned a time score equal to the maximum actual score for the event, plus five minutes. Across each of the six events, these individuals comprised no more than 6.5% of the sample.

possibility that re-test results reflect practice effects rather than basic spatial aptitude.

Results

Descriptive Statistics

Means (M) and standard deviations (SD) for the predictors are displayed in Table 1, for both the present sample and the original SFAS sample (Busciglio et al., 1991). In the SFQC sample there is a very slight increase (about one to two tenths of a standard deviation) in the means on the spatial test and military orienteering ratings relative to the initial SFAS sample (Busciglio et al., 1991). This indicates that a small number of the poorest performers on these measures were not admitted to the Q course. The restriction in range is so slight for these measures, however, that the potential for significant correlations between these predictors and the land navigation criterion variable should not be seriously diminished.

Table 2 shows intercorrelations among the predictor variables for the entire sample. The three spatial tests exhibit moderately high intercorrelations (r=.48 to .52) and Map test scores were strongly related to Wonderlic scores (r=.66). These results are very similar to those obtained for the entire SFAS sample (Busciglio et al., 1991). Intercorrelations among the orienteering times are nearly all significant, but quite low (r=.12 to .36) and similar in magnitude to those obtained in the SFAS sample. Correlations among the orienteering ratings, however, are largely nonsignificant and lower than those obtained in the SFAS sample. This reflects the impact of the reduced variance in the SFQC sample; there are very few students in the SFQC with unsatisfactory ratings on more than two events.

Mean Differences on Predictor Variables across Criterion Groups

Pass vs. fail first try. In these analyses, we examined mean spatial, orienteering, intelligence, and fitness scores for trainees who passed the SFQC land navigation course on the first try (n=167, 72%) and those who did not (n=65, 28%). Table 3 shows the means for both groups, the results of t-tests to assess the statistical significance of the mean differences, and point-biserial correlations between each predictor and the criterion variable.[3]

The t-test results showed that those who passed land navigation on their first try had significantly higher scores on

[3] Readers should consider the t-test and correlational significance levels as suggestive only, since no attempt was made to control the experiment-wide error rate; for instance, at alpha=.05, approximately 1 of the 17 comparisons shown in Table 3 will appear significant due to a Type I error.

Table 1

Means (M) and Standard Deviations (SD) for Predictor Variables in SFQC Sample and Original SFAS Sample

	SFQC SAMPLE (n=232)		SFAS SAMPLE (n=492)	
Predictors	M	SD	M	SD
<u>Spatial Tests</u>				
Map	12.91	4.99	12.45	5.24
Orientation	16.16	5.95	15.45	6.18
Maze	19.08	3.59	18.55	3.77
<u>Orienteering Times (in Minutes)</u>				
I Day	100	47.0	100	46.7
I Night	86.58	45.3	82.85	38.6
II Day	119.69	45.7	113.89	35.1
II Night	102.80	47.6	98.76	41.3
III	145.50	52.1	141.51	47.4
IV	250.15	77.9	240.49	68.2
<u>Orienteering Ratings</u>				
I Day	2.01	0.45	1.91	0.50
I Night	2.22	0.53	2.13	0.55
II Day	1.83	0.37	1.77	0.42
II Night	1.97	0.35	1.90	0.40
III	1.89	0.35	1.79	0.43
IV	1.93	0.27	1.83	0.39
<u>Intelligence and Fitness</u>				
Wonderlic	25.50	5.73	24.89	5.93
APFT	239.70	23.17	232.58	26.07

<u>Note</u>. Orienteering ratings were: 3=Outstanding, 2=Satisfactory, and 1=Unsatisfactory. Mean Orienteering times have been rescaled for test security reasons; proportionality across events in original data has been retained.

Table 2

Intercorrelations for Predictor Variables

Predictors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Spatial Tests																
(1) Map	--															
(2) Orient	52	--														
(3) Maze	48	48	--													
Orienteering Times (in Minutes)																
(4) I Day	-26	-21	-12	--												
(5) I Night	-20	-19	-13	28	--											
(6) II Day	-25	-12	-05	22	32	--										
(7) II Night	-11	-03	-14	18	25	22	--									
(8) III	-12	-21	-13	17	19	24	26	--								
(9) IV	-20	-09	-24	21	12	29	27	36	--							
Orienteering Ratings																
(A) I Day	16	17	07	-74	-11	-12	-07	-16	-17	--						
(B) I Night	13	17	09	-23	-76	-29	-24	-16	-14	08	--					
(C) II Day	22	08	05	-18	-19	-79	-11	-15	-19	12	16	--				
(D) II Night	12	05	15	-07	-17	-18	-72	-20	-15	03	16	06	--			
(E) III	08	14	09	-04	-02	-13	-14	-71	-30	06	06	09	11	--		
(F) IV	17	09	18	-09	02	-09	-17	-20	-59	08	-01	-03	11	19	--	
Intelligence and Fitness																
(G) Wonderlic	66	46	36	-25	-19	-22	-16	-24	-23	18	12	16	14	12	12	--
(H) APFT	-07	-01	-15	-07	05	-13	03	-09	-00	07	-05	05	-11	09	-03	-08

Note. Correlations with absolute values greater than or equal to .13 are significant at $p<.05$ or higher; decimal points have been omitted. Entire sample N=232.

Table 3

T-Test Results and Correlations for Predictor Variables and Land Navigation (Pass vs. Fail First Try)

	Land Navigation Performance					
	Pass (N=167)		Fail (N=65)			
Predictor	M	SD	M	SD	t	r
Spatial Scores						
Map	13.70	4.65	10.88	5.30	3.99***	.255***
Orientation	16.72	5.73	14.71	6.28	2.34*	.153*
Maze	19.47	3.37	18.09	3.94	2.66**	.173**
Orienteering Times (in Minutes)						
I Day	100	45.83	107.73	49.67	-1.13	-.074
I Night	86.23	43.25	95.07	49.86	-1.34	-.088
II Day	119.10	43.53	131.92	49.91	-1.93	-.126
II Night	102.13	46.89	114.13	48.56	-1.74	-.114
III	146.16	51.10	153.42	54.60	-0.95	-.063
IV	249.47	74.48	273.00	84.28	-2.08*	-.136*
Orienteering Ratings						
I Day	2.04	0.44	1.94	0.46	1.57	.103
I Night	2.25	0.53	2.15	0.54	1.18	.077
II Day	1.87	0.34	1.74	0.44	2.13*	.156*
II Night	1.97	0.34	1.95	0.37	0.32	.021
III	1.90	0.33	1.85	0.40	1.12	.074
IV	1.96	0.23	1.86	0.35	2.07*	.161*
Intelligence and Fitness						
Wonderlic	26.04	5.65	24.12	5.75	2.30*	.150*
APFT	239.90	22.89	239.18	24.05	0.21	.014

Note. Mean Orienteering times have been rescaled for security reasons; proportionality across events and magnitude of effects (PASS VS. FAIL) in original data have been retained. Correlations are point-biserial. ***$p<.001$. **$p<.01$. *$p<.05$.

all three spatial tests. They also had better times on one orienteering event (IV), higher ratings on two events (II Day and IV), and better scores on the Wonderlic.

The predictor/criterion point-biserial correlations show the same pattern of significant results. The correlational results also partially replicate findings from earlier Q Course research. Like Pleban et al. (1989), we found no significant relationship between APFT scores and land navigation performance. Also, while our correlation between Wonderlic test scores and performance on the land navigation test (r=.15) is lower than that found in the earlier research (r=.28 in Pleban et al., 1989), it is still positive and significant.

Pass first try vs. pass re-test vs. fail all re-tests. For the three outcome analyses, the 65 trainees who did not pass land navigation the first time are divided into those who later passed a re-test (n=46, 20% of total sample) and those who failed all re-tests (n=19, 8%). Analysis of variance (ANOVA) results to identify significant differences are displayed in Table 4.

Table 4

Results of ANOVA Testing Mean Differences in Predictor Variables Across Three Land Navigation Performance Groups

		Cell Means for Different Levels of Land Navigation Performance		
	F Ratio	Pass 1st Try (N=167)	Pass Re-test (N=46)	Fail Re-Test (N=19)
Spatial Scores				
Map	7.97***	13.70	10.98	10.63
Orientation	2.85			
Maze	3.72*	19.47	17.91	18.53
Orienteering Times				
I Day	0.64			
I Night	1.17			
II Day	1.86			
II Night	1.68			
III	0.53			
IV	2.20			
Orienteering Ratings				
I Day	1.24			
I Night	0.84			
II Day	3.11*	1.87	1.72	1.79
II Night	0.06			
III	0.97			
IV	6.09**	1.96	1.91	1.74
Intelligence and Fitness				
Wonderlic	3.31*	26.04	23.61	25.37
APFT	0.23			

Note. Cell means printed for predictors with significant F ratios only. Cell means not differing significantly (by Tukey HSD post-hoc tests) are connected by underlining. ***p<.001. **p<.01. *p<.05.

The overall ANOVAs show that scores on the Map, Maze, and Wonderlic tests and ratings on orienteering events II Day and IV were significantly different across groups. However, the more conservative Tukey HSD posthoc tests (SAS version 5.0) found significant differences across cell means for Map test scores and IV ratings only.

The underlining of cell means in Table 4 shows that those passing land navigation on the first try had significantly higher scores on the Map test than did the other two groups, whose Map scores did not differ significantly. Also, event IV ratings were significantly lower for the small group of students who were never able to pass a re-test.

Unique Variance Explained by Predictors

Overall, the results in Table 3 show that spatial tests, intelligence test scores, and military orienteering times for one event and ratings for two events are related to passing land navigation on the first try. Similarly, Table 4 shows that when the three outcome groups are used, Map test scores and ratings on orienteering event IV are related to performance differences.

To determine which potential predictors make a unique contribution to the prediction of land navigation performance we performed backward stepwise discriminant analyses. In this procedure, all predictors are entered into the prediction equation as a block. Nonsignificant predictors are then removed one at a time, based on their individual contribution to the overall prediction. This process continues until all predictors remaining in the equation are individually significant at a certain alpha level (.05), and thus account for an independent portion of the variance in the criterion. The high intercorrelations among the paper and pencil measures (spatial and intelligence tests) suggest that these measures, in particular, are likely to be redundant as predictors of land navigation performance.

The results of the discriminant analysis showed that the Map test was the only predictor to account for a significant proportion of unique variance in the pass vs. fail first time criterion (r^2=6.5%). Thus, the Map test is the best single predictor of first time land navigation success, and when Map scores are included in a prediction equation none of the other variables add any significant explanatory power.

When the same procedure was performed using the three criterion groups (pass first time/pass re-test/fail re-test) the Map test (partial r^2=5.5%) and ratings on event IV (partial r^2=4.0%) emerged as significant independent predictors of land navigation outcomes. This is consistent with the ANOVA results presented in Table 4. That is, individuals who excel (i.e., pass land navigation on their first try) tend to have higher Map test scores than other trainees, while the poorest performers (those who fail both the first test and later re-tests) are more likely to have unsatisfactory IV ratings.

Map Test Cut-Score Analyses

The results above suggest that it might be appropriate to use the Map test to identify SFAS candidates likely to have trouble with land navigation in the Q Course. To explore this possibility, we performed a series of hypothetical cut-score analyses with Map test scores.[4] These analyses are intended to provide an estimate of the potential costs and benefits of using spatial ability as a prerequisite for the Q Course.

We began by dividing students into six nearly equal sized groups, based on Map test scores. Then we determined first time pass rates for each group. As shown in Table 5, less than half (48%) of the students in the lowest scoring group passed the land navigation test on their first try. The pass rate generally increases with Map score range, first steeply and then more gradually. These results, in general, suggested two possible cut-scores, 7 and 11.

Table 5

Land Navigation Pass Rates for Different Map Test Score Ranges

Map Test Score Range	Number in Group	Percent of Sample	Percent Pass 1st Try
0 - 6	33	14	48
7 - 10	38	16	63
11 - 13	43	18	77
14 - 16	43	19	72
17 - 18	44	19	82
19 - 20	31	13	87
TOTAL	232	100	

In Table 6 we show how cut-scores of 7 and 11 on the Map test would have affected class size and overall 1st time pass rates, if applied to the present sample. A minimum Map test

[4]Another research opportunity revealed here is to explore different ways to use data from the military orienteering events to select trainees for SFQC. Such analyses, however, should be conducted using the FY91-93 SFAS Database, a much larger and more recent sample than what is available here. The present authors are planning such research - see the Discussion section for more on this topic.

score of 7, for example, would have eliminated 14% of the sample and resulted in a first time pass rate of 76% - a modest improvement over the current pass rate of 72%. A cut-score of 11 on the Map test would have excluded 30% of the sample and raised the first time pass rate another 3% to 79%. Of course, the trade-off for the slightly higher pass rates at cut-scores of 7 and 11 is that relatively large proportions of those excluded (48% and 56%, respectively) would have successfully completed land navigation on the first try.

Table 6

Outcomes Associated with Two Hypothetical Map Test Cut-Scores

	Cut-Scores			
	7		11	
Percentage of current sample admitted	86%	(199)	70%	(161)
First time pass rate for those admitted	76%	(151)	79%	(127)
First time pass rate for those excluded	48%	(16)	56%	(40)

Note. Current pass rate is 72%.

As Table 6 also shows, the stricter cut-scores would produce substantially fewer SFQC graduates (151 at a cut-score of 7 and 127 at a cut-score of 11). This happens despite the slightly higher pass rates, because so many candidates would have been screened out, and thus not available for the class.

If it is important to produce the highest number of graduates possible, a cut-score even lower than 7 might be most efficient. Only a few people would be excluded, and presumably, these would be the candidates with the lowest probability of passing the first time. Unfortunately, in the present sample the number of students with scores at or below 6 is too small to allow us to project outcomes. Additional research is clearly warranted, however, to replicate these results and assess the impact of cut-scores below 7.

The optimal cut-score, of course, depends on organizational objectives and the availability of qualified candidates. If there are more qualified candidates than needed, and the primary goal is to reduce the number of re-tests that have to be administered, then stricter cut-scores are called for, even if they eliminate many people who might otherwise have been successful. If, on the other hand, the goal is to produce as many graduates as possible, even if this means a relatively large number of re-tests, then a more lenient cut-score is necessary.

Discussion

Most importantly, these analyses have shown that students' scores on the Project A Map test are related to their performance on the Special Forces Qualification Course land navigation exercise. This finding is impressive because the Map test is a short, paper and pencil measure and land navigation is a multi-faceted performance criterion administered three months to two years later.

There are several possible explanations for this relationship. One is that the Map test predicts performance simply because it measures map-related knowledge and skills that facilitate performance on the land navigation field exercises. Although proposed as a measure of a relatively stable, innate spatial ability, the Map test, because of its similarity to actual maps, may be easier for people who have acquired map reading skills from prior training or experience. Previous research has indeed found that individuals with relevant prior training and experience are also likely to perform better on land navigation tasks (Peters, Bleda, & Fineberg, 1979; Pleban et al., 1989).

This interpretation, however, is not consistent with the fact that the "less realistic" spatial tests, Orientation and Maze, also had significant, albeit smaller, correlations with both military orienteering (Busciglio et al., 1991) and land navigation performance (see Tables 3 and 4). Scores on these more abstract tests are less likely to be affected by prior training or "real-world" experience in map-reading, orienteering or land navigation.[5] Moreover, the fact that pre-training measures predict post-training performance further supports the argument that the spatial tests measure basic abilities that are difficult to alter through training or experience.

Interpreting the effects of the Map test as evidence that spatial abilities are related to land navigation performance is consistent with much previous research (Hunt, 1991; Scholl, 1988; Stasz & Thorndyke, 1980; Thorndyke & Stasz, 1980; Weitzman, 1979). This conclusion also raises an important practical question - to what extent can training compensate for deficiencies in basic spatial abilities?

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[5] It should also be recalled that the Map test is significantly correlated with the Orientation and Maze tests (r=.52 and .48, respectively), as Table 2 shows.

Thorndyke and Stasz's (1980; Stasz & Thorndyke, 1980) results suggest that training can improve performance to some extent; however, the effectiveness of training depends on, or is moderated by spatial ability. Thorndyke and Stasz (1980) found that subjects who showed better spatial recall adopted a more systematic approach to a map learning task and employed more spatial-visual strategies (e.g., imagery, pattern encoding) in memorizing and using map information. In fact, even experienced map users did well on the recall task only if they used these learning strategies.

In a follow-up study, Thorndyke & Stasz (1980) attempted to determine if less skilled subjects could be trained to use the more effective strategies. They found that performance improved with as little as 30 minutes of training and practice. They also found, however, that high visual memory subjects benefitted most from training, and used the effective strategies more frequently and with better results.

Kozlowski and Bryant (1977) found somewhat similar results. Subjects who reported having a "good sense of direction" (and who also appeared to have better spatial-visual abilities) showed improved performance over several trials of a tunnel maze learning task, while "poor sense of direction" subjects did not. In a similar vein, Weitzman (1979) found that NCO's with greater spatial ability did better at using cues or prior information about the task to improve their performance.

In the research cited above, the training provided to subjects was minimal, yet the moderating effect of spatial ability on training effectiveness was clearly apparent. In contrast, land navigation training in the SFQC is long and intensive. Nevertheless, it is possible that a similar ability by training interaction may be operating in the Q Course.

The fact that pre-training measures (e.g., the Map test) are related to post-training performance suggests that even intensive instruction cannot fully compensate for individual differences in spatial ability. The Map-test cut-score analyses, for example, showed that only about half of the low ability trainees (scores below 7) passed the field exam the first time. In contrast, pass rates for the moderate and high ability students ranged from 77% to 87%. One interpretation is that high spatial aptitude students benefit more from the map reading and orientation training they receive, and this accounts for their higher first time pass rate.[6]

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[6]Of course, another hypothesis is that spatial ability and training are additive factors in determining land navigation performance (i.e., the relationship between spatial test scores and land navigation performance is unaffected by training). A strong test of this hypothesis would require measuring land navigation both before and after training.

General intelligence or cognitive abilities measured by standard verbal and math tests are also likely to be important factors in trainability. Intelligence is likely to determine how easily students can assimilate land navigation course material, particularly considering the compressed time period available for learning and practice in the Q Course. Intelligence is also likely to affect performance on specific tasks that require verbal comprehension or analytical skills. Scholl and Egeth (1982), for example, found that tests of verbal and math abilities were better at predicting performance on a relief test than spatial orientation and visual memory tests. The superior predictive power of general intelligence tests in this case appears to be due to the nature of the criterion task. Unlike the map recall tests used by Thorndyke & Stasz (1980), the test in Scholl and Egeth's study required subjects to follow fairly complicated written instructions and use multi-step calculations to estimate altitudes.

These results suggest that, despite the weak relationship between Wonderlic scores and the land navigation field exam in the present research, intelligence is probably an important determinant of performance on other components of the course (e.g., written tests and math-dependent exercises). Abstract spatial-visual abilities, on the other hand, may be most critical on field exercises when conditions preclude constantly checking one's map and navigators must rely on mental images of their maps or survey representations of the terrain to guide them (Weitzman, unpublished paper).[7]

The relative importance and differential predictive power of intelligence and spatial-visual abilities are difficult to sort out because in this and other research (Scholl & Egeth, 1982), these measures are highly correlated. However, research using more finely differentiated predictor and criterion measures might clarify how intelligence and spatial abilities jointly or interactively affect land navigation performance.

In summary, our conclusion that spatial-visual abilities are related to land navigation performance is consistent with a large body of previous research in this area. Of the three spatial tests examined here, Map appears to be the best measure of the relevant spatial abilities. Cut-score analyses show that students with very low scores on this test have trouble passing land navigation and may require more training to perform to standards - if they are to achieve those standards at all.

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[7] We once again point out that intelligence (Wonderlic) test scores were strongly correlated (r=.52) with performance on the Q course written map reading exam in the Pleban et al. (1989) research, although the same test was only modestly (r=.28) related to performance on the field exercise.

These results, considered in the context of related research, suggest several courses of action. First, it appears that the Map test or some alternative spatial-visual ability test could be used to identify and screen out the few SFAS candidates who are unlikely to benefit from training in the Q Course.[8] Additional research would be warranted to identify the most appropriate instrument and optimal cut-score in light of current organizational needs and constraints. A replication of the present study is especially important because of recent changes in the structure of the Q Course, possible changes in land navigation pass rates, and an expected increase in the quality of future SF candidates as a result of more selective Army recruiting. As noted earlier, the quality as well as the number of prospective applicants must be considered with manpower requirements and resource constraints in decisions about the practical utility of additional pre-requisites.

A more conservative interim step would be to use the current Map test or a test tailored specifically for the Q Course as a diagnostic tool to identify candidates who need to improve their map skills. Low scoring candidates could be given instructional materials and performance standards they are expected to achieve before they attend the Q Course. Implementation of such an option could be designed to allow researchers to evaluate the predictive ability of any new test, both with and without feedback or counseling for low ability students. In a related vein, adding a short block of instruction (or even just providing a handout) on effective map learning strategies might improve the performance of individuals who do not naturally use spatial-visual strategies.

Finally, our results with the orienteering events suggest several additional research possibilities. For example, it is interesting that the ANOVA results using three criterion groups showed that the "pass first try" group had higher Map scores than other groups, whereas students who failed both the first test and the re-test were distinguished only by lower MO IV ratings. Of the few trainees (17, 7% of the sample) who received unsatisfactory ratings on MO IV, 29% failed both the first test and at least one re-test, in contrast to only 6.5% of rest of the sample. Had all 70 of the SFAS candidates who received unsatisfactory event IV ratings been allowed to attend the Q Course, the relationship between these ratings and land navigation performance would undoubtedly have been stronger.

One interpretation for the modest relationship we did obtain is that candidates who fail event IV lack the experience and/or spatial ability to pass the land navigation course. An

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[8]Perhaps using an easier form of the Map test to more finely discriminate among low aptitude individuals.

alternative interpretation rests on the fact that of all the military orienteering events, event IV is most similar to the land navigation field exam in terms of length and physical difficulty. It is possible that candidates who fail the event are more likely to fail land navigation simply because they lack the strength, endurance, or determination to persist in a long and difficult task. Future research might clarify this issue by examining how other measures of fitness and motivation (e.g., ruckmarch times) are related to land navigation performance.

Future research might also suggest ways to fine-tune the efficiency of the military orienteering events as assessment events. For example, an analysis of land navigation pass rates as a function of different time score categories might suggest different standards for satisfactory performance. Ideally this would be accomplished by recording orienteering scores but suspending their use in selection decisions. However, useful analyses could still be conducted even if this were not possible. Another possibility is to make one or two events more demanding in terms of the spatial ability and/or orienteering skills required and track the relationship between performance on these events and land navigation.

Overall, however, the lack of a strong linear relationship between military orienteering scores and land navigation suggests that current SFAS selection criteria <u>are</u> effectively screening out most low potential candidates. Major changes would be indicated only if the correlation between MO performance and land navigation were quite high.

Another, more involved project would attempt to clarify underlying causal relationships and interactions across several types of predictors. These might include: 1) a map test that is more sophisticated and clearly knowledge based, 2) other abstract spatial ability measures, and 3) self-reports or "biodata" measures of past training and experience in map-reading, orienteering or navigation. For example, one set of analyses could attempt to determine the importance of prior experience and acquired map skills relative to spatial-visual abilities as determinants of field performance. Path analyses could also help clarify the potential mediating role of map reading skills in the relationship between abstract spatial-visual abilities and land navigation performance.

At a minimum, it would be worthwhile to replicate the present analyses using a larger sample of current Q course students. If the Map test or some similar instrument were administered just before the land navigation course, results showing the potential utility of this type of test as a selection tool could be obtained fairly quickly. We are also planning this type of research with another Project A spatial test, Assembling Objects, that has shown great promise in previous settings.

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Appendix A

Psychometric Properties of the Project A Spatial Tests[9]

Campbell & Zook (1991, p. 38; 1992, pp. 96-97) reported a series of factor analyses of scores on the spatial tests and the ASVAB subtests that were conducted at various stages of Project A and its follow-up, the Career Force project. Pertinent results are summarized in Table A-1. As can be seen, all three analyses isolated distinct ASVAB and spatial factors. Another consistent finding was that the Map test had the highest loading on the ASVAB factor and Maze had the lowest. Maze, on the other hand, had the highest loading on the spatial factor.

This finding is somewhat replicated by another analysis of the Concurrent Validation data reported by Campbell and Zook (1991). For each Project A measure, the authors computed a "Uniqueness Estimate," the proportion of total variance that was reliable but unrelated to ASVAB - i.e., the test's reliability minus the $\underline{R}^2$ obtained when it is regressed on the ASVAB subtests. The uniqueness estimates were: Map .46 (lowest of the six spatial measures); Orientation .60; Maze .74 (second highest of the spatial tests). Once again, Map appears to be the most influenced by general cognitive ability and Maze the least.

One final bit of evidence for the relative g-loadings of the measures comes from Busciglio's (1990) analysis of the Project A Concurrent Validation data. The author employed stepwise regression analyses to assess a total of 132 predictor-criterion relationships in which the Project A measures could increment the validity of an empirically determined best possible combination of ASVAB subtests. In these procedures, the ASVAB subtests were entered first, significant subtests were retained, and then the Project A tests were entered and significant incremental predictors were determined. Since the analyses used a very broad range of criterion measures - many of a nonspatial nature - it can be argued that overall incremental validity would come from tapping general cognitive skills. The results, as shown in Table A-2, indicate that the Map test was the strongest incremental predictor and the Maze test was the weakest.

Other factor analyses using the spatial measures alone reveal more about the three tests in the present study. For example, Campbell and Zook (1992) reported that exploratory factor analyses on the Concurrent Validation sample and two samples from the Longitudinal Validation supported a two factor solution: 1) power tests, including Map and Orientation,

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[9] All studies cited in this Appendix are included in the list of references.

Table A-1.

Summary of Factor Analytic Results from Project A and Career Force Samples (from Campbell & Zook, 1991, 1992)

	Loadings on ASVAB factor			Loadings on Spatial factor		
Test	FT	CV	LV	FT	CV	LV
Map	.60	.33	.33	.52	.56	.56
Orientation	.40	.21	.18	.46	.56	.59
Maze	nr	.07	.10	.70	.65	.65

Note. FT is Field Test sample (N=169; these analyses included the Project A perceptual-psychomotor tests; CV is Concurrent Validation sample (N=7,884); LV is from the Longitudinal Validation (N=6875); nr - less than .30, and thus not reported.

Table A-2.

Number of Equations for Which Individual Predictors are Statistically Significant, by Type of Criteria, Across MOS (from Busciglio, 1990)

	Type of Criteria (Maximum Possible[a])		
	Comprehensive[b] (86)	Specific (46)	TOTAL (132)
best 2 ASVAB subtests:			
Mathematics Knowledge	68	28	96
Auto and Shop Information	74	20	94
worst 2 ASVAB subtests:			
Number Operations	24	2	26
Electronics Information	18	4	22
Spatial:			
Map	33	8	41
Orientation	13	4	17
Maze	5	1	6
best 2 Perceptual-Psychomotor tests:			
Target Ident. - % correct	32	13	45
Target Ident. - time	23	18	41

[a]Across all measures pertinent to all MOS. [b]Comprehensive measures refer to overall success on the job; specific are more nearly defined areas, such as navigation, target identification, operating howitzer sights, tank gunnery, determining grid coordinates, etc.

and 2) speed tests, including Maze (see Table A-3). However, the same authors reported that a LISREL confirmatory factor analysis using data from one of the Longitudinal Validation samples favored a three factor solution: 1) figural reasoning, 2) orientation - composed of Map and Orientation, and 3) speed, including Maze. When the authors applied the Schmid-Leiman (1957, as cited in Campbell & Zook, 1992) transformation, it was discovered that all the tests loaded more highly on a second-order factor that included all the spatial tests than on the three specific factors (see Table A-4). From the analyses above, we have drawn the following general conclusions:

1) All three tests measure important aspects of general spatial ability.
2) The influence of general cognitive skills is strongest on the Map test and weakest on the Maze test.
3) Map and Orientation are power tests while Maze is a speeded test.
4) Map and Orientation do, in fact, converge on an "Orientation" construct.

Table A-3

Factor Analysis Results for Project A Spatial Tests (from Campbell & Zook, 1992)

	Loadings					
	Factor I			Factor II		
Test	CV	LV1	LV2	CV	LV1	LV2
Power tests:						
Assembling Objects	.54	.55	.54	.47	.49	.50
Figural Reasoning	.59	.54	.54	.40	.46	.42
Map	.60	.59	.58	.37	.38	.38
Orientation	.56	.57	.56	.34	.37	.35
Speed tests:						
Maze	.38	.38	.37	.57	.57	.55
Object Rotation	.32	.36	.34	.52	.54	.52

Note. CV is Concurrent Validation sample from Project A (N = 7939). LV1 and LV2 are two different samples from the predictor data collection phase of Career Force Longitudinal Validation (Ns = 6929 and 6436, respectively).

Table A-4

Schmid-Leiman Results for Project A Spatial Tests
(from Campbell & Zook, 1992)

	Loadings			
	General	Specific Factors:		
Test	Factor	Speed	Figural	Orientation
Assembling Objects	.753	.000	.065	.000
Figural Reasoning	.720	.000	.062	.000
Map	.685	.000	.000	.278
Orientation	.656	.000	.000	.266
Maze	.624	.367	.000	.000
Object Rotation	.592	.347	.000	.000

Note. Sample from predictor data collection phase of Career Force Longitudinal Validation (N = 4723).