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TECHNICAL NOTES ON

SOLDIER DIMENSIONS IN COMBAT MODELS

MAY 7, 1990

TRADOC ANALYSIS COMMAND - FORT BENJAMIN HARRISON

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FINAL REPORT

O N

SOLDIER DIMENSIONS IN COMBAT MODELS

7 May 1990

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The purpose of this report is to review research and to recommend an action plan which provides possible techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions. This study has been conducted because current combat models do not adequately portray human factors.

We reviewed previous research and determined which soldier dimensions are most likely to influence soldier performance on the battlefield; how different soldier dimensions affect different types of performance; what scales have been used to establish predictive relationships between soldier dimensions and soldier performance; and the extent to which soldier dimensions are currently portrayed in Army models.

We present research methodologies for implementation in simulated battle and simulation devices, for using data previously collected by others, and for surveying combat veterans.

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The words "he", "him", "his", "man", and "men", when used in this publication, represent both the masculine and feminine genders unless otherwise specifically stated.

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This study was initiated and sponsored by the TRADOC Analysis Command. The study was conducted by TRADOC Analysis Command - Fort Benjamin Harrison (TRAC-FBHN).

This report has been certified by the Commander, TRADOC Analysis Command, and approved by Commander, Soldier Support Center, Fort Harrison.

The conclusions and recommendations of this study are those of TRADOC Analysis Command - Fort Benjamin Harrison. They are based on the review of numerous past and ongoing studies of relevance.

The author was Dr. Phillip L. Vandivier. Assistance was provided by Dr. Gerald A. Klopp. Special thanks is extended to SGT Maria Garcia for computer graphics assistance.

SECURITY CHECKLIST

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ABSTRACT

The purpose of this report is to review research and to recommend an action plan which provides possible techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions. This study has been conducted because current combat models do not adequately portray human factors.

We reviewed previous research and determined which soldier dimensions are most likely to influence soldier performance on the battlefield; how different soldier dimensions affect different types of performance; what scales have been used to establish predictive relationships between human factors and soldier performance; what methodological techniques have been used to establish predictive relationships between soldier dimensions and soldier performance; and the extent to which soldier dimensions are currently portrayed in Army models.

We present research methodologies for implementation in simulated battle and simulation devices, for using data previously collected by others, and for surveying combat veterans. Each methodology:

-pinpoints which human factors are most significant contributors to changes in soldier performance and

-identifies a quantitative relationship between multiple human factors and soldier performance.

The overall research plan:

-spells out how soldier performance, as portrayed in models, can be adjusted for different human factor conditions and

-discusses the use of the regression equation to adjust soldier performance variables in view of different adverse conditions prior to inputting this information.

The study argues that a major consideration of whether a particular variable should serve as a dependent variable in subsequent research should be (1) whether the dependent variable serves as an input to one or more Army models, and (2) whether its alteration would result in significant differences in combat outcomes generated by the model.

EXECUTIVE SUMMARY

The purpose of this report is to review research and to recommend an action plan which provides possible techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions.

We conducted this study because current models do not adequately portray human factors. If this situation is not corrected, model predictions may provide unrealistic estimates of combat outcomes.

The objectives of this study are as follows:

To review previous research and determine:

-Which soldier dimensions are most likely to influence soldier performance on the battlefield?

-How do different soldier dimensions affect different types of soldier/unit performance, such as decision-making, operating different weapons systems, etc.?

-What scales have been used to establish predictive relationships between human factors and soldier performance?

-What methodological techniques have been used to establish predictive relationships between soldier dimensions and soldier performance?

To determine the extent to which soldier dimensions are currently portrayed in Army models which predict combat outcomes.

To develop a research plan which identifies a preferred technique for quantitatively inputting soldier dimension information into computer models so that unit performance can be realistically adjusted in view of adverse conditions.

Results indicated the following:

There exists a total of approximately 23 different soldier dimensions (human factors) which significantly influence unit performance. Not all are independent.

Sleep loss, stress, fatigue, training, and leadership are among the most frequently cited human factors in the literature.

Soldiers become militarily ineffective following 48 to 72 hours of no sleep; continuous work for 72 hours results in . 75% performance degradation; mental tasks (including alertness) are likely to degrade quicker than physical or routine motor tasks.

A wide variety of scales have been developed to measure soldier dimensions and performance. Questionnaires, SQTs, and ARTEPs were often used. Many scales had estimates of reliability but few had validity data.

Most studies attempt to predict soldier performance from human factors using parametric statistical analysis procedures. Very few of the studies considered in this report utilized dependent variables which could serve as inputs to models that predict combat outcomes.

The review of selected documentation of 279 models in the Army military community disclosed that only a single model, JANUS(T), showed clearcut evidence of portrayal of soldier dimensions.

We developed a conceptual model in which all soldier dimensions (human factors) can be classified as to their location with reference to the soldier (are they "inside" the soldier or in the external environment?) and their endurance (how long will the factor prevail?). According to this model all human factors are endogenous/transitory, endogenous/enduring, exogenous/transitory, or exogenous/enduring. This model is presented for discussion purposes only pending its validation.

Research plans were provided for applications in simulated combat and with simulation devices, for data previously gathered by others, and for surveying combat veterans. Three applications were presented in the interests of covering all--or at least most--of the bases in this area of study.

The study plan for simulated environments or devices calls for random assignment of crews to different sleep and fatigue (continuous work) conditions over a 72 hour period of time. Data is collected for baseline and at 8 hour intervals for amount of sleep, fatigue, stress/anxiety, morale, cohesion, motivation/will, quality of leadership, and soldier performance. Previous experience and cognition data are also gathered. Multiple regression is used to establish quantitative, predictive relationships between these variables and crew performance at different time intervals into the battle. Following analysis, the regression equation can be used to predict adjusted crew performance in view of different combinations of human factors.

The approach to be used with data previously collected by others is largely a function of which variables are available and the format in which each is collected. If variable data is classificatory, then factorial analysis of variance can be used to determine which human factors are significant determinants of soldier performance. However, only general trends can be gleaned from classificatory data. What is needed is data collected on continuous, equal interval scales so that multiple regression can be used to establish a predictive relationship between human factors and soldier performance. Prospects for research of this type are limited by the scarcity of good soldier dimensions data which has been collected in a useable format.

The research plan for surveying combat veterans:

-pinpoints which human factors are most significant contributors to changes in soldier performance. A survey instrument (see Appendix B) was developed and is discussed for this purpose. Analytic procedures (magnitude estimation, discriminant analysis, factor analysis, and factorial analysis of variance) are also spelled out.

-identifies the quantitative relationship between multiple human factors and soldier performance. Another survey instrument (see Appendix C) is provided for this purpose, along with discussion regarding how multiple regression can be used for analysis of data.

For all three research options the report discusses how to use the regression equation to adjust soldier performance in view of different adverse conditions prior to inputting this information into the model. In a nutshell, if performance measures are used which serve as inputs to combat models, then researchers can determine future predicted performance by substituting human factors values into the predictive equations which are generated by the multiple regression procedure. This predicted performance level, which is adjusted according to human factor value inputs, can be inputted into combat models. Resultant model outputs can be studied to determine the effects of numerous combinations of human factor conditions on combat outcomes.

Of utmost importance is the point that the dependent variable of the soldier dimensions study MUST serve as an input to one or more Army models. The selection of a dependent variable measure should also be guided by consideration as to whether its alteration would result in significant differences in combat outcomes generated by the model. If significant changes in a variable will not result in significant combat outcomes, another variable should be used.

PREAMBLE

This report recommends techniques which would determine how to adjust Army model outcomes for changes that might occur as a result of soldier dimension (human factor) conditions on the battlefield. This plan is not necessarily the only plan, or even the best plan, that might be followed. However, it does provide procedures which, if followed, will provide answers to many of the basic questions in this area of research. We urge our reviewers to provide constructive suggestions regarding ways to improve this plan. Moreover, we challenge everyone in the military scientific community to formulate a better plan than this one. Hopefully, our combined efforts will eventuate in the implementation of one or more research initiatives that will provide all the information needed to adjust combat outputs in view of soldier dimension conditions.

CHAPTER I

INTRODUCTION

1-1. <u>Study Purpose.</u> The purpose of this report is to review research and to recommend an action plan which provides possible techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions. This study was conducted because current combat models do not adequately portray soldier dimensions* such as sleep deprivation and fatigue which undoubtedly have an adverse impact on unit performance and achievement of combat objectives.

1-2. <u>Objectives.</u> Specific objectives addressed in this study follow:

a. To review previous research conducted in the military** and civilian*** communities to determine:

(1) Which soldier dimensions are most likely to influence soldier/unit performance?

(2) How will each dimension identified affect different types of soldier/unit performance (e.g., decision-making, gross motor performance, fine eye-hand coordination performance, performance on different weapons systems, etc.)?

(3) What scales are available for the measurement of each soldier dimension and each soldier performance area?

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* For purposes of this report, a "soldier dimension" is any factor which alters the physical, mental, or emotional capability of the soldier to perform his job effectively. Soldier dimensions can exist in the environment, inside the soldier, or both. The terms "soldier dimension" and "human factor" are used interchangeably throughout this report.

** Military research includes results supplied by foreign allied services.

*** Civilian research was considered because numerous nonmilitary studies have been conducted which demonstrate the influence various environmental human conditions (i.e., the counterpart of soldier dimensions for civilians) have on different kinds of performance--such as decision-making and gross/fine motor functioning.

(4) What methodological techniques have been used to establish predictive relationships between soldier dimensions and soldier performance?

b. To determine the extent to which soldier dimensions are currently portrayed in Army models which predict combat outcomes. This portion was conducted in conjunction with the Personnel Service Support (PSS) in Army Models AR 5-5 study (POC: Major James R. Thomas, TRAC-FBHN, AV 699-6883).

c. To identify a possible technique for quantitatively inputting soldier dimension information into computer models so that unit performance can be realistically adjusted in view of adverse conditions.

1-3. Problem.

a. Current computer models which predict combat outcomes do not adequately portray soldier dimensions which degrade unit performance. For purposes of illustration, a unit which has had little sleep during a 72-hour period of intensive conflict probably will not perform as well as a fresh unit. Nevertheless, current combat models fail to take into account the performance degradation that is likely to result when soldiers are required to fight for prolonged periods of time under adverse conditions.

b. This problem is critical in view of current AirLand Battle doctrine, which calls for continuous combat operations under exceedingly adverse, life-threatening conditions. Failure to solve this problem would mean that computerized models will continue to exclude soldier dimensions when predicting combat outcomes. As a result, model predictions may provide unrealistic estimates of combat capabilities which could result in poor planning and deficient readiness for future AirLand Battle conflicts.

1.4. Scope.

a. This study is nonexperimental in that it neither concerns data collection, data analysis, the testing of hypotheses, nor other such empirical activities. Rather, this study largely consolidates and builds on the work of others in the interests of developing an action plan which will provide a technique that adjusts combat outcome predictions of computer models based on different combinations of soldier dimension conditions.

b. This study focuses primarily on the impact that different soldier dimensions have on group or unit--rather than individual--performance. This bias is a reflection of the assumption that battle outcomes are inherently determined by group or unit performance. There can be little doubt that specific individuals and individual differences are important determinants of battle outcomes. Nevertheless, the collective nature of warfare calls for a focus on group performance.

c. This study focuses on high-quality, applied research results published within the last five years which investigated predictive relationships between relevant independent/predictor (soldier dimensions) and dependent/criterion (performance) variables.

1.5. <u>Limitations.</u>

a. As mentioned above, this study was largely limited to a review of previous work done in this area, rather than the conduct of experimental methodological techniques. For this reason, many of the conclusions are an outgrowth of previous findings.

b. This study was limited by stipulated manpower resources of 1.1 PSY. A study with such a broad scope as this one could easily take several times this amount of work. Limited resources disallowed the perusal of entire books on related topics.

c. This study was limited by the necessity to consider particular types of soldier performance, such as decision-making, gross motor functioning, fine motor functioning, and performance on specific weapon systems, etc., rather than performance of specific military tasks. This limitation is a reflection of the impossible undertaking of attempting to relate multiple soldier dimension variables to literally thousands of military performance tasks--each of which might have slightly different relationships--with different soldier dimensions.

1-6. <u>Assumptions.</u>

a. Soldiers are human beings whose performance is influenced by various conditions under which they are required to function. These conditions--called soldier dimensions--might reside within the individual (e.g., fatigue), in the surrounding environment (e.g., extreme temperatures), or both (e.g., extreme stress as a result of numerous casualties). Soldiers are "fighting machines" to the extent that they have been properly trained to perform certain tasks under peacetime and wartime conditions. Nevertheless, actual soldier performance will vary according to the unique combination of soldier dimension variables which impinge on the unit at any given time. Other soldier dimensions include sleep loss, motivation/will to fight, morale, unit cohesion, quality and maintenance of training, high altitude, humidity, toxicity (i.e., nuclear fallout), cognitive abilities as measured by the Armed Forces Vocational Aptitude Test, and so on. This list is by no means exhaustive.

b. Soldier dimensions are attributes which can be reliably and validly measured.

c. Soldier performance can be reliably and validly measured.

d. If we know the relationship between different soldier dimensions and soldier performance for a known group of soldiers, we should be able to predict soldier performance given different combinations of soldier dimension information for future soldiers. If all relationships can be described in mathematical terms, then a simple program or programs could be written which would adjust soldier performance in view of different combinations of soldier dimension conditions. This program could be added to existing models so that combat outcomes could ultimately be adjusted in view of expected degradation of soldier performance which results from various conditions under which soldiers are required to fight.

e. Because the research problem has to do with the delineation of the relationship between (and among) multiple predictor (soldier dimension) variables and multiple criterion (soldier performance) variables, the assumption is made that the underlying relationship is multivariate in nature. In other words, different soldier dimension variables are probably simultaneously influencing each other and various performance variables in different ways. Because of this complex, interactive relationship among the different variables, the effects that all soldier dimension variables have on performance when all impinge simultaneously on the soldiers (as in the real world) WILL PROBABLY NOT BE ADDITIVE. For purposes of illustration, if a particular kind of soldier performance is degraded by 45 percent for sleep deprivation, 30 percent for extreme anxiety, and 30 percent for fatigue, then the soldier is functioning at the -5 percent level--which makes no sense. Obviously, some overlap will probably exist in the predictive power of the different soldier dimensions. Whatever methodology is used to ascertain this relationship will have to be sensitive to this overlap. Otherwise, estimates of performance degradation will be inflated.

CHAPTER 2

BACKGROUND

2-1. Soviet doctrine presently calls for conducting continuous warfare, day and night, until the enemy is defeated. A strategy of replenishing battle-weary troops by echeloning forces is expected to force outnumbered US/NATO forces into sustained combat on a battlefield characterized by confusion, extreme stress, high intensity, and high lethality (FM 22-9, 1983). Unlike Soviet troops, which will be replaced every two or three days of fighting, our soldiers cannot count on replacements. They must conduct continuous land combat with only brief or fragmented opportunities for rest or sleep (Belenky, 1987). Continuous operations (CONOPS) is continuous land combat with some opportunity for sleep, although sleep may be fragmented or brief. On the other hand, sustained operations (SUSOPS) provides no opportunity for sleep (FM 22-9, 1983). Within any CONOPS, periods of SUSOPS are likely to occur.

2-2. Soldiers are "fighting machines" in that they have been trained to perform combat tasks and to achieve combat objectives, but they also are human beings with critical abilities that are depressed by continuous combat. When these critical abilities are depressed, performance of combat tasks is degraded, both in terms of performance time and the quality of performance. Combat task performance is eroded, and combat objectives are not met even though soldiers might be highly motivated and well-trained (FM 22-9, 1983).

2-3. If soldier performance is degraded by the Army's need for continuous combat for lengthy periods of time, then models which predict combat outcomes should adjust outputs in view of anticipated degradation. Unfortunately, models which control for this human degradation factor are the exception, rather than the rule. Why haven't they? Possibly because some sponsors of models are unaware of the probable impacts of the omission of the human element. But even more likely is the fact that pressures to "get on with it" postponed the inclusion of human considerations (Lester, 1986). Efforts to include human factor information in models have been hampered by a shortage of human factors data needed regarding fundamental physiological and psychological processes at all levels of combat operations (Thomas, 1986). Apparently few psychological studies have been undertaken with a view to what military analysts need, but neither have analysts provided clearly-stated specifications regarding what is needed to address the human factors issue. In the meantime, professional working groups in the field have identified lack of data and modeling attention on human factors as serious problems confronting the modeling community (Thomas, 1986).

CHAPTER 3

STUDY METHODOLOGY

3-1. Methodological procedures. Procedures employed are described under the different Essential Elements of Analysis (EEA) which follow.

3-2. EEA #1: Which soldier dimensions are most likely 'o influence soldier/unit performance? An extensive literature search was conducted through literally hundreds of journal articles, research reports, books, and symposium reports to identify products which relate to soldier dimensions, human factors, and soldier performance in continuous operations. The literature search included utilization of the automated Defense Technical Information Center. A total of 42 products (see Figure F-1 in Appendix F) were identified which provided discussion and/or research related to at least several soldier dimensions - as opposed to only a single factor. Results appear in Figure F-2 in Chapter 4. Please note that Figure F-2 provides only a global indication of the collective opinions of authors of studies in this area. A technique for analytically determining which soldier dimensions are most important determinants of performance is provided under EEA#6.

3-3. EEA#2: How does each dimension identified above affect different types of soldier/unit performance (e.g., decision-making, gross motor performance, fine eye-hand coordination performance, performance on different weapons systems, etc.)? Given the limited resources available to conduct this study, comprehensive review of all studies regarding all types of soldier dimension variables was not feasible. Instead, we concentrated on products identified in the literature search in EEA#1 which summarized or reviewed findings in each of the soldier dimension areas. Results appear in Figure F-3 in Appendix F.

3-4. EEA#3: To what extent are soldier dimensions currently portrayed in Army models which predict combat outcomes? Original plans calling for the circulation of a questionnaire to address this issue were rendered unnecessary by a separate action which elicited the needed information. Major James Thomas at TRADOC Analysis Command - Fort Benjamin Harrison (AV 699-6883) recently headed up a study team which reviewed selected documenta- tion of 279 models in the Army military community. This initiative was part of the Personnel Service Support (PSS) in Army Models, an AR 5-5 study. Results presented for this EEA in Chapter 4 are from this review.

3-5. EEA#4: How can each soldier dimension and each soldier performance area be measured? During the review of literature (see

In actuality, many different dependent variables could be used in conjunction with specific combat models. For purposes of illustration, we described the use of "lay time" for the 25mm cannon on the Bradley Fighting Vehicle. This dependent variable inputs nicely into the JANUS(T) model. These procedures are described and explained further in Chapter 4.

CHAPTER 4

ISSUE ANALYSIS

4-1. <u>Essential Element of Analysis #1: Which soldier dimensions are most likely to influence soldier/unit performance?</u>

a. Figure F-1 in Appendix F shows a total of 23 soldier dimensions were identified by different authorities as having a relationship with soldier performance during continuous operations. This number was reduced to 19 to avoid redundancies. (See the explanatory note on the front page of Figure F-1 in Appendix F.) Definitions of these factors appear in Appendix A.

b. Figure 4-1 (see next page) presents the frequency that each soldier dimension was cited across the products identified in Figure F-1. A frequency of 1 was assigned for a particular soldier dimension if it was mentioned one or more times in a product. The total frequencies for each soldier dimension (the total number of products which mention each soldier dimension) divided by the number of products gives the percentage of products that mention each dimension. For example, sleep loss (69.0 percent) and stress (69.0 percent) were cited most frequently followed by mental fatigue (64.3 percent), physical fatigue (61.9 percent), leadership (61.9 percent), cognition (54.8 percent), training (54.8 percent), cohesion (52.4 percent), morale (50.0 percent), and will/motivation (50.0 percent). Those mentioned least frequently include confinement/isolation (11.9 percent), altitude (9.5 percent), and national differences (7.1 percent).

c. These percentages provide a <u>very rough</u> indication of the importance of each soldier dimension in influencing soldier performance--at least in the collective opinion of authors of recent human factors articles. This conclusion is based on the assumption that topics which are more frequently cited are probably considered more influential than their less frequently mentioned counterparts. In other words, logic indicates that authors will write about human factors that are most likely to be influential--and ignore the rest. We reviewed numerous nonexperimental articles to insure adequate representation of soldier dimensions which might be considered important.

d. Please note that Figure 4-1 provides literary support, rather than analytic proof, of the relative influence of different soldier dimensions. This information was gathered for background information purposes only. A procedure for analytically determining the relative importance of each factor is provided later in this Chapter.

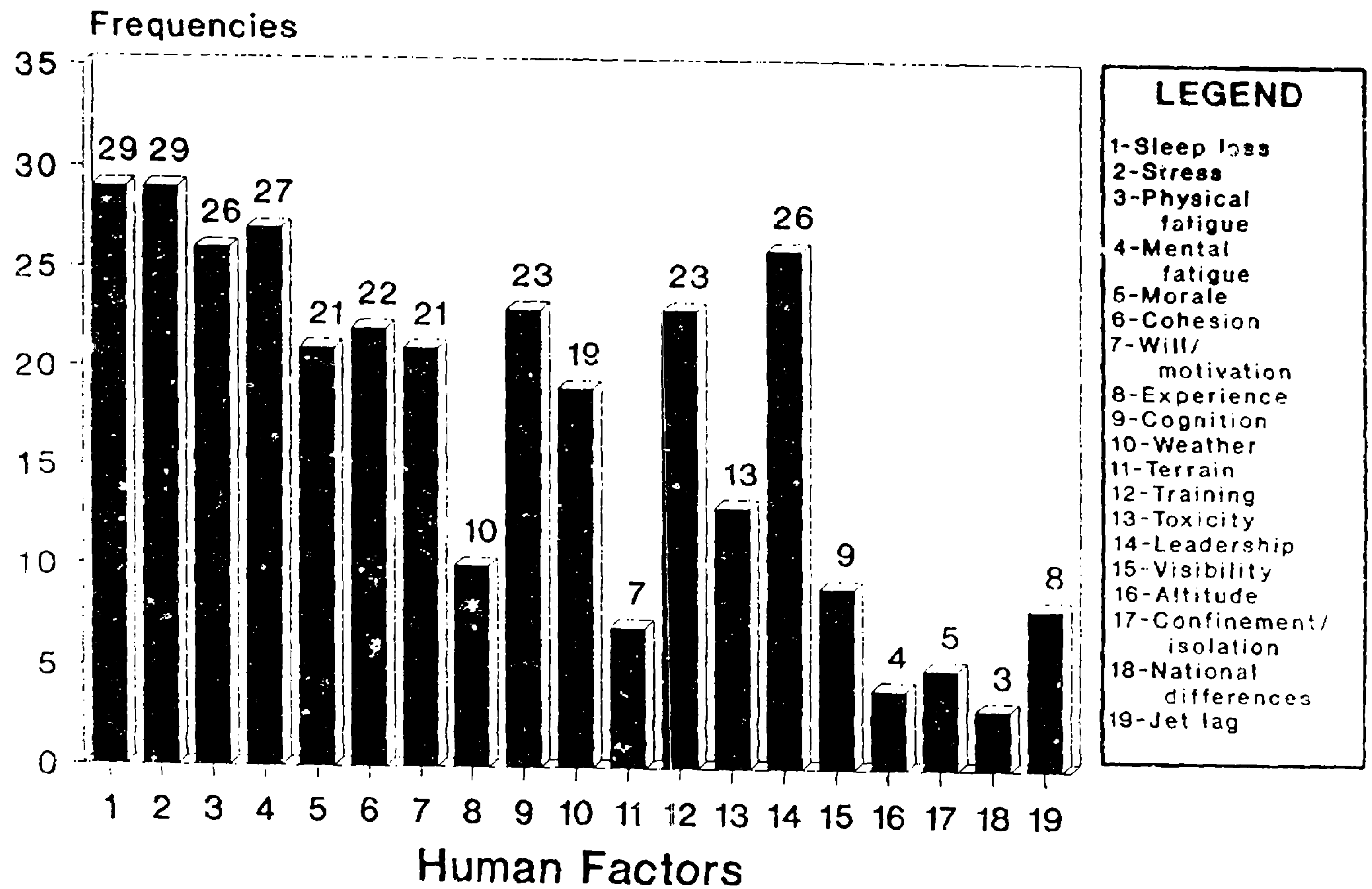

Figure 4-1. FREQUENCIES OF HUMAN FACTORS IN DOD STUDIES

4-2. Essential Element of Analysis #2: How does each dimension identified above affect different types of soldier/unit performance (e.g., decision-making, gross motor performance, fine eye-hand coordination performance, performance on different weapons systems, etc.)? The review of findings in each of the soldier dimension areas are summarized in Figure F-2 in Appendix F.

4-3. Element of Analysis #3: To what extent are soldier dimensions currently portrayed in Army models which predict combat outcomes? We reviewed the Catalog of Simulation Models and Wargames Used for Unit and Leadership Training (January, 1987), the Inventory of TRADOC Models (January, 1988), and visited several organizations that are major users of Army models. Results indicate that only a single model -- JANUS(T) -- showed clearcut evidence of portrayal of soldier dimensions.

a. JANUS(T) is a two-sided, stochastic, ground force model designed for conflict at up to BLUE brigade versus RED division force levels. The model focuses on individual fighting system engagements and assessments with aggregation capability up to company size elements. The JANUS(T) code is event-sequenced, runs in near real time, and uses probabilistic solution techniques. For more information regarding JANUS(T), refer to JANUS(T) Documentation, published by the U.S. Army TRADOC Analysis Center, White Sands Missile Range, New Mexico, 1986.

b. JANUS(T) portrays heat stress and "in" and "not in" a chemical protective environment. Units portrayed as in MOPP by JANUS(T) have more limited ability to move, detect, and fire (US Army TRADOC Analysis Center, White Sands Missile Range, NM, 1986).

4-4. Essential Element of Analysis #4: How can each soldier dimension and each soldier performance area be measured?

a. Resource constraints precluded a comprehensive review of soldier dimensions studies. Nevertheless, Figure F-3 (see Appendix F) provides a cross section of different types of measurement devices, procedures, and scales which have been used to quantify human factors and soldier performance. Descriptions of instruments, procedures, and scales follow each measurement device, along with information regarding reliability and validity. Lack of information following an instrument indicates neither reliability nor validity information was provided by the author(s). Such was the case regarding at least some of the measurements for reliability, and nearly all regarding validity. Unfortunately, the lack of reliability and validity data calls into question whether scales utilized provide consistent, genuine estimates of the human factors and abilities they purport to measure.

b. Human factor measurement procedures ranged from heartbeat rate and percent of maximum oxygen uptake during fatiguing exercise to questionnaires which quantify sleep loss, stress, and leadership skills, among others Because many of the human factors related to individual or personal behaviors, feelings, and experiences, there is little surprise that questionnaires were preponderant in the assessment of these areas. Respondents typically were asked to rate statements regarding intrapsychic phenomena (i.e., tiredness or stressfulness) on a Likert Scale of 1 (very low amount) to 5 (very high amount). Exceptions to this rule were exhibited by more objective measurements utilized in some studies such as reported number of hours of sleep or rest during a specified time period, temperature, and weight in pounds of soldier loads.

c. Soldier performance was typically measured by Skills Qualifications Tests (SQTs), Army Training Evaluation Programs (ARTEPs), weapons qualification, performance on simulation devices, and even questionnaires. Once again, the lack of reported reliability and validity data measurements was almost universal. Although reliability data is typically gathered on SQTs, it was not reported. Lack of validity data for SQTs and ARTEPs is not a major problem: Most SQTs and ARTEPs have face validity in that subject matter expert panels have reviewed and revised procedures until they measure critical skills. On the other hand, validation of simulation outputs is particularly important to verify their relationship with actual performance.

d. Despite the review of several hundred soldier dimensions studies, no examples were found which measured terrain, visibility, suppression/noise, altitude, confinement/isolation, national characteristics, and jet lag. Part of this lack of representation might reflect the fact that the research community feels that these factors are not as significant as others -- at least not at the present stage of soldier dimensions research. Furthermore, some of the factors, including supression/noise, confinement/isolation, and national characteristics are not as easily researched as other areas. Other factors, such as terrain and visibility, are classificatory variables which cannot be measured on a continuous scale. Finally, altitude could be easily measured by feet above sea level. Although numerous Air Force studies regarding altitude have been conducted, coverage of this factor in land-battle application studies appears to be meager.

4-5. <u>Essential Element of Analysis #5: What methodological techniques have been used to establish predictive relationships between soldier dimensions and performance?</u>

a. Table F-4 in Appendix F presents the experimental objectives and statistical methodologies employed in a number of soldier dimension studies. These studies, which relate to the effects that sleep loss, fatigue, cognitive factors, toxicity, cohesion, and motivation have on performance, are representative of the hundreds which were reviewed. "Predictive relationships" in EEA #5 is interpreted as any attempt to ascertain how performance varies with changes in human factors. This broad definition was embraced to ensure the consideration of the wide range of methodological techniques used in soldier dimension studies.

b. Conclusions drawn from the review of research include the following:

(1) Although a few studies employed nonparametric statistical techniques such as Chi Square and the Spearman Rank Correlation, the overwhelming majority used parametric techniques. Parametric techniques used in studies reviewed include the Pearson Product Moment Correlation Coefficient, analysis of variance, the t-test, multiple regression, and factor analysis. All these techniques are explained in Foundations of Behavioral Research (Kerlinger, 1973), and Multiple Regression in Behavioral Research (Kerlinger and Pedhazur, 1973).

(2) The studies generally tried to accomplish one or more of the following:

-Development of a human factor scale - Factor analysis was frequently used for this purpose.

-Determination of how soldier performance is affected by changes or differences in human factor conditions. Analysis of variance and t-tests for independent and related groups were often used.

-Establishment of noncausal, predictive relationships between performance and human factors. Pearson correlations and multiple regression were often used in these studies. Stepwise multiple regression was particularly popular.

(3) Slightly more than half of the studies utilized univariate statistical techniques. The remainder employed multivariate methods. Univariate methods are those which are limited to one independent variable and one dependent variable. Multivariate techniques, on the other hand, are those analytic methods which have more than one independent variable or more than one dependent variable or both (Kerlinger and Pedhazur, 1973). According to this definition, multiple regression and factorial analysis of variance, both of which have two or more independent variables and one or more dependent variables, are multivariate techniques. (Some authorities define multivariate as any analytic method which has two or more dependent variables.)

(4) Multiple regression was the most widely used technique. It was used in approximately 20 percent of the studies. Step-wise multiple regression (see Kerlinger and Pedhazur, 1973) was particularly popular.

(5) None of the studies utilized dependent variables (or outputs) that could serve as inputs to models. Understanding of how much soldier performance degrades as a function of human factors in and of itself is not enough. We also need to have the capability of inputting the adjustments into combat models. In order to do this, the outputs of human factors studies must serve as inputs to models. Unfortunately, relatively few studies have met this standard.

4-6. <u>Essential Element of Analysis #6: What specific actions need to be taken to determine the quantitative interrelationships among soldier dimension and soldier performance variables?</u> This section presents general considerations for soldier dimensions research followed by three separate methodologies which address EEA #6. Three methodologies are provided in the interests of most of the bases regarding soldier dimensions research. More specifically, the section is divided as follows:

a. General considerations for soldier dimensions research.

b. Methodology to be used in simulated environments or when using simulation devices.

c. Methodology to be used for soldier dimensions and performance data previously collected by others.

d. Methodology to be used to draw on the experience of veterans.

Individuals interested in using simulated environments or simulating devices should refer to paragraph b. Researchers who wish to use data collected by others should refer to paragraph c. Those who wish to draw on the experience of combat veterans should refer to paragraph d. Advantages and disadvantages of all these methodological approaches are presented in Figures F-5 to F-8 in Appendix F. Individuals who are contemplating soldier dimensions research should begin by reviewing these charts.

Before we begin, a few words need to be said about the use of subject matter expert (SME) panels for research in this area. Specific approaches utilized with SMEs often include open discussion and the utilization of the "Delphi" technique, which attempts to converge on the "right" answer via successive querying of SMEs. The use of SME panels was not considered in this report because, relative to the other approaches mentioned above, this approach is much more subjective and lacking in the quantitative precision necessary to sort out the simultaneous effects that multiple independent variables have on soldier performance. SME panels can be a source of valuable information for many types of military research; however, this approach is not recommended for soldier dimensions research.

a. General Considerations

(1) Neither this nor any other single study plan will provide answers to all the questions in this area. Quite the contrary; knowledge regarding human factors will become substantiated only as findings are verified or replicated by independent research teams throughout the Department of Defense. Hopefully, this study will shed some light on issues which impact on the problem, and provide direction for future research. If it serves no other purpose than to stimulate discussion--critical or otherwise, which furthers the growth of knowledge in this area--then this study will have been worthwhile.

(2) Any procedural methodology which attempts to quantify the impact that human factors have on performance should take into account the following: In the real world, multiple human factors simultaneously and interactively impinge upon combat performance, which is a product of the orchestration of numerous military tasks at critical times. In view of this complexity, a multivariate study design, which determines the effects that multiple independent variables have on one or more performance variables is more likely to address critical issues than those that have a single independent variable. If all human factors were independent of each other (i.e., were uncorrelated), then the amount of degradation in performance explained by each would be additive. But such is unlikely to be true. For this reason, multivariate methods that adjust degradation accounted for by a single factor, after controlling for all others, is needed. Only methods such as this will provide accurate information regarding the extent to which performance should be adjusted given differing soldier dimension conditions.

(3) Outputs (soldier performance or dependent variable measures) of human factor methodologies should serve as inputs to Army combat models. If outputs of a study cannot be translated into inputs for models, results are unlikely to be used by the modeling community. How can we adjust combat effectiveness in accordance with human factor conditions if we cannot input differential levels of soldier performance into models?

(4) The three different methodologies presented complement each other. Each has advantages and disadvantages (see Figures F-5 to F-8 in Appendix F). Nevertheless, if high quality research is conducted we should see similar patterns

emerge from all three methodologies. Then and only then will we have true understanding how soldier performance varies in accordance with different soldier dimension conditions.

(5) The methodology must spell out how different human factors of different severity levels impact on soldier performance at different time periods in a battle. For example, perhaps during the first 24 hours severe stress is a more salient determinant of soldier performance than very limited amount of sleep. However, by 72 hours, the cumulative effects of the same amount of sleep each night might supersede degradation due to stress. And variation of human factor conditions at different times might further complicate matters. Battle times must be varied to determine differential effects that result from different combinations of human factor conditions at different time intervals into the battle.

(6) The methodology must take into account the different <u>kinds</u> of human factor variables that exist in the real world. Human factors can be categorized in terms of whether their impact on performance is due to changes inside the soldier (endogenous factors, such as sleep loss, stress, and fatigue) or outside the soldier (exogenous factors, such as inclement weather or toxicity), and according to the extent to which each human factor is subject to change over a relatively short period of time (i.e., transitory vs enduring). For example, the impact some human factors have on performance can be altered in short periods of time (e.g., a good night's sleep might significantly alter the influence of several sleepless nights).

(7) Other human factors, such as cognition and national differences, might not be so easily altered. Figure 4-2 (see next page) represents a single model we developed which displays these differing characteristics of human factors. According to Figure 4-2, all human factors can be classified into Endogenous/ Transitory, Endogenous/Enduring, Exogenous/Transitory, and Exogenous/Enduring. Please note that this model is presented for purposes of discussion and as a tentative way to classify soldier dimensions until the model can be validated. The model would be validated if these four factors emerge from factor analysis results. Otherwise, the model should be revised and/or discarded in view of factor analysis findings. More information regarding the validation of this model is presented later in this Chapter.

(8) Human factors and performance data should be collected at 8 hour intervals to determine the effects of time and changes in human factor conditions on performance. Eight hour intervals are used because this time period is sufficiently short to be sensitive to changes in soldier performance and yet long enough so as to not overly burden soldiers with data collection procedures. Endogenous/enduring human factors such as cognition will probably not require daily reassessment like endogenous/transitory factors, such as sleep loss and fatigue, because they are not expected to change over a few days.

CHANGEABILITY

SOURCE	TRANSITORY	ENDURING
ENDOGENOUS	SLEEP LOSS MENTAL FATIGUE PHYSICAL FATIGUE STRESS CONFINEMENT/ISOLATION JET LAG MORALE COHESION WILL/MOTIVATION COMBAT EXPERIENCE TRAINING LEADERSHIP QUALITY	COGNITIVE FACTORS NATIONAL DIFFERENCES
EXOGENOUS	WEATHER CONDITIONS VISIBILITY ALTITUDE	TOXICITY • TERRAIN • ENDURANCE VARIES WITH KIND OF CONTAMINANT

Figure 4-2. A HUMAN FACTORS MODEL

(9) One of the major analytic techniques which is mentioned time and time again for all methodological approaches is stepwise multiple regression. This approach is reasonable because it provides answers to the major soldier dimensions research questions. A stepwise multiple regression procedure tells:

-Which human factors collectively are most predictive of soldier performance?

-What are the relative weights, or importance, of the predictors in explaining performance? (Which does the best job, second best job, etc?)

-Which human factors are relatively unimportant in predicting performance?

-How will future soldiers perform given differing human factor conditions? This information would be provided by the predictive equation which is a by product of multiple regression. Further elaboration on this point is presented later in this Chapter.)

b. Methodology to be used in simulated environments or when using simulation devices.

(1) This methodology would be appropriate to use in simulated combat environments, such as the National Training Center at Fort Irwin and with simulated combat systems, such as the Simulation Networking (SIMNET) system at Fort Knox. For purposes of illustration, the SIMNET system, which simulates tank crew operations, is used. Data could be collected on at least nine of the soldier dimensions mentioned elswhere in this report. These include sleep loss, fatigue, stress/anxiety, morale, cohesion, motivation/will, previous experience, cognition (if Armed Forces Vocational Aptitude Battery (ASVAB) scores are available), and quality of leadership. Figure F-9 (see Appendix F) provides information regarding how information should be collected on each variable. [For further information about SIMNET, contact the SIMNET Program Office, Perceptronics, Inc., 21135 Erwin Street, Woodland Hills, CA 91367.]

(2) Crews should be assigned to random sleep schedules of from 0 to 8 hours of sleep for each 24-hour period. Likewise, crews should be randomly assigned to continuous work schedules which comprise 60 to 100 per cent of the time they are awake. "Continuous work" will consist of crew performance of duties in the SIMNET tank. The total experiment would last 3 full days and nights--a total of 72 hours. Randomly generated numbers from a simple BASIC program using the RND command could be used. Whatever schedule is randomly determined for each crew should be maintained throughout the 72 hours of the experiment. For example, the crew which is

assigned two hourswill be on continuous duty for all but two hours for each 24-hour period for the duration of the experiment. This means only two hours of sleep per night.

(3) Data on sleep loss, fatigue, stress/anxiety, morale, cohesion, motivation/will, and quality of leadership should be collected at eight-hour intervals in accordance with Figure 4-3 (see next page), the Data Collection Schedule. Previous experience and cognition need to be collected only once at the onset of the research project because these variables are unlikely to change over short time periods.

(4) Data on crew performance, such as average target acquisition time for each 8-hour time period, should be collected along with soldier dimension variables during a baseline 8-hour period of time and at 8-hour intervals throughout the remainder of the experiment (see Figure 4-3). This measure of performance--target acquisition time--is used for purposes of illustration only. In actuality, the researcher should always ensure that the soldier performance which is an output of the soldier dimension study should serve as an input which would make a real difference in the combat model to be used. Also, researchers should try to ensure that all tank crews are provided relatively similar scenarios which control for number of enemy tank exposures across crews to the greatest possible extent.

(5) Familiarization with SIMNET and opportunities to practice with SIMNET should be provided prior to the baseline period. Ideally, at least 200 crews should be used in view of the analytic techniques to be used. Nevertheless, 60 or even 25 to 30 would work, although less confidence could be placed on results with the smaller number of crews.

(6) Determination of which soldier dimensions are most important determinants of soldier performance is provided by a stepwise multiple regression procedure: This procedure would determine the quantitative relationship between the different soldier dimensions and performance. A comprehensive description of this technique is provided in F.N. Kerlinger's Multiple Regression in Behavioral Research (see Kerlinger and Pedhazur (1973) in references at Appendix E). The primary reason stepwise multiple regression is recommended is because it provides answers to the questions posed by this project. No other methodology addresses these questions as well as stepwise multiple regression. This procedure will determine:

-Which combination (linear composite) of human factor variables collectively and simultaneously do the best job of predicting estimated combat performance? Conversely, which soldier dimension variables are not needed (add nothing unique above and beyond the linear composite) for the prediction of soldier performance?

DAY ONE				
TIME OF DAY	0700 1600*	1600 2300	2300 0700	0700 1600
TIME PASSAGE	0 HRS	8 HRS	16 HRS	24 HRS
DATA COLLECTION	1ST*	2ND	3RD	4TH

DAYS TWO & THREE				
TIME OF DAY	1600 2300	2300 0700	0700 1600	1600 2300
TIME PASSAGE	32 HRS	40 HRS	48 HRS	56 HRS
DATA COLLECTION	5TH	6TH	7TH	8TH

DAY THREE (CONTINUED)		
TIME OF DAY	2300 0700	0700 1600
TIME PASSAGE	54 HRS	72 HRS
DATA COLLECTION	9TH	10TH

FIGURE 4-3. DATA COLLECTION SCHEDULE

* BASELINE

-What is the magnitude of the relationship between the soldier dimensions and soldier performance? This information determines the strength of the relationship--whether it is mild, moderate, or strong.

-Which soldier dimension variable does the best job, second best job, etc., of predicting soldier performance? This information is provided by the stepwise entry of the different predictor variables into the multiple regression equation (see Kerlinger, 1973).

-How will future soldier perform given different combinations of human factor conditions? Performance estimates can be made from the regression equation that is produced by the multiple regression analysis. These estimates should increase or decrease in accordance with the different values assigned to different soldier dimension conditions. The answer to this question provides the answer to EEA# 7 which is considered later in this report.

(7) Please note that the importance of soldier dimensions in predicting performance might vary with the amount of time on the simulated battlefield. For example, cohesion and morale might be relatively more important predictors of soldier performance during the first 24 hours than after 48 hours on the simulated battlefield. For this reason, separate stepwise multiple regression analyses must be performed on data collected at each 8 hour interval.

(8) A few cautionary notes are needed regarding the use of multiple regression. Problems regarding its use can occur if relationships between individual predictors and soldier performance are not linear, in which case step-wise curvilinear regression might be used (see Kerlinger, 1973). The researcher should be on the lookout for situations when multiple regression residuals might not be normally distributed (see Norusis, 1986), when data is skewed (data can be transformed to achieve normality), and multicollinearity.

(a) Multicollinearity refers to situations in which some or all of the predictor variables are <u>very highly</u> intercorrelated. "Very highly" is emphasized because in most regression analysis applications some or all of the predictor variables will be correlated. As a matter of fact, intercorrelation of predictor variables is one of the reasons multiple regression was developed as a technique. However, extreme intercorrelation can result in inability of the computer program to calculate the multiple R and reduced reliability of regression coefficients.

(b) Multicollinearity does not render regression analysis ineffectual. Ways to counteract this problem include elimination of one of the problem predictor variables or combining both into a single variable (as in factor analysis).

(c) Please note: An alternate non-stepwise procedure could be used, which would determine the predictive relationship between all soldier dimensions (considered simultaneously) and soldier performance. However, the inclusion of a large number of predictor variables is seldom a good strategy. Irrelevant variables often increase the standard error of estimate without improving prediction. In selecting variables to be included in a regression model, the goal is to build a concise model that predicts reasonably well (Norusis, 1988). Stepwise regression eliminates unimportant predictors. For this reason, we recommend the stepwise alternative.

c. Methodology to be used for human factors and soldier performance data previously collected by others.

(1) Analysis of data collected by others might seem appealing in that the actual study will have been conducted--leaving only the analysis of data and interpretation of results. Nevertheless, good soldier dimensions data is hard to come by. And even if the data is obtained, the likelihood of data on specific needed variables being collected in a usable format is slim. For example, will data be collected on a soldier performance variable that serves as an input to models which predict combat outcomes?

(2) The most useful data collected by others would all be on equal interval, continuous scales. In other words, all data would have scales with scores like what appears in Figure F-13. Such data can be used to provide answers to Essential Element of Analysis #6 using stepwise multiple regression procedures as demonstrated in the previous section. This data is much more useful than data that is classified into high/medium/low, or some other classification scheme. Equal interval, continuous data like the examples in Figure F-13 have the requisite precision for the formulation of predictive algorythms, in addition to determination of which soldier dimensions are most significant predictors of soldier performance. In contrast, classificatory data can only provide the latter.

(3) Figure F-14 in Appendix F shows how classificatory data can be graphed, and Figure F-15 shows how factorial analysis of variance can be used to determine which of several soldier dimension factors seem to be most highly related to soldier performance. F-16 provides models which compare changes in performance across different levels of sleep/fatigue and time in hours of the battle.

d. Methodology to be used to draw on the experience of veterans. This section is subdivided into Phase I, which determines which human factors are most important determinants of soldier performance, and Phase II, which identifies the predictive relationship between and among multiple human factors and soldier performance.

(1) Phase I

(a) The Phase I Human Factors Survey (see Appendix B) was developed to determine the relative importance of various human factors in relation to soldier performance. The instrument portrays most types of human factor/ soldier dimension variables identified in the human factors model (Figure 4-2). Variables include human factors that are endogenous/transitory, endogenous/enduring, exogenous/transitory, and exogenous/enduring are presented with variable frequency (low, medium, and high) and duration (two to six days). Time duration was omitted for enduring human factors.

(b) The reliability of the Phase I instrument (see Appendix B) needs to be determined using Kuder-Richardson Formula 21 (r_{KR21}; Stanley and Hopkins, 1972):

$$r_{KR21} = (ks^2 - M(k-M)/(k-1)s^2,$$

where M = the survey mean,
s^2 = the survey variance, and
k = the number of items on the survey.

(c) The survey utilizes a magnitude scaling format which, if properly utilized, often results in much greater precision of measurement of subjective opinion than other types of scales. Respondents are requested to provide numerical estimations to lines of different lengths (Part 1) to familiarize them with the response format. This technique facilitates the elicitation of proportional responses when respondents are asked to make judgements regarding soldier performance (Part 2). The extent to which proportional responses are made can be documented by the correlation of actual and estimated line lengths (in millimeters) from Part 1 results. (Additional explanation is provided below.)

(d) The sample instrument asks respondents to make judgements regarding how much "time to lay" (get enemy target in gun sights following identification) varies with different human factor conditions, during continuous battlefield operations, in comparison with performance of the average soldier under ideal conditions.

(e) "Lay time" for the 25mm cannon on the Bradley Fighting Vehicle is recommended as a dependent variable because this is an input to JANUS(T) (and other models) which, if significantly altered, will result in differences in combat effectiveness outputs. This situation was used also because the 25mm cannon engages a wide variety of targets and provides a situation with which most veterans could identify.

(f) Please note that other dependent variables and scenarios could have been used with other models. For example, the amount of time to identify the the enemy target, time to prepare weapon for firing, time to acquire target with a variety of weapons, and time to kill (or probability of killing) the enemy target are a variety of dependent soldier performance measures that could be used in human factor methodologies. Perhaps even an entire series of multiple, additive dependent variables could be used that sum up to the required time to the entire sequence needed to identify, prepare, acquire, and kill the enemy target. These are the types of inputs that are needed for models. The important point to remember is that soldier performance variables must be "modelable." Once again, what difference does it make to know that certain human factors result in degradation in soldier performance, if there is no way to input that degraded performance into the combat model?

(g) A middle-level intensity scenario is used because most models operate at this level.

(h) A pilot sample of Vietnam veterans with combat specialties should be selected utilizing random selection procedures. Subjects will be stratified within enlisted and officer categories based on the highest rank held while in Vietnam. Random selection from the population of active Army members will systematically control different respondent variables that might influence results. Survey results will be solicited by mail. Sample size requirements for both categories will be determined by use of the following formula which determines sample sizes (n) for estimating population means within a specified confidence interval (McClave and Dietrich, 1985, p. 318).

$$n = (Z^2_{alpha/2}\ S^2)/B^2$$

where Z is the standard score for half the alpha level decided upon,

S is a "best guess" of the population standard deviation, and

B is the margin of acceptable error (for example, .05).

(i) Analysis of Phase I results should consist of the following:

1 Magnitude estimation methodology (Lodge, 1981) should be used to determine which individual items are

most highly related to changes in soldier performance. Data analysis is performed by conversion of responses to common logs, calculation of arithmetic mean of the common logs for each item, and conversion of these arithmetic means to geometric means, the measure of central tendency for magnitude estimation. Comparison of geometric means will determine which items are most highly related to changes in performance. Magnitude estimation should be used because this procedure often establishes a ratio scale which has more precision and power than categorical scales, and paves the way for use of advanced parametric statistical techniques. Such scales have been validated (shown to be a ratio scale with equal intervals) via the correlation of actual line lengths drawn by subjects and their numeric estimates of line lengths. (See Lodge, 1981.) This procedure should be conducted with numeric estimations and actual line lengths from Part 1 of the survey to provide evidence that the scale elicits genuinely proportional judgments.

2 Factorial analysis of variance should be used to determine how estimated soldier performance varies as a function of type of human factors, frequency and duration of each factor. The three-way analysis model (Figure 4-4 on next page) will provide information regarding the relative effects of each human factor on estimated soldier performance, as well as the effects of possible interactions between/among type of factor, frequency, and duration. The Scheffe post hoc procedure will be used to pinpoint differences between/among different contrasts following the finding of overall statistical significance for interactions (rows x columns, rows x slices, columns x slices, and rows x columns x slices), and main effects (comparisons of rows). (See Kerlinger and Pedhazur, 1973, for a description of the Scheffe technique.)

3 Separate discriminant analysis procedures should be used to determine whether estimated soldier performances for all items vary as a function of rank and MOS of respondent. In general, discriminant analysis is used to determine whether a classicificatory variable (i.e., rank) can be predicted from multiple variables with continuous scale data (i.e., estimated soldier performance for all questionnaire items). Discriminant analysis is similar to multiple regression, except that the variable being predicted is classificatory. For our purposes discriminant analysis will provide an answer to the following question:

Does a statistically significant, predictive relationship exist between soldier performance estimates of the multiple questionnaire items and rank of respondents?

If the answer to this question is "no," then we know that soldiers of different ranks and MOS are likely to provide similar soldier performance estimates. This knowledge would indicate that soldier performance estimate data for all ranks should be pooled into a single sample for subsequent data

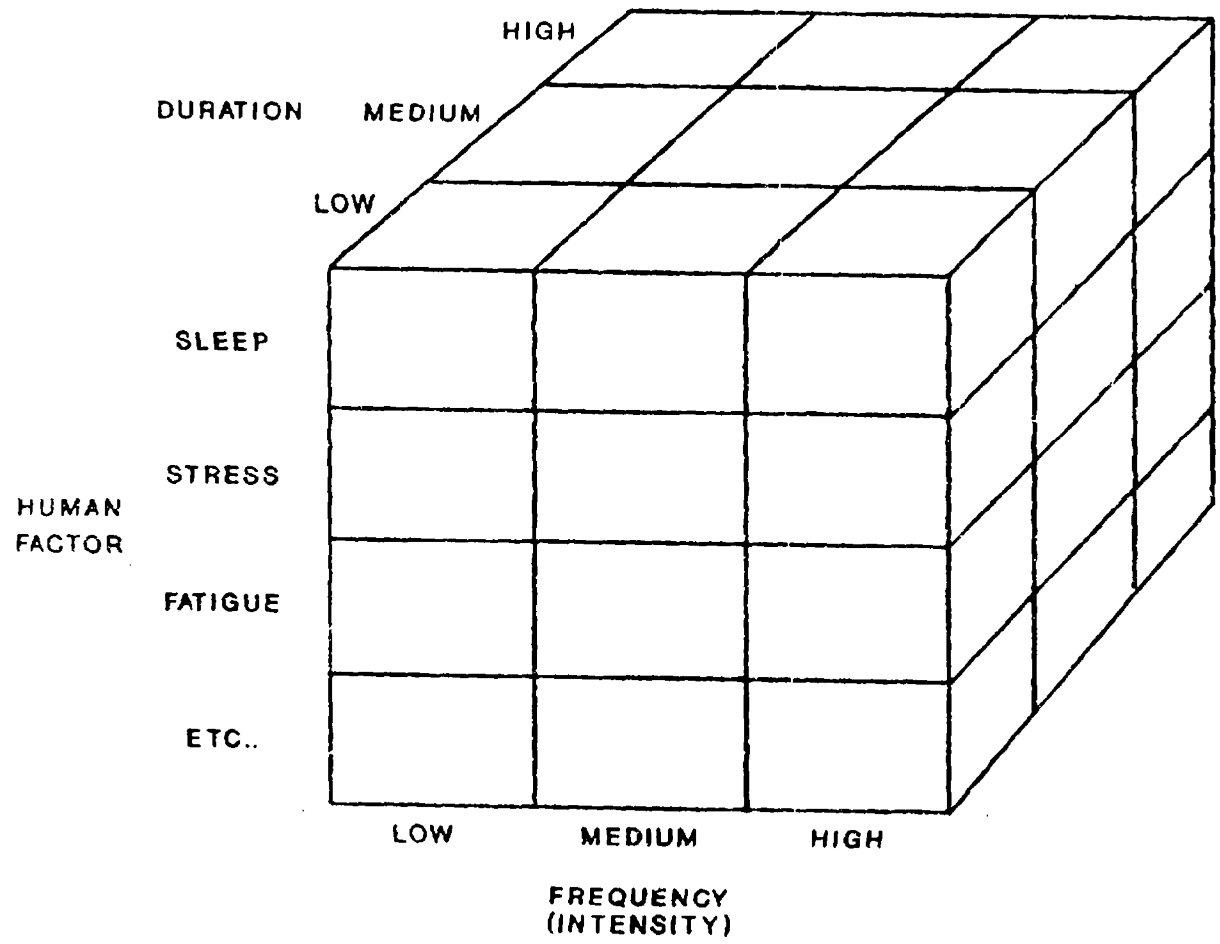

Figure 4-4. ANOVA MODEL FOR ANALYSIS OF ESTIMATED SOLDIER PERFORMANCE AS A FUNCTION OF FREQUENCY, DURATION, AND TYPE OF HUMAN FACTOR

analysis. If the answer is "yes," further research is needed to determine the reason for different estimates across various ranks and MOS.

4 The researcher should also use the Pearson Product Moment Correlation to determine if relationships are found between soldier performance estimates and age and experience of respondents. Once again, significant relationships should be researched to determine why performance estimates vary across these variables.

5 Factor analysis should be used to determine which items intercorrelate into factors which explain the greatest amount of variance in estimated soldier performance. Factor analysis is a procedure which reduces a large number of variables into a few groups of clustered, interrelated items or factors. Factors which emerge frequently identify underlying major characteristics of data patterns which are not directly observable. These underlying patterns can be given names which clarity, describe, and define the relationship they might have with each other and other variables.

When factor analysis is conducted, a principal components analysis could be used to derive orthogonal or uncorrelated linear combinations of observed variables. Varimax rotation should be used to minimize the number of variables that have high loadings on a factor. This should enhance interpretability. Finally, factor scores should be computed for all factors which explain significant proportions of variability in soldier performance estimations. Descriptions of all these procedures are available in Advanced Statistics SPSS/PC+ for the IBM PC/XT/AT (Norusis, 1986) or any text on advanced statistical analysis techniques.

6 In conclusion, magnitude estimation, factorial analysis of variance, and factor analysis are complementary procedures which could be used to determine which variables are to be used in Phase II. The final determination is more of an artistic, than a scientific, endeaver. The researcher must select no more than six soldier dimensions for the next phase. The researcher should look across results of the three techniques and choose those which have significant relationships with performance on two or more techniques. For example, if sleep loss and fatigue load highly on a factor which explains a considerable amount of performance variance, and if they both have high geometric means on magnitude estimation results, then they both should be considered for use in the next phase. Soldier demensions which look particularly strong on only one of the methodologies should be used as a last resort.

7 In a very real sense, Phase I results will serve to provide construct validity for the survey instrument used in the next phase. Construct validity is proof

that a survey or test is measuring a particular construct. Constructs are variables that have evolved from theory or observation. For purposes of illustration, factor analysis results might suggest that soldier performance scores for sleep loss, physical fatigue, and mental fatigue cluster together into a factor (or construct) we might wish to call Battle Weariness. Factor analysis results not only determine which factors or constructs are being measured by the questionnaire. The factor loadings also would provide analytical evidence that the questionnaire is a valid measurement of a factor or construct we choose to call Battle Weariness. Others might disagree with the name we assign to the attribute, but they cannot dispute the existence of the factor itself.

8 While factor analysis will tell us what constructs the questionnaire is measuring, magnitude estimation and factorial analysis of variance will tell which individual human factor variables do the best initial job of predicting soldier performance. Phase I reduces the number of human factors to the few that seem to do the best job of explaining soldier performance. These few are then further investigated in Phase II. Final selection of human factors for Phase II should be determined by consideration of which are most important determinants of soldier performance both collectively in factor analysis results and individually in magnitude estimation and factorial analysis of variance results.

(2) Phase II. Phase I showed how to use survey data from veterans to determine which soldier dimensions are most highly related to changes in soldier performance. Phase II demonstrates how to use survey data from veterans to establish a predictive relationship between and among multiple human factors and soldier performance.

(a) An example of a survey which could be used to obtain necessary data for Part II is in Appendix C. This survey is similar to the one used in Phase I in that it has the same scenario, an introductory exercise which requires both numerical estimates of line lengths, and requires estimates regarding combat effectiveness defined as "lay time" using the 25mm cannon on the Bradley Fighting Vehicle. However, the Phase II survey is different from the other in that it solicits single soldier performance responses to multiple human factor conditions in existence for different time periods. A total of 100 items are used - ten items are presented for each of 1 to ten days into battlefield operations defined by six values assigned to different human factors. The six factors used will be determined by Phase I results. The investigator should assign values to the six factors based on numbers generated by a random number program. The assignment of random number values to human factors will ensure an unbiased range of data for each human factor. Nevertheless, restrictions should be imposed to ensure that values of different human factors are within conditions anticipated on future battlefields.

(b) A limit of six human factors was maintained in light of previous findings that individuals can mentally process only about seven bits (plus or minus two) of information at one time (Miller, 1956; cited in De Cecco, page 354). Six is used because, being within the lower range of seven plus or minus two, this number should not overtax respondents with more information than can be effectively processed.

(c) The number of respondents required for the Phase II survey should be determined by the formula used for the same purpose in Phase I. The respondents should consist of a randomly selected group of active Army soldiers stratified within enlisted and officer classifications.

(d) Analysis of Phase II results should consist of the following:

1 Internal validity of the scale should be determined using the same magnitude estimation procedures used in Phase I: That is, numeric estimates of line lengths and actual line lengths from Part 1 of the survey should be correlated to provide evidence that the scale elicits genuinely proportionate judgments.

2 Data should be computerized as deviations from the reference lay time mean. Because soldier respondents are asked to make estimates in comparison to a standard on the Phase II survey, some of the deviations will be negative numbers. If negative numbers are not desired, the deviations can be transferred to standard T scores, which eliminate negative numbers, using the formula

$$T=50+10Z, \text{ where } Z=\frac{\text{raw score} - \text{mean}}{\text{standard deviation}}.$$

T scores have a mean of 50 and a standard deviation of ten (Stanley and Hopkins, 1972).

3 The reliability of the Phase II survey should be determined. Reliability provides an estimate regarding how consistently the instrument is measuring whatever it measures. In this application we are concerned with test-retest reliability, or reliability over two different administrations. Test-retest reliability provides an estimate regarding whether soldiers would provide similar responses if they took the same survey two different times. Test-retest reliability should be determined by administering approximately ten randomly selected items from the Phase II survey to a minimum of approximately 30 soldiers twice with an intervening period of two to three months. (The two surveys must be identical in all respects--including the values assigned to each soldier dimension factor.) This time period is selected because it is sufficiently long that soldiers will forget initial responses to

specific items but not long enough to alter survey responses as a result of new soldier experiences following the first session. Following this data col`ection, a Pearson Product Moment Correlation Coefficient should be calculated between the pairs of first and second responses for all soldiers for each of the ten items. Ten correlation coefficients should be calculated in all. The ten coefficients should provide an indication of how stable estimates of soldier performance are over twc separate administration.

4 All human factors data should be regressed against soldier performance estimations using a stepwise multiple regression procedure. This procedure will determine the following:

-Which combination (linear composite) of human factor variables collectively and simultaneously do the best job of predicting estimated soldier combat effectiveness? Conversely, which human factor variables are not needed (add nothing unique above and beyond the linear composite) for the prediction of estimated soldier performance?

-What is the magnitude of the relationship between the human factors and estimated soldier performance? (The answer to this question is obtained by squaring the multiple R, which provides an indication of the percentage of the variance in soldier performance that is explained by the human factors in the regression equation.)

-Which variable does the best job, second best job, etc., of predicting estimated combat effectiveness?

-How will future soldiers perform given different combinations of human factor conditions? Performance estimates can be made from the regression equation that results from the multiple regression analysis. These performance estimates should adjust or degrade soldier performance in view of the different human factor conditions on the battlefield.

5 Please note: An alternate non-stepwise (full regression model) procedure could be used, which would determine the predictive relationship between all human factors (considered simultaneously) and soldier performance. However, the inclusion of a large number of predictor variables is seldom a good strategy. Irrelevant variables often increase the standard error of estimate without improving prediction. In selecting variables to be included in a regression model, the goal is to build a concise model that predicts reasonably well (Norusis, 1988). Stepwise regression eliminates unimportant predictors. For this reason, we recommend the stepwise alternative.

6 A. mentioned earlier, the primary reason stepwise multiple regression is recommended is because it

provides answers to the questions posed by this project. No other methodology addresses these questions as well as stepwise multiple regression. Nevertheless, the researcher is urged to consider the cautionary notes about multiple regression mentioned earlier in this Chapter.

4-7. <u>Essential Element of Analysis # 7: What specific actions need to be taken to develop a technique for quantitatively inputting soldier dimension variable information into existing computer models so that unit performance can be realistically adjusted in view of variable conditions?</u> This section is divided into procedures to be used for simulations and previously-collected data methodologies, on the one hand, and for the survey of veterans, on the other.

a. Procedures to be used for simulations and previously-collected data.

(1) The reader will recall that stepwise multiple regression can be used for all three methodologies presented in the last section. For this reason, the same general approach can be used to adjust soldier performance in accordance with differing soldier dimension conditions for all three methodologies presented in section 6. Nevertheless, specific comments for the survey of veterans methodology are presented in paragraph b below.

(2) The key to addressing EEA # 7 lies with the employment of multiple regression statistical analysis which adjusts or degrades the dependent variable that serves as an input to one or more combat models. The multiple regression technique which we have been discussing does this quite nicely. The formula for the regression equation used for this calculation follows (Kerlinger and Pedhazur, 1973):

$Y' = a + b1X_1 + b2X_2 + \ldots bkXk$ where

Y' = Predicted or adjusted estimated soldier performance.

b1, b2, ...bk = Regression coefficients associated with human factors 1 through k.

$X_1, X_2, \ldots X_2$ = Values for different human factor predictors.

a = an intercept constant

(3) Please note that this equation should permit us to determine the impact that various combinations of changes in different human factor values have on estimated soldier performance. But how is this information inputted into models which predict combat outcomes? The procedure could be simple. For both the simulations and previous data collection

methodologies simply substitute the raw score values into the above equation, multiply each against its respective regression coefficient weight (determined by most multiple regression software), add the products to a constant (also determined by most regression software), and you have a predicted soldier performance score. This predicted soldier performance score, which is adjusted up or down according to the particular combination of soldier dimensions values which are inputted into the equation. In essence, the regression equation permits future predictions regarding performance to be made based on past results (i.e., data gathered during simulated combat or human factors and performance data gathered from a previous study).

(4) How do we input this information into computer models so that soldier performance can be adjusted in view of different soldier dimension conditions (e.g., an average of 20 hours of work and 1.5 hours of sleep per day)? Please recall that, regardless of which methodology is used, the authors have urged researchers to use soldier performance measures that can be inputted into one or more combat models. The reason for this condition is so that predicted soldier performance adjustments from the regression equation above can be inputted directly into a model.

(5) Please note that the researcher can determine the effects that numerous different combinations of soldier dimension conditions have on combat outputs by simply substituting different soldier dimension values into the regression equation above and inputting the result into a model. Comparison of the model outputs will show the effects that different combinations of soldier dimension values have on combat outcomes. While some combinations might result in minimal changes, other soldier dimension values might result in major changes in combat outcomes. Furthermore, the comparison of combat outcomes with and without "adjusted" performance inputs will tell the difference that soldier dimension conditions make in combat outcomes.

(6) Once the data analysis is completed, the calculation of adjusted performance is easy and inputs are entered in the combat model, much the same as they are now. (The only difference being that inputs will be adjusted in view of changes made by the regression equation.) This methodology can be done without any major changes in the computer model! This advantage should have particular appeal to individuals who believe that soldier dimensions have little impact on combat outcomes. This methodology permits this hypothesis to be tested for a variety of combinations of human factor conditions.

(7) Please note that performance levels can be adjusted using the same procedure for both Blue and Red troops. Just input the different soldier dimension values into similar

predictive regression equations--one for Blues and one for Reds--and input the adjusted performance values into the Blue and Red model inputs, respectively. The assumption here is that soldier dimensions should affect Reds the same as Blues--so the same predictive regression equation is used for both. But different soldier dimension values (e.g., 2 hours of sleep per day for Blues versus 8 hours for Reds) should be used to reflect the different constraints under which the two forces must fight. And different soldier dimension values should result in differential adjustment of soldier performance for Blues and Reds, which should translate into different performance for each when they are inputted into a combat model. However, the researcher should also understand that differences between Red and Blue tactics, strengths, and doctrine will interact with soldier performance in such a way as to bring about different battle outcomes.

b. Procedures to be used for the survey of veterans methodology.

(1) The procedure is very simple: Determine the extent of change in predicted soldier performance (from the reference standard on the survey), and input this percentage of increase or decrease into combat models. If "lay time" is used as the soldier performance to be predicted, first determine how a particular combination of human factor values affect lay time. If one combination resulted in a 0 per cent increase in lay time, then no changes should be made in the lay time inputs of a combat model. But if another combination determined a twenty percent increase in lay time, then this percentage of increase should be inputted in the model, so the changes (if any) in combat outcomes can be observed.

(2) More specifically, suppose a certain combination of human factor values resulted in a predicted soldier performance of 3 seconds, which is 0 seconds from the standard of 3 seconds. (3 - 3 = 0.) Recall that all raw scores should be computed as deviations from the given reference mean "lay time" of 3 seconds, and transformed to standard T scores (T=50+10Z) with a mean of 50 and a standard deviation of 10. If this transformation is made, a predicted soldier performance score of 0 (from the regression equation above) would result in a transformed performance score of 50. (50 + 10(0) = 50.) A transformed soldier performance predicted value of 50 indicates no degradation as a result of the combination of human factor values which were in effect. In this case, lay time inputs to combat models which predict outcomes would not be varied at all, because no degradation occurred.

(3) On the other hand, if another set of human factor values resulted in a different transformed T score of 60, this transformed predictive value indicates a 20 percent degradation or increase in "lay time" as a result of a certain combination

of human factors values. (60 - 50 = 10; 10/50 = .20 or 20 per cent.) This percentage of increase should be inputted into JANUS or other combat models by simply increasing the "lay time" inputs for the 25mm cannon on the Bradley by 20 percent. The effects on combat effectiveness indicators could then be reviewed by perusal of appropriate model outputs.

(4) In similar fashion, modelers could experiment with numerous combinations of different human factor values to determine the extent to which percentages of change in estimated soldier performance associated with each impact on combat model outcomes. Furthermore, the comparison of model outcomes with and without human factor information could provide valuable information regarding relative impact of soldier dimension information on soldier performance.

(5) Once again, the same predictive regression equation can be used with different soldier dimension values to determine adjusted soldier performance levels for Reds and Blues. Different value inputs into the equation will result in differential outputs which are then inputted into the combat model.

4-8. <u>Summary.</u> We have reviewed previous research in the soldier dimension area and the extent to which soldier dimensions are portrayed in Army models. We identified specific techniques for determining which soldier dimensions are most significant predictors of soldier performance using three different methodologies including data gathered in simulated combat, previously collected data, and surveys of combat veterans. We provided instructions for how to use the regression equation to obtain adjusted soldier performance levels in view of different combinations of soldier dimensions values for all three methodologies. Finally, we provided instructions regarding how to input adjusted performance levels into models to determine the effects that different combinations of soldier dimensions conditions have on combat outcomes.

4-9. <u>Which method is best?</u> In closing, different reviewers will probably disagree as to which methodology is the best to use. As we indicated earlier, each methodology has specific advantages and disadvantages. Which is chosen will probably be a function of what is feasible rather than which is the best. Nevertheless, each methodology has at least some merits, and for this reason, we view them as complementary procedures which should provide relatively consistent results. For this reason, the researcher might wish to validate the results of one type of methodology by using another--particularly if the other one has been validated. For example, survey results could be validated against data gathered in a simulated combat setting. We will never truly understand the way soldier performance varies as a function of soldier dimensions until we start getting relatively similar answers from different methodologies.

CHAPTER 5

CONCLUSIONS

5-1. The purpose of this report is to review research and to recommend an action plan which provides alternative techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions. This action plan is presented in Chapter 4 and summarized in Chapter 6. Major conclusions which led up to the formulation of this plan are presented in this Chapter.

5-2. If soldier performance is degraded by the need for continuous combat for lengthy periods of time, then models which predict combat outcomes should adjust outputs in view of anticipated degradation. Unfortunately, very few models presently portray human factors.

5-3. A total of 19 different soldier dimensions (human factors) were identified as possibly having a relationship with soldier performance during continuous operations. The human factors are sleep loss, stress, physical fatigue, mental fatigue, morale, cohesion, will/motivation, experience, cognition, weather, terrain, training, toxicity, leadership, visibility, altitude, confinement/isolation, national differences, and jet lag.

5-4. Human factors most frequently cited in articles and reports regarding sustained and continuous operations include sleep loss, stress, physical and mental fatigue, leadership, training, cognition, cohesion, morale, and will/motivation.

5-5. Results of studies indicate:

a. Soldiers become militarily ineffective after only 48 to 72 hours with no sleep.

b. A degradation of 75 percent in performance on most tasks occurs after 72 hours of work with no sleep.

c. Cognitive abilities begin to degrade as soon as 18 hours into sustained operations.

d. Physical performance and well-practiced, routine motor tasks degrade less rapidly than those that require alertness, concentration, reasoning, decision-making, and leadership abilities.

e. Stress is likely to significantly impede the combat effectiveness of some soldiers; stress casualties are expected to be as high as 1:4 to 1:3 in comparison to WIAs.

g. Relatively high levels of cohesiveness, morale, and will/motivation reduce stress casualties and partially offset degradation due to other human factors such as sleep loss and fatigue.

h. If all other factors remain equal, soldiers with better leadership, superior training, and higher mental aptitude perform better on the battlefield.

i. Extremes in heat, rough terrain, and high altitudes cause fatigue which degrades performance; and cold weather impedes manual dexterity required in operation of equipment.

j. Poor visibility caused by fog, weather conditions, or smoke reduces battlefield performance.

k. Performance in MOPP gear is degraded due to the heat-containing and bulky nature of the suit and gloves. Performance accuracy in MOPP gear is often maintained at the expense of speed.

l. Numerous scales are available for the measurement of human factors and soldier performance. Human factors measurements ranged from heartbeat rate, temperature in degrees Fahrenheit, and maximum of oxygen uptake during exercise to number of hours of sleep during a time period and Likert-scale questionnaires which rated tiredness or stressfulness. Soldier performance was typically measured by Skills Qualifications Tests, Army Training Evaluation Program results, weapons qualification, performance on simulation devices, and even questionnaires. Lack of reported reliability and validity was a problem for both human factor and soldier performance measurements.

5-6. The majority of studies which attempted to predict performance from human factors used parametric techniques. More than half were univariate--the rest were multivariate. Multiple regression was particularly popular. Unfortunately, none of the studies reviewed utilized dependent variables (outputs) that could serve as inputs to models: This finding severely limits the applicability of results for use by the modeling community.

CHAPTER 6

RECOMMENDATIONS

6-1. General recommendations. Neither this nor any other single study will provide answers to all the questions in the human factors area. Quite the contrary, knowledge regarding human factors will become substantiated only as findings are verified or replicated by independent research teams throughout the Department of Defense. Hopefully, this study sheds some light on issues and provides direction for future research: If it serves no other purpose than to stimulate discussion--critical or otherwise--which furthers the growth of knowledge in this area, then this study will have been worthwhile.

The following general recommendations are made for future research in the human factors area:

a. In the real world, multiple human factors impinge interactively and simultaneously upon combat performance, which is a product of the orchestration of numerous military tasks. For this reason, human factors research should employ multivariate study designs, which determine the simultaneous effects that multiple independent variables have on one or more dependent variables. Furthermore, the interrelationship of different human factors mandates the use of a methodology which controls for the overlap in predictability. Multiple regression analysis meets both of these stipulations.

b. Dependent variables or outputs of human factors studies must serve as inputs to Army combat models. Otherwise, results are unlikely to be used by the modeling community.

c. Three major approaches to human factors studies exist--collection of data during simulated exercises, the use of previously-collected data, and surveying combat veterans. Each method has advantages and disadvantages which complements the others. For this reason, we recommend that all three approaches be implemented.

d. The Human Factors Model presented in this report provides a useful way to organize soldier dimensions in future research. This model, which designates all human factors as endogenous/transitory, endogenous/enduring, exogenous/transitory, and exogenous/enduring, should be validated by factor analysis or other procedures to determine the extent to which soldier factors intercorrelate within such dimensions. In the meantime, the model provides a useful way of classifying different human factors.

e. Future research must also take into account the effects that different combinations of interactions among types of human factors by different intensities of human factors by different time periods have on soldier performance. For purposes of illustration, a MODERATE amount of FATIGUE might be a more significant determinant of soldier performance than a SEVERE loss of SLEEP for a time period that is TWO DAYS into CONOPS. On the other hand, a SEVERE loss of SLEEP on the THIRD DAY of CONOPS might be much more important than MODERATE FATIGUE. An interactive model is necessary to sort out such differences.

6-2. Specific recommendations. The purpose of this report is to review research and to recommend an action plan which provides techniques for adjusting Army combat model outputs for different soldier dimension (human factor) conditions. Abbreviated versions of methodologies to be used for simulated combat and simulation device situations, for data gathered by others, and for the surveying of combat veterans follow. Detailed instructions are provided in EEAs #6 and #7 in Chapter 4.

a. Steps for simulated combat and simulation devices.

(1) Assign a minium of 25 crews to random sleep (from 0 to 8 hours a night) and random fatigue (continuous work from 60 to 100 percent of nonsleeping time) schedules to be maintained for up to 72 hours.

(2) Collect data on amount of sleep, fatigue, stress/anxiety, morale, cohesion, motivation/will, and quality of leadership at eight hour intervals. Collect data on previous experience and cognition prior to experiment.

(3) Collect data on baseline crew performance and at 8 hour intervals for the duration of the experiment. Crew performance must be:

(a) a variable that is capable of being inputted into the combat model in question.

(b) a variable that when inputted into a model is capable of having a significant impact on combat outcomes.

(4) Perform separate data analyses using stepwise multiple regression for baseline and for each 8 hour interval of the experiment. This provides information regarding which human factors are significant predictors of soldier performance--and which are not, as well as a predictive multiple regression equation (explained below).

b. Steps for data collected by others (including historical data).

(1) Find soldier dimensions and performance data. Good, reliable data in useable format is hard to find.

(2) Type of data analysis determined by format of data.

(a) Strive to obtain data on equal interval, continuous scales. This requirements permits multiple regression analysis, which tells which variables are significant predictors, and produces a predictive equation (explained below).

(b) Classificatory data only provides information regarding how soldier performance varies across various levels of different human factors. Factorial analysis of variance can be used to analyze classificatory data. But this analysis does not produce a predictive equation.

c. Steps for surveying combat veterans.

This methodology is divided into Phase I and II.

(1) Phase I: Determines which human factors are most important determinants of soldier performance.

(a) Administer Human Factors Survey Instrument for Phase I (Appendix B) to a randomly selected sample of Vietnam Veterans who are still in the Active Army.

1 The survey asks respondents to make judgments regarding how soldiers perform in combat given a mid-level intensity scenario under different kinds of human factors with different intensities and duration of each.

2 The sample should be stratified within officer and enlisted categories as determined by the highest rank held while in Vietnam.

3 The sample size should be determined by use of a formula for estimation of population parameters within a specified confidence interval (see EEA# 6 in Chapter 4).

4 The internal consistency reliability of the scale needs to be determined using the Kuder-Richardson Formula 21 procedure.

(b) Select a dependent variable measure that serves as an input to one or more Army models and which, if varied, will result in significant differences in combat outcomes. "Time to lay" using the Bradley Fighting Vehicle was used in the Human Factors Survey Instrument for Phase I because it meets both criteria in regard to the JANUS model.

(c) Analyze results using the magnitude estimation procedure which will

1 indicate which individual items are most highly related to changes in estimated soldier performance. (Determined by the calculation of geometric means across all subjects for each human factor item.)

2 validate the survey scale by providing evidence (or lack thereof) of a ratio scale of measurement. (This consists of correlating two response modalities--numerical estimation and line drawing--to the same judgements for a randomly selected subsample of at least 30).

(d) Analyze results using factorial analysis of variance, which determines the extent to which estimated soldier performance varies as a function of type of human factor, factor intensity, and factor duration. (See the three-way Anova model provided under EEA#6 in Chapter 4.)

(e) Analyze results using separate discriminant analysis procedures which determine whether estimated performance differences for different items vary as a function of rank and MOS of respondent. Correlations should be conducted between performance estimates, on the one hand, and age and experience of respondents, on the other.

(f) Analyze soldier performance estimates using a factor analysis procedure using principal components analysis and varimax rotation. This procedure will determine which survey items intercorrelate into orthogonal factors which explain the greatest amount of variance in estimated soldier performance. This analysis should also provide an indication of the degree to which the Human Factors Model proposed in this study has construct validity.

(g) The results of the above analytical procedures should be used to determine which human factors are most significant determinants of estimated soldier performance. Soldier dimensions which emerge as having significant relationships with soldier performance on two or more of the procedures (magnitude estimatation, factorial analysis of variance, and factor analysis) should be used in Phase II. Human factors that have a particularly strong showing on only one analytic procedure might also be used. No more than six soldier dimensions should be used in Phase II.

(2) Phase II: Identifies the predictive relationship between and among multiple human factors and estimated soldier performance.

(a) Administer the Human Factors Survey for Phase II (Appendix C) to a randomly selected sample of Vietnam Veterans who are still in the Active Army.

1 The survey is similar with respect to scenario and response formats used in Phase I; however, it is different in that each item requires a single estimate of soldier performance to situations with six human factor conditions in existence for different periods of time. A total of 100 items should be presented--10 items for each of 1 to 10 days into battle. The human factors used in this portion are determined from Phase I results. Values for each factor are determined by a computer program which generates random numbers within practical ranges.

2 The sample size should be determined by use of a formula for estimation of population parameters within a specified confidence interval (see EEA#6 in Chapter 4).

3 The same dependent variable employed in Phase I should be used.

4 Determine internal validity of the scale (verify that it is a ratio scale) by using magnitude estimation techniques used in Phase I. (This consists of correlating two response modalities--numerical estimation and line drawing--for the same judgments for a randomly selected subsample of 30.)

5 Determine the internal consistency reliability of the scale using the Kuder-Richardson Formula 21.

(b) Analyze results using a stepwise multiple regression procedure, which determines which of the human factors are significant predictors of soldier performance, and provides a predictive equation used in the final research step (see next paragraph).

d. All three approaches (collection of data during simulated exercises, use of previously-collected data, and surveying veterans) mentioned above utilize stepwise multiple regression, which provides the following information:

-Which combination of human factor variables collectively and simultaneously does the best job of predicting soldier performance?

-What is the magnitude of the relationship between the composite of human factor predictors and estimated soldier performance?

-How will future soldiers perform given different combinations of human factor conditions?

d. The answer to the final question above provides a way to adjust soldier performance in models in accordance with human factor conditions. Performance can be adjusted by using the regression equation which predicts an adjusted performance level given different values for human factor predictors. More specifically, the regression equation takes the following form:

$$Y' = b1X1 + b2X2 + \ldots bkXk + K \quad \text{where}$$

Y' = predicted or adjusted soldier performance

b1,b2,...bk = Weights for each significant human factor predictor (determined by regression analysis computer program) up to k predictors.

X1,X2,...Xk=Values for different human factor predictors up to k predictors.

K = A constant (determined by the regression program).

(1) How do we input this information into computer models so that performance can be adjusted in view of different soldier dimension conditions (e.g., an average of 1.5 hours of sleep and 20 hours of work per day)? The reason we have urged researchers to use soldier performance measures that can be inputted into one or more combat models is so that predicted soldier adjustments from the above regression equation can be inputted directly into the model in question.

(2) The effects that different combinations of soldier dimension conditions have on combat outputs can be tested by simply substituting different soldier dimension values into the regression equation above and inputting the result into a model. Comparison of model outputs will show the effects that different combinations of soldier dimensions values have on combat outcomes. While some combinations might result in minimal changes, others might result in major changes in combat outcomes. Furthermore, the comparison of combat outcomes with and without "adjusted" performance inputs will indicate the difference that soldier dimension conditions make in combat outcomes.

(3) If the simulations or previously-gathered data options are used, the calculation of adjusted performance is done using the above predictive equation. This adjusted performance level then is inputted into the combat model, much the same as inputs are entered now. (The only different is that inputs will be adjusted in view of changes made by the regression equation.) Model outputs can then be examined to determine what difference the particular combination of soldier dimension values makes in combat outcomes. A variety of combinations of different soldier dimension

values can be tested to determine their respective impacts on combat outcomes. Furthermore, the comparison of combat outcomes with and without "adjusted" performance inputs will indicate the difference that soldier dimensions make in combat outcomes. And all of this can be done without altering a single program line of the combat model!

(4) If the survey of combat veterans option is used, simply transform all responses on the Phase II survey to standardized T scores with a mean of 50 and a standard deviation of 10. Then run the regression analysis program on the Phase II survey data to derive the values needed to plug into the regression equation (see above). Next, substitute human factor values that are expected into the equation above, using the weights and constant provided by the regression analysis output. Inputs into the model, such as "lay time" for the 25mm cannon on the Bradley, can then be altered by whatever percentage of increase or decrease that the predicted value comes from the mean of 50. (For example, a predicted value of 60 is 20 per cent higher than 50.) If the "average" or usual lay time input into the model is 2.8 seconds, this figure could be increased or decreased by 20 per cent or by whatever percentage of increase or decrease that comes from the regression equation prediction.

e. Using the procedure just described, combat effectiveness outputs of models can be adjusted for degradations as a result of different human factors without altering the model programs one iota! Adjustments are made by altering the inputs in accordance with regression equation predictions. This procedure can be used to determine what different effects on combat outcomes might result from different combinations of human factor conditions over various time durations.

f. The same predictive equation can be used for Red and Blue forces. Simply input the different soldier dimension values into the predictive regression equation. Then input the adjusted soldier performance levels into the model in question.

g. Results of adjusted combat effectiveness predictions from Army models must be validated to determine the realism or accuracy of adjustments. Given the assumption that the model under consideration has been validated, which isn't always the case, validation of adjusted combat outcomes could consist of comparisons of predictions against simulated battle results given differing human factor considerations.

6-3. <u>Soldier dimensions research is complex and "dirty."</u> Research in this area is very complex, and does not lend itself to straightforward, "clean" designs that are universally embraced by the scientific community as being methodologically sound. As a result, almost any research effort in this area will be attacked in view of various shortcomings, disagreement over assumptions, etcetera. The temptation is great to throw up our collective hands and say that research in this area is "too hard," if not impossible.

a. We do not believe that soldier dimensions research such as what is outlined in this report is impossible. We have presented step-by-step procedures which could provide at least tentative answers to many of the difficult questions that must be addressed before soldier dimension variables are inputted into Army models.

b. The techniques outlined in this report are presented as options to consider for further research in this area. The plan described herein is not necessarily the only plan, or even the best plan, that is available. However, the plan does provide procedures which would contribute to our understanding of how to adjust combat model outcomes in view of soldier dimensions conditions.

6-4. Conclusions. In closing, we challenge our reviewers to provide constructive suggestions regarding ways to improve this research plan. Moreover, we challenge anyone in the military reserach community to formulate a better blueprint than this one. Hopefully, our combined efforts will result in the implementation of a series of research initiatives that will provide all the information needed to adjust combat outputs in view of soldier dimension conditions.

APPENDIX A

DEFINITIONS

1. Altitude - How far above sea level the battlefield is. (Reduced oxygen at high altitudes is likely to impair physical and cognitive performance.)

2. Cognitive factor - Various mental abilities which can be measured on standardized tests such as the Armed Services Vocational Aptitude Battery.

3. Cohesion - A feeling of group unity which entails common interests, goals, and responsibilities.

4. Confinement/Isolation - Being confined or the feeling of being isolated on the battlefield.

5. Coordination - Gross (large muscle) and fine (visual-motor) coordination.

6. Decision-Making - The ability of someone in charge to make sound, logical decisions in view of available information.

7. Experience - The amount of time in combat soldiers have actually worked on a daily basis in a particular specialty.

8. Human Factor - see soldier dimension. Both terms are used interchangeably in this report.

9. Jet lag - Temporary disruption of the normal biological rhythms following long distance airplane travel across several time zones. Closely related to the circadian rhythmic cycle.

10. Leadership - Ability to lead so as to exact maximum effort toward achieving objectives on the battlefield.

11. Mental fatigue - Extreme tiredness which results from prolonged exercise of mental processes.

12. Morale - Mental condition in a group which consists of cheerfulness and confidence.

13. National characteristics - Differences between soldiers of Armies from different countries which might affect performance. For example, german soldiers are very strong disciplinarians and the Japanese have a history of tenacity in the face of over-whelming odds.

14. Physical fatigue - Extreme tiredness which results from prolonged and/or considerable physical exertion during combat.

15. Sleep loss - loss of sleep over a specified period of time. Often quantified as the number of hours sleep sustained for a specified time period. (Closely related to the circadian rhythm cycle, which varies soldier alertness as a function of time of day.)

16. Soldier dimension - any factor which alters the physical, mental, or emotional capability of the soldier to perform his job effectively. Soldier dimensions can reside within the individual (e.g., fatigue), in the surrounding environment (e.g., extreme temperatures), or both (e.g., extreme anxiety as a result of numerous casualties).

17. Soldier load - The weight foot soldiers are required to carry on or en route to the battlefield.

18. Stress - Extreme anxiety which results from fear of injury or loss of life during combat.

19. Suppression/Noise - The deafening noise of the battlefield, and the reduced return of fire which is likely to result from it.

20. Terrain - A physical description of the major geophysical features of the battlefield. Examples include flat, hilly, forest, mountainous, desert, or urban areas.

21. Toxicity - The presence of nuclear, biological, or chemical agents on the battlefield. This dimension often refers to degradation in performance which results when soldiers wear MOPP gear.

22. Training - Resident and unit training. (Training decay is included under this dimension because it results from inadequate refresher training or opportunity to practice the tasks in question.)

23. Visibility - The ability to see what is happening on the battlefield. Visibility might be hampered by nightfall, fog, weather conditions, or smoke.

24. Weather - Variations in temperature and humidity (including fog, rain, snow, storms, and other inclement conditions) which affect the soldier's ability to fight.

25. Will/Motivation - Willingness to do whatever is necessary to fight and win.

HUMAN FACTORS SURVEY - PHASE I

The Human Factors Survey on the following pages provides a prototype instrument which can be used to estimate the extent to which soldier performance varies as a function of type and intensity of different soldier dimensions. It was developed to be used to determine which of numerous soldier dimensions are most significant determinants of soldier performance. The survey, which is designed to be completed by active Army veterans, defines soldier performance in terms of "lay time" to sight an enemy using a 25 mm cannon on a Bradley fighting vehicle. However, the soldier performance task can be changed to suit the needs of the researcher or modeler. Part 1 provides a brief exercise which familiarizes respondents with the response format. Part II solicits estimates of soldier performance.

APPENDIX B

HUMAN FACTORS SURVEY

Phase I

Instructions: Thank you for agreeing to take this survey. Its purpose is to help determine how much combat effectiveness is altered by adverse human factor conditions such as loss of sleep, extreme fatigue, etc. Only combat veterans of Vietnam who are still in the active Army should complete this survey: If you are not a Vietnam vet with combat experience, please pass this survey on to someone who is.

Please fill in the blanks below. Please note that your name is optional.

Today's Date _______________

Name (optional) -------------------------

Time in Vietnam: From ----------- To --------------- .

From ----------- To ---------------

From ----------- To ---------------

Highest rank while in Vietnam: ---------------

Military specialty while in Vietnam: ---------------

Age when you left Vietnam (the last tour if more then one: ---------------

Did you actually engage in combat? (check one): ----- yes

----- no

What percentage of your time were you engaged in combat-related duties?

-------------%

Part 1 (COMPLETED BY ALL RESPONDENTS). This exercise familiarizes you with the reponse format to be used in this survey. Directly below you will notice a line labelled "A":

A. (reference line)
[50]

This line is your reference line--it has the number "50." Below you will notice 12 additional lines labelled "B" thru "L." Note that some are longer than the reference line, and some are shorter. Your task is to say how much longer or shorter the lines are compared to the first line by <u>giving each line a number compared to 50</u>. The longer a line appears to be compared to line A, the bigger the number you will give it compared to 50. The shorter the line compared to the first line (A), the smaller the number you should give it compared to 50.

No rulers, please. Just give each line a number that seems appropriate: If a line seems to be about twice as long as line A, give it a number about two times bigger than 50--about 100. If a line appears about one-fourth as long as line A, give it a number smaller than 50--about 12. Write your numeric estimates in the spaces provided to the right of each line. Begin below line A, the reference line, below:

	Estimate
A [Reference Line]	50
B	---------
C	---------
D	---------
E	---------
F	---------
G	---------
H	---------

I

J

K

L

Part 2 (TO BE COMPLETED BY ALL RESPONDENTS.) Now that you have practiced the response format we are going to ask you to estimate soldiers' combat effectiveness under different conditions by estimating numbers. Please review the following scenario which provides the setting in which judgments are to be made:

The year is 1994. Your unit is part of a Light Infantry Division engaged in a middle intensity conflict in Eastern Europe. Reports indicate an enemy infantry division is approaching. Your orders are to fire on and destroy the enemy without hesitation.

The following factors apply for all items unless stated otherwise.

Combat experience: 6 months for everyone in unit.
Last contact with enemy: 2 weeks ago.
Time of day: Early afternoon.
Weather: Fall. 55 degrees Fahrenheit. No precipitation.
Terrain: Hilly countryside with mixed trees.
Equipment: All operable.
Provisions: Adequate.
Communications: No problem.
Replacements: No problem. Unit strength is 100%.
Air Strike and Artillery Support: None expected.
Reinforcements: None expected.
Recent casualties: Light (less than 1%).
Field hospital care: Excellent.

The soldier you will be rating is operating a 25 mm cannon on a Bradley Fighting Vehicle. Read each item carefully and decide how effective the average soldier would be in combat given the above scenario and the conditions of each item. Compare the effectiveness of the average soldier in combat against the following standard:

A. Reference for "lay time" comparisons.

[3.0 seconds]

The number "3.0" represents an approximate average "lay time" for a forward-facing target for the 25 mm cannon on the Bradley during simulated combat conditions. "Lay time" is the amount of time in seconds required to get a target in the gun sight following identification as an enemy target.

If 3.0 is the average "lay time" required for an average soldier during simulated combat, how much time would be required of the average soldier during the combat conditions described in the items below? If you think three times as much "lay time" would be required, write 9.0 (3 x 3.0). If you think only about one third as much lay time would be required, write 1.0 in the space provided, and so on. Please write all lay times to the nearest tenth of a second (i.e., 1.3, 5.8, etc.).

Go ahead and complete <u>all</u> of the following items in comparison to the reference standard. The reference standard is repeated for the sake of clarity.

INSTRUCTIONS: FOR EACH ITEM BELOW ESTIMATE HOW MUCH AVERAGE "LAY TIME" IS REQUIRED DURING REAL COMBAT TO GET AN ENEMY IN THE SIGHTS OF A 25 MM CANNON ON A BRADLEY VEHICLE IN COMPARISON TO THE AVERAGE TIME OF 3.0 SECONDS FOR A FORWARD-FACING TARGET DURING SIMULATED CONDITIONS.

(reference standard)
[<u>3.0 seconds</u> to get target in sight during simulated combat.]

[PEASE NOTE: IN THE ACTUAL SURVEY PROTOCOL THESE ITEMS SHOULD BE PRESENTED IN RANDOM ORDER WITHIN EACH MAJOR CATEGORY. SEPARATE ITEMS SHOULD BE WRITTEN FOR EACH POSSIBLE COMBINATION OF HOURS AND DAYS.]

ENDOGENOUS/TRANSITORY FACTORS

	Estimated "Lay Time"
1. Your unit has averaged only 5/3/1 hours sleep in the last 2/4/6 days.	______
2. Your unit has averaged 12/16/20 hours of search and destroy operations in the last 2/4/6 days.	______
3. Your unit has undergone 8/16/24 hours of regular artillery/rocket/mortar bombardment in the last 2/4/6 days.	______
4. Your Bradley vehicle has been separated from your unit for 2/4/6 days. (Assume firing on enemy target is right thing to do.)	______
5. Your unit used to have very high morale. But recently it has undergone a 25/50/75 % drop in morale.	______
6. Your unit used to have very high cohesiveness. But personnel changes have resulted in a 25/50/75 % drop in cohesiveness.	______

Estimated
"lay time"

7. Your unit used to have a very strong will/motivation to fight. But recently it has undergone a 25/50/75 % reduction in will/motivation to fight. ________

8. A soldier has approximately 1/6/12 months combat experience. ________

9. A soldier received training 6/12/18 months ago and has had weekly/monthly/no opportunities to practice prior to combat. ________

10. Your unit used to have good leadership. But personnel changes have resulted in a 25/50/75 % drop in quality of leadership from NCOs and officers. ________

ENDOGENOUS/ENDURING FACTORS

11. Your unit has an overall average of 84/50/16 on the Armed Forces Qualification Test (AFQT) on the Armed Services Vocational Aptitude Battery (ASVAB), which shows above average/average/below average general aptitude in comparison with other units. ________

EXOGENOUS/TRANSITORY FACTORS

12. Your unit has been operating in 105/55/-10 degree (Fahrenheit) temperature for the past 2/4/6 days. ________

13. Your unit has been operating in 4/8/12 inches of snowfall a day for the last 2/4/6 days. The snowing continues at that rate. ________

14. Your unit has been operating in 4/8/12 inches of rainfall a day for the last 2/4/6 days. The raining continues at that rate. ________

15. Your unit has been operating in fog which limits visibility to 50/100/200 yards for the last 2/4/6 days. ________

16. Your unit has been operating in the smoke of battle that limits visibility to 50/100/200 yards for the last 2/4/6 days. ________

17. Your unit is operating at 1:00 in the afternoon/ 1:00 in the morning/4:00 in the morning. ______

EXOGENOUS/ENDURING FACTORS

18. Your unit has been operating in MOPP-1/2/3/4 for 2/4/6 days in a contaminated environment. ______

19. Your unit has been operating on flat/hilly/rough terrain. ______

APPENDIX C

HUMAN FACTORS SURVEY - PHASE II

The Human Factors Survey on the following pages provides a prototype instrument which can be used to determine the relationship between six or less soldier dimension predictor variables, on the one hand, and soldier performance, on the other. The survey, which is designed to be completed by active Army veterans, defines soldier performance in terms of "lay time" to sight an enemy using a 25 mm cannon on a Bradley fighting vehicle. However, the soldier performance task can be changed to suit the needs of the researcher or modeler. Part 1 provides a brief exercise which familiarizes respondents with the response format. Part II solicits estimates of soldier performance in response to as many as six human factor conditions for varied time periods. The values for human factors and time periods are randomly selected for each factor within logical limits expected on future battlefields.

APPENDIX C

HUMAN FACTORS SURVEY

Phase II

Instructions: Thank you for agreeing to take this survey. Its purpose is to help determine how much combat effectiveness is altered by adverse human factor conditions such as loss of sleep, extreme fatigue, etc. Only combat veterans of Vietnam who are still in the active Army should complete this survey: If you are not a Vietnam vet with combat experience, please pass this survey on to someone who is.

Please fill in the blanks below. Please note that your name is optional.

Today's date ---------------

Name (optional) --------------------------

Time in Vietnam: From ----------- To ---------------

From ----------- To ---------------

From ----------- To ---------------

Highest rank while in Vietnam: ---------------

Military specialty while in Vietnam: ---------------

Age when you left Vietnam (the last tour if more than one): ---------------

Did you actually engage in combat? (check one): ----- yes
----- no

What percentage of your time were you engaged in combat-related duties?

--------------%

Part 1 (COMPLETED BY ALL RESPONDENTS). This exercise familiarizes you with the reponse format to be used in this survey. Directly below you will notice a line labelled "A":

A. (reference line)

[50]

This line is your reference line--it has the number "50." Below you will notice 12 additional lines labelled "B" thru "L." Note that some are longer than the reference line, and some are shorter. Your task is to say how much longer or shorter the lines are compared to the first line by giving each line a number compared to 50. The longer a line appears to be compared to line A, the bigger the number you will give it compared to 50. The shorter the line compared to the first line (A), the smaller the number you should give it compared to 50.

No rulers, please. Just give each line a number that seems appropriate: If a line seems to be about twice as long as line A, give it a number about two times bigger than 50--about 100. If a line appears about one-fourth as long as line A, give it a number smaller than 50--about 12. Write your numeric estimates in the spaces provided to the right of each line. Begin below line A, the reference line, below:

	Estimate
A [Reference Line]	50
B	---------
C	---------
D	---------
E	---------
F	---------
G	---------

H

I

J

K

L

Part 2 (TO BE COMPLETED BY ALL RESPONDENTS.) Now that you have practiced the response format we are going to ask you to estimate soldiers' combat effectiveness under different conditions by <u>estimating numbers.</u> Please review the following scenario which provides the setting in which judgments are to be made:

The year is 1994. Your unit is part of a Light Infantry Division engaged in a middle intensity conflict in Eastern Europe. Reports indicate an enemy infantry division is approaching. Your orders are to fire on and destroy the enemy without hesitation.

The following factors apply for all items unless stated otherwise.

Combat experience: 6 months for everyone in unit.
Last contact with enemy: 2 weeks ago.
Time of day: Early afternoon.
Weather: Fall. 55 degrees Fahrenheit. No precipitation.
Terrain: Hilly countryside with mixed trees.
Equipment: All operable.
Provisions: Adequate.
Communications: No problem.
Replacements: No problem. Unit strength is 100%.
Air Strike and Artillery Support: None expected.
Reinforcements: None expected.
Recent casualties: Light (less than 1%).
Field hospital care: Excellent.

The soldier you will be rating is operating a 25 mm cannon on a Bradley Fighting Vehicle. Read each item carefully and decide how effective the <u>average</u> soldier would be in combat given the above scenario and the conditions of each item. Compare the effectiveness of the <u>average</u> soldier in combat against the following standard:

A. Reference for "lay time" comparisons.

[3.0 seconds]

The number "3.0" represents an approximate average "lay time" for a forward-facing target for the 35 mm cannon on the Bradley during <u>simulated</u> combat conditions. "Lay time" is the amount of time in seconds required to get a target in the gun sight <u>following identification</u> as an enemy target.

If 3.0 is the average "lay time" required for an average soldier during simulated combat, how much time would be required for the <u>average soldier</u> during the <u>combat</u> conditions described in the items below? If you think three times as much "lay time" would be required, write 9.0 (3 x 3.0). If you think only about one third as much lay time would be required, write 1.0 in the space provided, and so on. Please write all lay times to the nearest tenth of a second (e.g., 5.4, 1.8, etc.)

Go ahead and complete <u>all</u> of the following items in comparison to the reference standard. The reference standard is repeated for the sake of clarity.

INSTRUCTIONS: FOR EACH ITEM BELOW ESTIMATE HOW MUCH AVERAGE "LAY TIME" IS REQUIRED DURING REAL COMBAT TO GET AN ENEMY IN THE SIGHTS OF A 25 MM CANNON ON A BRADLEY VEHICLE IN COMPARISON TO THE AVERAGE TIME OF 3.0 SECONDS FOR A FORWARD-FACING TARGET DURING SIMULATED CONDITIONS.

(reference standard)

[<u>3.0 seconds</u> to get target in sight during simulated combat.]

[PLEASE NOTE: THE ACTUAL SOLDIER DIMENSION FACTORS (FACTOR ONE, FACTOR TWO, ETC.) WHICH WILL APPEAR IN THIS SURVEY WILL BE DETERMINED BY PHASE I RESULTS. VALUES FOP TIME PERIODS (TIME FACTORS) AND SOLDIER DIMENSION FACTORS (FACTOR 1 VALUE, FACTOR 2 VALUE, ETC.) FOR EACH ITEM WILL BE DETERMINED BY RANDOMLY SELECTING VALUES FROM RANGES APPROPRIATE FOR EACH. (SEE ACTION PLAN IN STUDY REPORT FOR DETAILS.) A TOTAL OF 100 ITEMS WILL APPEAR IN THIS PORTION OF THE SURVEY.]

Estimated "Lay Time"

1. During the last TIME FACTOR days your unit has averaged only: ________

FACTOR 1 VALUE for FACTOR ONE.
FACTOR 2 VALUE for FACTOR TWO.
FACTOR 3 VALUE for FACTOR THREE.
FACTOR 4 VALUE for FACTOR FOUR.
FACTOR 5 VALUE for FACTOR FIVE.
FACTOR 6 VALUE for FACTOR SIX.

2. During the last TIME FACTOR days your unit has averaged only: ________

FACTOR 1 VALUE for FACTOR ONE.
FACTOR 2 VALUE for FACTOR TWO.
FACTOR 3 VALUE for FACTOR THREE.
FACTOR 4 VALUE for FACTOR FOUR.
FACTOR 5 VALUE for FACTOR FIVE.
FACTOR 6 VALUE for FACTOR SIX.

3. During the last TIME FACTOR days your unit has averaged only: __________

FACTOR 1 VALUE for FACTOR ONE.
FACTOR 2 VALUE for FACTOR TWO.
FACTOR 3 VALUE for FACTOR THREE.
FACTOR 4 VALUE for FACTOR FOUR.
FACTOR 5 VALUE for FACTOR FIVE.
FACTOR 6 VALUE for FACTOR SIX.

4. Etc.
5. Etc.
100. Etc.

APPENDIX D

COORDINATION

This study report has been coordinated with the following agencies:

Academy of Health Sciences (Behavioral Sciences Department)
Army Research Institute (Dr. Headley)
Deputy Chief of Staff for Personnel (DAPE-MR (Rm 2C733, LTC Hewitt)
Directorate of Combat Developments, Soldier Support Center (Analysis Division)
HQ Lab Command (Ms. Van Nostrand)
Office of the Surgeon General (COL Belenky, Walter Reed Institute of Research)
TRADOC Analysis Command:
- Requirements and Programs Directorate
- Research Directorate
- Technical Operations Directorate
- TRAC-Fort Leavenworth
- TRAC-Lee
- TRAC-Monterey
- TRAC-White Sands Missile Range

APPENDIX E

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APPENDIX F

FIGURES AND TABLES

Figure F-1. SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS *	STRESS ****	PHYSICAL FATIGUE ***	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE **	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
Soldier Dimensions in Battle - Final Report, Volume 1, McMichael & Associates, 1982.		X				X	X	X				X		X					
Developing a Continuous Operations Capability: A System for Countering Stress and Other Adverse Factors Encountered in the Airland Battlefield, Giles, no date.	X	X	X	X			X					X		X	X				
Personnel Service Support and Soldier Performance Factors in Army Models, Simulations, and Weapons: An Interium Study Report, Hughes, no date.	X	X	X	X	X	X	X					X		X					
Combat Stress and Battle Fatigue Training Support Package, Soldier Support Center, 1985.	X	X					X		X	X		X	X	X					
Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance, Krueger, 1986.	X	X	X	X	X	X	X		X			X		X					

* Includes circadic factors
** Includes decision-making
*** Includes soldier load
**** Includes suppression/noise

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
Behavior Research Methods, Instruments, and Computers, Sidowski (Editor), 1985.	X	X	X	X			X		X			X							
Proceedings: Fifth User's Workshop on Combat Stress, Mangelsdorff, et.al., 1988.	X	X			X	X	X						X	X					
Management of Sleep/Stress in Continuous Operations, Morgan Management Systems, Inc., 1984.	X	X	X	X	X	X			X				X						
Human Performance in Continuous/Sustained Operations and the Demands of Extended Work/Rest Schedules: An Annotated Bibliography, Krueger, et.al., 1985.	X	X		X	X				X								X		X
Combat Models or Firepower Models? Van Nostrand, 1987.	X	X	X	X	X	X		X	X	X			X	X				X	

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
FM 22-9 Soldier Performance in Continuous Operations, Dec. 1983.	X	X	X	X	X	X	X					X			X				
Including the Soldier in Combat Models, Van Nostrand, 1988.	X		X		X	X		X	X	X	X	X	X	X					
Development of a Soldier Load Assessment Methodology, Wagner, 1986.			X							X	X								
Human Factors Representations for Combat Models, Miller and Binder, 1982.									X		X								
Model Effectiveness as a Function of Personnel, Van Nostrand, 1986.	X	X	X	X	X	X			X	X	X			X	X	X	X	X	
Deployment Threats to Rapid Deployment Forces, Hegge and Tyner, 1982.		X			X					X				X		X			X
Minutes of the 6th Meeting of the DoD HFE Subgroup on Sustained/Continuous Operations, Nov, 1987, Krueger.	X	X	X	X					X	X	X	X	X	X		X			
Human Factors in Sustaining High Rates of Artillery Fire, Manning, 1985.	X	X	X	X	X	X	X					X	X	X					

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
An Investigation into the Value of Unit Cohesion in Peacetime, Manning and Ingraham, 1983.					X	X													
Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, et.al., 1987.	X					X	X		X			X	X	X					
Issues Concerning the Psychological Impact of Tactical Nuclear Warfare, Human Sciences, 1979.		X											X						
Psychological Dimensions of Combat Readiness, Leadership, Morale, and Group Cohesion, Havron, 1984.					X	X								X					
Force Modernization: Relating Human Capability to System Performance, Trexler, et.al., 1982.									X			X							
A Study of Human Factors that Affect Combat Objectives on the Battlefield, Marashian, 1962.				X		X	X	X				X		X					

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
Management of Stress in Army Operations, Applied Psychological Services, Inc., 1981.	X	X	X	X	X	X	X					X		X	X		X		
What is a Quality Soldier? Symons, et.al., 1982							X		X										
FM 26-2 Management of Stress in Army Operations, August 1986.	X	X	X	X	X	X			X	X		X		X	X		X		X
Strategies for Sustaining Soldier and Unit Performance in Continuous Operations, Krueger, et.al, 1987.	X		X	X	X	X	X		X			X		X					
Minutes of the 7th Meeting of the DOD HFE Subgroup on Sustained/Continuous Operations, May 10, 1988, Krueger, 1988.	X	X	X	X					X	X			X		X				X
Impact of Soldier Quality on Performance in the Army, Horne, 1986.									X										
Physical Fitness as a Moderator Moderator of Cognitive Degradation During Sleep Deprivation, Thompson, 1983.	X	X	X	X					X	X		X	X	X		X			X

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
Human Performance in Continuous Operations: Volume III Techni al Documentation Siegel, et.al., 1980.	X	X	X	X	X	X	X	X	X	X		X	X	X	X				X
Proceedings of the AMEDO Psychology Symposium 27-31 October 1980, Walter Reed Army Medical Center, Hegge and Marlowe, 1980.	X	X	X	X		X	X	X		X		X	X						
Understanding War: History and Theory of Combat, Duprey, 1987.			X	X	X			X		X	X	X		X					
Continuous Operations in Europe: Feasibility and the Effects of Leadership and Trai ing. Manning, no date.	X	X	X	X	X	X	X	X	X	X		X		X	X				
The Psychological Burden of the Soldier in Combat, Scherer, no date.	X	X	X	X	X	X	X			X		X		X			X		

SOLDIER DIMENSIONS IDENTIFIED IN STUDIES AND PUBLICATIONS

SOURCE	SLEEP LOSS	STRESS	PHYSICAL FATIGUE	MENTAL FATIGUE	MORALE	COHESION	WILL/ MOTIVATION	EXPERIENCE	COGNITIVE	WEATHER	TERRAIN	TRAINING	TOXICITY	LEADERSHIP	VISIBILITY	ALTITUDE	CONFINEMENT/ ISOLATION	NATIONAL DIFFERENCES	JET LAG
Human Factors Played Role in Airbus Tragedy, Harvey, 1988.		X						X	X	X									
How Much Do Soldiers Sleep? Van Nostrand, 1988.	X		X	X										X					
Forty-Eight versus Twenty-Four Hour Duty for USA Missile Crews: A Feasibility Study Using Subjective Measures of Fatigue, Gray, 1980.	X	X	X	X															
Commander Fatigue and Firepower, Van Nostrand, no date.	X	X	X	X			X	X		X				X					
An Annotated Bibliography of the Literature Dealing with the Physiological Correlates of Cognitive Performance.	X	X		X			X		X	X								X	X
Staying Effective in Continuous Operations, Stallard, 1985.	X	X	X	X	X	X	X		X	X	X	X		X					X

Figure F-2

Review of Effects of Soldier Dimensions on Soldier/Unit Performance

FACTOR	EFFECTS ON PERFORMANCE
1. SLEEP LOSS (Continuous Operations (CONOPS) Final Report, De Wulf, 1987).	1. Cognitive performance begins to degrade after 18 hours of continuous performance. 2. Soldiers become militarily ineffective after two or three days of no sleep (48 to 72 hours.) 3. Generally, less than four hours of sleep each night leads to rapid decline in military effectiveness. 4. Decision-making and leadership capabilities are among the most affected. 5. Performance of physical tasks is not generally affected by lack of sleep - but no sleep requires longer periods of recuperation. 6. Alertness varies as a function of time of day (called circadian rhythm cycle). Soldiers will be most alert between 1800-2130 hours--and least alert from 0400-0600 hours.
2. FATIGUE* (Effects of continuous operations (CONOPS) on Soldier and Unit Performance: Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, et. al., 1987.	1. Cognitive abilities begin to degrade as soon as 18 hours into sustained operations. Declining performance, which often takes the form of sacrificing speed for accuracy, are most pronounced during early morning (0300-0600) hours.

* Studies which concern fatigue differ from those which concern sleep loss in that the former entail continuous or semi-continuous work under no sleep or limited sleep conditions. Persons interested in a comprehensive review of how sustained work, fatigue, and sleep loss impact on performance should review Krueger (1989).

FACTOR	EFFECTS ON PERFORMANCE
	2. Cognitive performance following <u>semi-continuous</u> mental work (working 30 minutes out of every hour) declines approximately 25% for every 24 hours of work without sleep.
	3. Cognitive performance following <u>continuous</u> brigade headquarters work (message trafficking and information processing) declines 30% for every 24 hours of work without sleep.
	4. Cognitive performance following continuous "patrolling" declines with each 24 hour period up to 65% (only 35% effective) after 72 hours with no sleep. Soldiers in the field are militarily ineffective after 72 hours with no sleep.
	5. As indicated above, the amount of reduction depends on the task requirements. However, a general rule of thumb is that a 75% reduction is expected after 72 hours of work with no sleep.
	6. Performance of physical tasks (loading a magazine or marching) degrade much less rapidly than mental tasks.
	7. Well-practiced, routine motor tasks degrade much less rapidly than those which require alertness, concentration, reasoning, or encoding/decoding.
STRESS (Israeli Battle Shock Casualties; 1973 & 1982, Belenky, et.al, 1983; A Conceptual Model of Behavior Under Stress, with Implica-	1. Because of reaction to the stress of combat, estimates from the Korean War suggest that as few as 12 to 20% of the men in a unit might function

FACTOR	EFFECTS ON PERFORMANCE
tions for Combat Training, Kern, 1966; Management of Stress in Army Operations, FM 26-2, 1983; A Study of Human Factors that Affect Combat Effectiveness on the Battlefield, Marashian, 1982.)	with maximum effectiveness; as many as 25 to 35% will vacillate between borderline and effective performance; and as many as 45 to 65% will not provide any fire support activity. (Some sources argue these estimates - especially the latter - are inflated. For this reason, these statistics should be applied with extreme caution).
	2. Nonproductive behaviors likely to be encountered on the battlefield include forgetfulness, losing equipment, excessive talking, "bugging out," failure to maintain weapons, refusal to leave a position of safety, or doing something which gives away a unit's position.
	3. Frequent psychological reactions to combat include active withdrawal, malingering, defensive overreactions (firing weapons at "imaginary" enemy soldiers), and hysterical incapacitation.
	4. Stress casualties during conventional (non-Nuclear, Biological, or Chemical) combat could vary between ratios of 1:4 to 1:3 of stress casualties to wounded in action. Approximately 75% of the stress casualties can be returned to duty within 72 hours (given proper psychiatric intervention).
	5. Cumulative efforts of 80-100 or more days of frequent combat make soldiers more vulnerable to stress reactions that reduce combat effectiveness.

FACTOR	EFFECTS ON PERFORMANCE
COHESIVENESS (A Study of Human Factors that Affect Combat Effectiveness on the Battlefield, Marashian, 1982).	Enhanced cohesiveness will likely result in greater soldier morale, lower stress casualties, and increased combat effectiveness.
MORALE (Israeli Battle Shock Casualties: 1973 and 1982, Belenky, et.al, 1983); Management of Stress in Army Operations, FM 26-2, 1983).	Units high in morale will have lower psychiatric casualties and increased combat effectiveness.
WILL/MOTIVATION (Effects of Continuous Operations (CONOPS) on Soldier and Unit, Review of the Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, 1987; Management of Stress in Army Operations, FM 26-2, 1983).	1. High levels of motivation will improve performance--even under sleep-deprived conditions. (But no amount of motivation will completely counteract the effects of sleep loss.) 2. High levels of motivation will reduce stress casualty rates.
EXPERIENCE (Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	Soldiers experienced in combat will be more effective in combat than inexperienced soldiers.
COGNITIVE FACTORS (Report from the House Appropriations Committee, from briefing slides presented at a SPRAR meeting, Jan, 1989; Are Smart Tankers Better, Scribner, et.al, 1986; A Natural Experiment Analysis of an Almost Unselected Army Population; Shields and Grafton, 1983).	Soldiers higher in mental capability (as measured by AFQT scores) perform better on SQTs and in training, and are better able to perform some combat skills (such as accuracy with M2 Bradley guns and proficiency during simulated tank warfare). However, many questions remain regarding how mental capability affects unit readiness or ability to fight. (This is a very controversial area. Many argue the cost of recruiting "smart" soldiers is exorbitant compared to relatively meager gains which could be expected on the battlefield.)

FACTOR	EFFECTS ON PERFORMANCE
WEATHER (Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986.	Extremes in heat will likely result in degradation of physical work, while extreme cold temperatures will degrade fine manual dexterity performance (manipulating knobs, switches, etc.). Humidity causes no direct performance degradation, but it magnifies the effects of heat.
TERRAIN (Continuous Operations Study (CONOPS) Final Report, DeWulf, 1987; Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	Rough terrain, such as a dense jungle or mountainous areas, can contribute to fatigue and, thus, degrade performance.
SOLDIER LOAD (Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, 1987.)	Amount of load soldiers can/should carry varies with mission requirements and the combat scenario. But excessive load leads to fatigue, physical discomfort, and degradation of combat performance.
TRAINING (A Study of Human Factors that Affect Combat Effectiveness on the Battlefield, Marashian, 1982; Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, 1987).	All other things remaining equal, Armies with well-trained small units will prevail on the battlefield. Overlearning and cross-training particularly help the unit maintain maximum combat performance during highly stressful conflicts and when soldiers might be called on to perform several tasks.
ALTITUDE (Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	Thin air in high altitude areas could result in performance decrements. Also, high altitudes are likely to impact on helicopter crew performance, and on flight crews in general.
LEADERSHIP (A Study of Human Factors that Affect Combat Effectiveness on	Units with better leadership are generally more effective in combat.

FACTOR	EFFECTS ON PERFORMANCE
the Battlefield, Marashian, 1982).	
VISIBILITY (Model Effectivenesss as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	Combat efficiency is likely to be degraded during periods of reduced visibility (i.e., from night time, fog, rain, or snow. NOTE: Problems such as eye strain with night vision equipment limits soldier effectiveness during night-time operations.
SUPPRESSION/NOISE (A Study of Human Factors that Affect Combat Effectiveness on the Battlefield, Marashian, 1982; Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	By definition, suppression that results from incoming artillery, rocket, missile, etc., attacks weaken combat effectiveness. The psychological impact of heavy bombardment can result in reduced task performance, failure to return fire, purposeless behavior, and battle fatigue, all of which are counterproductive. Just the noise alone is sufficient to degrade performance which results from poor verbal communications.
CONFINEMENT/ISOLATION (Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986; A Study of Human Factors that Affect Combat Effectiveness on the Battlefield, Marashian, 1982).	Confinement to even very limited space, such as a tank, should not significantly affect performance for periods of less than 48 hours. Thereafter problems with reduced circulation and complex monitoring tasks might occur, although no deficits result with psychomotor, perceptual, and intellectual tasks. Isolation from a group can result in significant performance degradation as a result of extreme emotional reactions.
NATIONAL CHARACTERISTICS (Model Effectiveness as a Function of Personnel [ME=f(PER)], Van Nostrand, 1986).	Several authorities have hypothesized that combat effectiveness varies with nationality; nevertheless, the predictive value of such information has not yet been conclusively demonstrated.

FACTOR	EFFECTS ON PERFORMANCE
TOXICITY (Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS, Belenky, et. al., 1987; Assessment of the Effects of Heat and NBC Protective Clothing on Performance of Critical Military Tasks, Fine & Kobrick, 1985)	Performance of military tasks while soldiers are in Mission Oriented Protective Posture (MOPP gear, which protects soldiers against contaminants in the environment) clothing is decremented due to the heat-containing and bulky nature of the suit. Accuracy in performance of military tasks (i.e., firing the howitzer) is usually maintained at the expense of speed. Hot and/or humid environments can limit endurance of tank and howitzer crews for example, to approximately 3 to 17 hours. However, frequent rest breaks, suit changes every six hours, food, and 6-hour sleep periods can allow infantry fighting vehicle crews to last up to 60 hours. MOPP gloves present problems with manual dexterity tasks. Even cognitive functioning (speed and accuracy) deteriorates rapidly after only 4 or 5 hours in MOPP gear in a moderately hot (91° F) environment.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
Fine & Kobrick, 1985	Toxicity & heat	Hours (7-8) in MOPP-4 at various (55, 70, & 91° F temperatures	Cognitive performance	1. Computation of trajectory of artillery rounds receiving. 2. Decoding map grid coordinates receiving. 3. Decoding messages 4. Plotting targets on map and determining range and deflection.
A. E. McMichael & Associates, no date.	Training (unit effectiveness)	ARTEPs	N.A.	N.A.
Martin, 1981	Fatigue (Physical)	Treadmill grades were selected which provoked heart rates of 160 to 170 beats a minute.	N.A.	N.A.
Martin & Gaddis, 1981	Fatigue (Physical)	Percentages (25,50,& 75) of maximal oxygen uptake (VO_2 max) achieved during performance on a mechanically-braked cycle ergometer.	N.A.	N.A.
Stamper, 1978	Fatigue (Physica)	Physical activity questionnaire (utilizes a	N.A.	N.A.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		Likert scale of 1 to 5 to access degree of fatigue across 16 symptom areas.)		
James, et. al, 1983	Training (individual soldier's ability to perform military specialty)	Skills Qualifications Test (SQT: reliability coefficients are too numerous and varied to mention.)	Ability of unit to perform TO&E mission under simulated combat conditions.	ARTEP
Glickman, et.al, no date.	Toxicity	Defined by a questionnaire which presented ranges of symptoms associated with different levels of radiation exposure.	Performance with artillery, tank crews, TOW-ITV crews, and fire direction center.	Questionnaire which solicited estimates of time required to perform different tasks (given different radiation symptoms).
Young & Auton, no date.	Toxicity (radiation)	Defined by a questionnaire which presented ranges of symptoms associated with different levels of radiation exposure.	Performance of tank crews (M60A3), howitzer, TOW vehicles, and fire direction centers.	Questionnaire which solicited response times required to perform different tasks. (Appeared on same questionnaire listed under 'How Measured').
Van Nostrand, 1986	N.A.	N.A.	1. Armor crew performance. 2. General unit effectiveness.	1. Table VII (tank crew qualifications on gunnery tests.) 2. Army Training Evaluation Program (ARTEP).

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
Wagner & Kunz, 1986	Soldier Load	Pounds (lbs) of equipment and supplies carried by light infantry soldiers.	N.A.	N.A.
Van Nostrand, 1986	Sleep Loss	Informal Questionnaire (Responses solicit information regarding numbers of hours spent sleeping and working a 24-hour period during simulated combat.	N.A.	N.A.
Harlon & Hickey, 1986	Cold Weather	Degrees Fahrenheit (-80 to +34 degrees)	Infantry performance during Arctic training (testing experimental equipment)	1. ARTEP results. 2. Questionnaires elecited responses on a 1 (very poor) to 5 (excellent) scale regarding quality of equipment.
Harlon & Hickey, 1986.	Soldier Load	Weight of a load carrying vest, and field pack.	Infantry performance during Arctic training (testing experimental equipment).	1. ARTEP results. 2. Questionnaires elicited responses on a 1 (very poor) to 5 (excellent) scale regarding quality of equipment.
Scott, 1984	N.A.	N.A.	Maneuver-arms unit performance during tactical exercises.	Go/No Go's based on ARTEP standards.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
Medland & Hammer, 1961	Leadership	1. Leadership Characteristics Inventory (Consists of 150 multiple and forced-choice paired items). 2. Noncommissioned Officer Leadership aptitude rating (provides a global rating regarding how individual is ranked as a leader by his peers and superiors.)	N.A.	N.A.
Belenky, et.al., 1987	Sleep loss and fatigue	Number of continuous hours (72) without sleep under semi continuous work conditions	Cognitive performance	Tasks measured include letter search, addition, logical reasoning, memory, serial addition and subtraction, pattern recognition, verbal processing, and vigilance.
Belenky, et.al., 1987	Sleep loss and fatigue	Number of continuous hours (43) without sleep under continuous work conditions	Tank crew performance	Tasks measured include communication, driving, surveillance, gunnery, and maintenance.
Dewulf, 1987	Sleep loss and fatigue	Number of continuous (54) hours without sleep	Cognitive (brigade headquarters) performance	Tasks required processing of messages and information.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		under contin-uous work conditions		
Krueger, 1987	Does not apply	Does not apply	The Naval Aerospace Medical Research Lab Multi-disciplinary performance test battery	1. Cognitive tests. Tests reasoning, memory, perceptual speed, visual learning, and other abilities. 2. Visual tests. Tests acuity, detection skills, and visual sensitivities, among other abilities. 3. Accoustical tests. Tests auditory sensitivity and perception, and clarity of speech, among others. 4. Vestibular tests. Tests for balance, eye tracking, and motion sickness, among others. 5. Physical performance tests. Tests for muscular strength/endurance, cardiorespiratory functioning, and urinalysis, among others.
Starling, no date	Cognition	Armed Forces Qualification Test and other composite scores from the Armed Services Vocational Aptitude Battery	Tank crew weapons system performance	Table VIII, Gunnery Qualification results
	Cognition	Armed Forces Qualification Test	Tank crew weapons system performance	Table VIII, Gunnery Qualification results
Rosa, 1985	Fatigue	1. Stanford Sleepiness Scale	1. Data entry	1. Accuracy of 5 digit entry on computer

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		2. Questionnaire for Subjective Symptoms of Fatigue	2. Cognitive abilities	1. Grammatical reasoning. 2. Williams Work Memory 3. Digit Addition
			3. Perceptual motor	1. Auditory reaction time 2. Visual reaction time
			4. Sensory acuity	Two-point auditory discrimination
			5. Motor Skills	1. Response alteration, performance (tapping) 2. Hand steadiness
Marashian, 1982	Fatigue	Defined by statements in a questionnaire	Combat effectiveness	Likert scale questionnaire administered to combat veterans.
Marashian, 1982	Combat experience	Defined by statements in a questionnaire	Combat effectiveness	Likert scale questionnaire administered to combat veterans.
Marashian, 1982	Leadership	Operationally defined by statements in a questionnaire.	Combat effectiveness	Questionnaire (Likert Scale of 1 (strongly agree) to 5 (strongly disagree). Administered to combat veterans.
Marashian, 1982	Training	Operationally defined by statements in a questionnaire.	Combat effectiveness	Likert scale questionnaire administered to combat veterans.
Marashian, 1982	Stress (Ability to withstand fire and possibility of survival).	Defined by statements in a questionnaire.	Combat effectiveness	Likert scale questionnaire administered to combat veterans.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
Navaco, et.al., 1983	Stress	1. Recruit Stress Scale (reliability = .82; employs a Likert 1 (very little stress) to 5 (very much stress) scale). 2. DI Stress Scale (reliability = .84; employs a 0 (no stress) to 9 (great deal of stress) scale.) 3. Jenkins Activity Survey.	N.A.	N.A.
Van Nostrand, no date.	Sleep loss	Questionnaire which asked respondents the number of hours they expected to work and sleep during combat.	N.A.	N.A.
Walker and Smith, no date.	Cognition and leadership	Cognition: 1. Psychomotor - one and two hand tracking tests. 2. Special abilities - Orientation & Mazes tests. 3. General aptitude -	Tube-launched (optically-tracked, wire-guided missile performance.	1. M70 Score--a measure of TOW tracking ability. 2. Live fire TOW performance.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		General Technical (GT) score from the Armed Services Vocational Aptitude Battery.		
		4. Leadership - Assessment of Background and Life Experiences (ABLE) Test.		
Walter Reed Institute of Research, no date.	Will	Soldier Will Survey (semantic differential and Likert scales are used to gather information about feelings toward the unit and battalion).	N.A.	N.A.
Siebold, 1987	Cohesion	Questionnaire on Combat Platoon Cohesion (includes ratings of vertical and horizontal bonding. Reliability coefficients = .7 to .8).	N.A.	N.A.
Knudson, et.al., 1985	Cohesion	Company Perceptions Scale. (33-item questionnaire which uses a 1 (strongly agree) to 5 (strongly disagree) scale.	N.A.	N.A.
Braun, 1983	Cohesion	1. Company Commander's	N.A.	N.A.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		Survey (question-answer and checklist formats.) 2. Individual survey questionnaire (uses checklists and semantic differential technique.)		
Siebold & Kelly, 1987	Cohesion (For all these scales, subjects respond to statements regarding cohesiveness.)	Horizontal Affective Scale (reliability = .88). Horizontal Affective Leaders (reliability = .72). Horizontal Instrument (reliability = .82). Vertical Affective (reliability = .91). Instrument (reliability = .90). Organizational Affective - Pride (reliability = .85).	N.A.	N.A. Organizational Affective - First Termers (reliability = .95) Organizational Affective - Leaders (reliability = .95).
Griffith, 1987	Cohesion & Morale	Unit Cohesion and Morale Scale (Measures company combat confidence, senior command confidence, small-unit commander confidence, concerned leadership, sense of	N.A.	N.A.

FIGURE F-3

Techniques Used to Measure Soldier Dimensions and Performance

Source	Soldier Dimension	How Measured	Soldier Performance	How Measured
		pride, unit social climate, and unit teamwork. Reliability coefficients range from .82 to .91. Validity of scal s established by factor analysis.)		
Manning 1980	Cohesion	Measurement of Cohesion Scale (questionnaire assigns 2,1, and 0 points for high, low, and zero cohesion responses. Reliability coefficient = .98. Higher cohesive scores for small groups vs large groups of soldiers is offered as evidence of validity.	N.A.	N.A.
Sterling, 1984	Leadership	Leadership Survey (requires response from 1 to 5 regarding frequency of occurrence of rating from below average to above average.	Effectiveness of units	Evaluation questionnaires.
Capretta, et.al., 1960	Stress	1. Subjective Stress Scale (a quantified objective checklist.)	Assemblage and disassemblage of M1 rifle.	Time to perform task.

Figure F-4
Experimental Objectives and Statistical Analysis Techniques Used in Soldier Dimension Studies

REFERENCE	EXPERIMENTAL OBJECTIVE	STATISTICAL METHODOLOGY
Martin, 1981	Comparison of actual and perceived tolerance to prolonged physical exercise across treatment (no sleep) and control conditions.	t-test
Martin & Gaddis, 1981	Comparison of actual and perceived fatigue across treatment (no sleep) and control conditions.	t-test
Stamper, 1978	Prediction of physical endurance from human factor information.	Pearson product moment correlations and multiple step-wise regression.
Horne, 1986	Prediction of weapons performance from human factors inputs.	Multiple regression.
Marashian, 1982	Analyzed survey data to determine relationship between human factors and combat effectiveness; and relative importance of different human factors.	t-test, factor analysis, Pearson product moment correlation, Spearman rank correlation.
Fine and Kobrick, 1985	Comparison of mental performance across hot and MOPP vs Control conditions.	Factorial analysis of variance.
Angus and Heslegrave, 1985	Compared progressive cognitive performance declines as a function of time of continuous work with no sleep.	Analysis of variance.
Siegel, et.al., 1980	Determination of relationship of multiple human factors with soldier performance.	Impact vector model & progressive degradation function (See pages 53-57 of original source); and multiple regression.

REFERENCE	EXPERIMENTAL OBJECTIVE	STATISTICAL METHODOLOGY
Walker & Smith, no date	Prediction of soldier performance (M70 TOW Simulator) from tracking/spatial and General Technical scores.	Multiple regression.
Braun, 1983	Prediction of cohesion from multiple unit variables.	Factor analysis and multiple regression.
Novaco, et. al., 1983	Comparison of successful vs unsuccessful Drill Instructor marines across psychological, behavioral and physiological variables.	Analysis of variance, analysis of covariance, Chi square, and Pearson product moment coefficients.
Storm, 1980	Comparison of sleep and fatigue prior to, following, and during 30-hour continuous airborne mission.	Factorial analysis of variance.
Haslam, 1985	Comparison of cognitive performance of treatment (limited sleep) vs controls.	Analysis of variance.
Scribner, et.al., 1986	Prediction of M1 tank crew performance from human factors.	Multiple regression.
Tziner & Edner, 1985	Comparison of tank crew performance as a function of ability and motivation of crew.	Factorial analysis of variance using multiple regression.
Sterling, no date	Relationship of tank crew performance with ASVAB and other human factors.	Pearson product moment correlation and Chi square.
Wallace, 1982	Relationship between tank crew performance with ASVAB variables.	Pearson product moment correlation and factorial analysis of variance.
Ellis, et. al., 1986	Comparison of beginning and ending tank performance levels with intervening simulated CONOPS in a contaminated environment.	t-test

REFERENCE	EXPERIMENTAL OBJECTIVE	STATISTICAL METHODOLOGY
Van Nostrand, * no date	Comparison of survey responses regarding "guestimates" of sleep during combat conditions for differences in duty position, specialty, rank, and echelon.	Visual inspection of means.

* How much do soldiers sleep?

Griffith, 1987	Determined relationship between cohesion and weapons (M16) qualification results.	Correlation coefficients (specific technique not specified in report).
Manning, 1980	Determined relationship between cohesion and multiple performance measures (ARTEPs, SQTs, etc.) of several Army battalions.	Spearman rank correlation.
Young and Auton, no date	Compared estimated soldier performance decrements as a function of severity of radiation sickness and physical demands of task.	Two-way Anova and Newman-Keuls.
Glickman, et.al., no date	Determined amount of variance in soldier performance degradation that was explained by six physiological factors associated with radiation exposure.	Step-wise multiple regression.

Figure F-5. Advantages and Disadvantages of Using Simulated Environment or Simulation Device

Advantages

- Uses state of art equipment and technology.
- Has high visibility and credibility with Army leadership.
- Results considered relevant to current doctrine and scenarios.

Disadvantages

- Artificiality.
- Difficulty assigning soldiers to many different combinations of different human factor conditions.
- Difficulty controling extraneous variables.
- Difficulty manipulating some variables (e.g. sleep loss, fatigue).
- Lack of validation with real combat.
- Logistical problems with obtaining permission, arranging, and conducting research.
- Expensive.

Figure F-6. Advantages and Disadvantages of Using Previously Collected Data

Advantages

Quick.
Easy.
The research has been done--just analyze data.

Disadvantages

Good soldier dimensions data is hard to find.
Data is often expensive.
Often requires extensive conversion of data to obtain relevant information.
Types of analysis limited by the kind of data collected and the way in which it was collected.
Information regarding accuracy, reliability, and validity of data is often unavailable.

Figure F-7. Advantages and Disadvantages of Using Subject Matter Expert Panels

Advantages

Quick.

Easy to obtain general impressions.

Disadvantages

Too subjective.

Lacking in scientific rigor.

Lacking in quantitative precision needed to determine the simultaneous effects that multiple independent variables have on soldier performance.

Problem with reliability and validity of results.

Reduced credibility with Army leadership (i.e., It's just another SME panel).

What people say and do might not coincide.

Reduced visibility and credibility with Army leadership (i.e., It's just another SME panel).

Figure F-8. Advantages and Disadvantages of Surveying Combat Veterans

Advantages	Disadvantages
Easy to manipulate large numbers of variables to determine simultaneous impact that multiple independent variables have on soldier performance.	Equipment and scenario used in past are obsolete.
Easy to control extraneous variables.	Perceptions are blurred with passage of time.
Realism.	Reduced credibility with Army leadership (i.e., It's just another survey).
Draws on experience of those with actual combat experience.	What people say and do might not coincide.
Inexpensive.	

Figure F-9. WAYS TO MEASURE SOLDIER DIMENSIONS VARIABLES

Variable	How to measure
Sleep loss	Ask crew members how much sleep they got during the last 24 hours. Use the average response for all crew members as the measure of sleep loss.
Fatigue	Ask crew members how many hours each has performed during the last 24-hour period. Use the average response for all crew members as the measure of fatigue.
Stress/anxiety	Ask crew members to respond to the following question: Right now my stress/anxiety level is: 1 2 3 4 5 6 7 8 9 10 very low — moderate — very hi Use the average response for all crew members as the measure of stress/anxiety.

Figure F-9. WAYS TO MEASURE SOLDIER DIMENSION VARIABLES (Continued)

Variable	How to Measure
Morale	Ask crew members to repond to the following question: Right now the morale of this crew is: 1 2 3 4 5 6 7 8 9 10 very low — moderate — very hi Use the average response for all crew members as the measure of morale.
Cohesion	Ask crew members to respond to the following question: Disregarding other factors such as location of duty assignment, I would rather: 1 2 3 4 5 6 7 8 9 10 work with a different crew — work with present crew Use the average response for all crew members as the measure

Figure F-9. WAYS TO MEASURE SOLDIER DIMENSION VARIABLES (Continued)

Variable	How to Measure
Motivation/will	Ask crew members to respond to the following question: Right now my motivation/will to perform "combat" duties is: 1 2 3 4 5 6 7 8 9 10 very low … moderate … very hi Use the average response for all crew members as the measure of motivation/will.
Previous experience	Ask crew members to respond to the following item: The number of total months I have worked on a crew like this one since training is ______ months. Use the average response for all crew members as the measure of experience.

Figure F-9. WAYS TO MEASURE SOLDIER DIMENSION VARIABLES (Continued)

Variable	How to Measure
Cognition	Use crew average of Armed Services Vocational Aptitude Battery scores (Armed Forces Qualification Test (AFQT) or Area Composition scores).
Leadership	Ask crew members to respond to the following item: I would rate the leadership of this crew as: 1 2 3 4 5 6 7 8 9 10 very ineffective · moderately effective · very effective Use the crew average as the measure of leadership quality.

Figure F-10. KIND OF DATA NEEDED FOR SOLDIER DIMENSIONS STUDIES

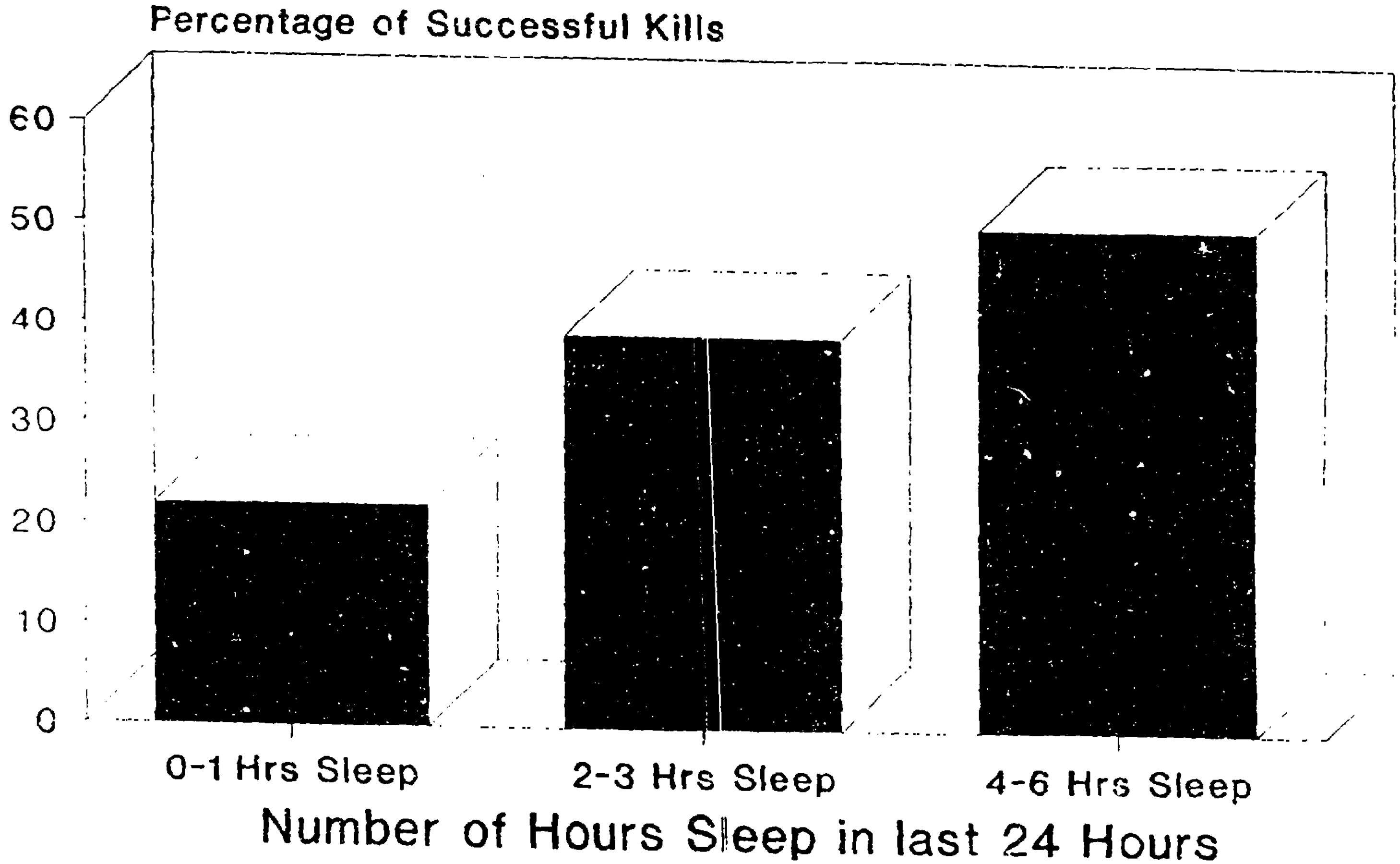
Sleep*	Fatigue**	Stress/anxiety***
2.5	12.1	3.5
3.1	10.5	9.0
5.5	15.5	4.5
1.5	8.0	3.1
6.0	18.4	6.9

*Based on average number of hours sleep for a crew in the last 24 hours.

**Based on the average number of continuous work hours performed for a crew in the last 24 hours.

***Based on the average response for crews on a stress/anxiety scale which ranges from 1 (very low) to 10 (very high).

Figure F-11. FREQUENCIES DATA SHOWING RELATIONSHIP BETWEEN SLEEP LOSS AND PERFORMANCE



Please note: Data is hypothetical.

Figure F-12. DATA ANALYSIS PLAN

- Compare changes in crew performances across different levels of sleep/fatigue and hours on the battlefield:

		Time on the Battlefield			
		Baseline	24 hrs	36 hrs	48 hrs
	Lo				
Sleep Loss	Med				
	Hi				

		Time on the Battlefield			
		Baseline	24 hrs	36 hrs	48 hrs
	Lo				
Fatigue	Med				
	Hi				

APPENDIX G

ATRC-B 1 April 1990

MEMORANDUM FOR RECORD

SUBJECT: Significant Staffing Comments Not Incorporated into "Soldier Dimensions in Combat Models"

1. Significant staffing comments not incorporated in the report follow. These staffing comments were added to the study report at Appendix G.

a. The literature search was too limited in scope. This shortcoming is a practical limitation which is due to limited resourcing (originally .5 PSY). Realization of this problem compelled us to limit our consideration to studies conducted within the last five years. While every study conducted within this time frame is not referenced, we feel those which are provide a representative cross section of work being done in this area.

b. A survey is less desirable than actual testing in a simulated environment. Testing in a simulated environment was added as a methodological option. Advantages and disadvantages of these and other alternatives are provided in Appendix F of the report. The survey method should not be dicarded because it provides an element of realism that is missing from other methologies. Also, many different combinations of human factor conditions can be more easily manipulated with this option than with others.

c. The Vietnam Veteran sample is inappropriate because

(1) It is a highly biased sample. Neither simulations, nor wargames, nor study of battlefield conditions will--in and of themselves-- inculcate a comprehensive understanding of the stark terror of real battlefield conditions. Given the fact that surveys are used to determine the relationship between human factors and soldier performance, we can think of no other group that would be more appropriate.

(2) It is hardly representative of unseasoned troops facing hostile fire for the first time. Combat experience is one of the human factor conditions which is varied on the survey. Given the fact that surveys are used, we can think of no better group to ask than combat veterans who have first-hand knowledge regarding behavior of unseasoned troops.

(3) The lapse of time since the Vietnam conflict. Traumatic events are less likely to become "fuzzy" with the passage of time than routine experiences. Embellishments will be minimized by the strict adherence to a very specific response format.

(4) Significant differences exist between Vietnam and other battlefield scenarios. Although differences do exist, the American soldier in Vietnam experienced many of the same conditions, such as sleep loss, fatigue, severe stress, and so on, as our soldiers will face on future battlefields. The impact of different scenarios on human factors and soldier performance is deserving of future study.

d. The proposed Human Factors Model (Figure 4-2) is arbitrary and of questionable validity. This model was presented as a conceptual scheme to be used to classify human factors until a future validation study can be performed. The report outlines a factor analysis procedure to be used in providing evidence (or lack thereof) of validity. Characteristics of the final model should reflect factors which emerge naturally from the data, rather than preconceived notions about what form they should take.

e. The study failed to address the sensitivities of different models to changes to inputs which might be altered as a result of performance degradation. Neither does it take into account the fact that model processes might have to be improved to adequately portray human factors. Investigation of these areas was beyond the scope of the present study. Knowledge regarding the extent to which soldier performance is expected to vary needs to be addressed before the determination can be made whether changes to model inputs will be large enough to effect model outputs of various models. The same can be said for determination of changes required in current models. Nevertheless, these are very important points that require future study.

f. The study assumes a linear relationship exists between human factor predictors and soldier performance. The methodologies (factor analysis followed by multiple regression) were selected because they provide a means to deliver an equation which would adjust soldier performance in view of different combinations of human factor inputs. If relationships are nonlinear, data transformations such as natural logs, square roots, and reciprocals can usually be used to coax data to linearity. If transformations fails to work, curvilinear regression can be used.

g. The Bradley Fighting Vehicle used on the survey did not exist during Vietnam.

(1) The Bradley is only one of many weapons systems

that could be used on the survey. The report clearly states that other systems could be used, as long as outputs from the system serve as significant inputs to models. (Inputs must be "significant" in that their changes would make a difference in combat outcomes.)

(2) This study gave rise to two conflicting needs: The need to use war machinery portrayed in current models versus the need to draw on the experience of soldiers with first-hand combat experience. This presents a delimma. If we use Vietnam era equipment, results will not have relevance to present models. But if we use current equipment, Vietnam veterans probably have not used it--at least not in Vietnam. The use of the Bradley is seen as a compromise between these needs. The problem of lack of experience is mitigated by the use of only veterans on active duty status. Most have sufficient familiarity with the Bradley and with weapons firing in general to be able to provide estimates of performance degradation using the Bradley.

(3) Judgments regarding weapons performance are made relative to the average weapons firing performance for the Bradley. For this reason, lack of experience with this particular system is not nearly as significant of a liability as it would be if absolute judgments were made.

(4) Finally, anyone conducting research in this area will be faced with this problem. But if only soldiers in a specific MOS were used who have training and experience with a specific weapons system, like the Bradley, results can be generalized only to that group of soldiers, rather than to combat soldiers in general. This approach would require separate studies for every major weapons systems, which would probably become obsolete before studies were completed. The use of a broader combat soldier sample which requires respondents to make judgments relative to average performance on a familiar weapons system is the preferable method.

h. The erroneous assumption is made that the frequency that different human factors are cited in current literature (depicted in Figure 4-1) provides an indication of the importance of each factor in explaining soldier performance. Figure 4-1 provides only a rough indication of the extent to which different factors are cited in current literature. The assumption of relative importance here is made only in a literary (i.e., factors mentioned more often are probably considered more influential in the collective mind of the military establishment), rather than an analytic, sense. This information was gathered as background for EEA#6, which provides an objective means to analytically determine the relative importance of different human factors.

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