DEFENSE WOMEN'S HEALTH RESEARCH PROGRAM

FINAL REPORT:

THE EFFECTS OF SUSTAINED OPERATIONS ON FEMALE SOLDIER PERFORMANCE

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Many studies have evaluated male soldiers from combat arms occupations during sustained operations. However, it is not known to what extent these findings can be applied to female soldiers for determining whether Army training and doctrine ensure their military effectiveness. Therefore, the major objective of this study was to compare the effects of sustained operations of male and female soldiers in a field environment. The field study examined cognitive performance; subjective mood, fatigue, and environmental ratings; and physiological measurements. Sleep deprivation and time-of-testing factors were evaluated for these measures. The study's secondary objective was to describe changes in the soldier's activity levels and performance assessments of field work. A total of 26 soldiers (13 females and 13 males) from the 180th Transportation Battalion, stationed at Ford Hood, Texas, participated in this study. One of the main objectives of this study was to determine if sustained operations affected women and men differently. With the exceptions of oral temperature and logical reasoning, gender differences during sleep deprivation were not found. Results indicate there would be minimum impact on extended military operations involving women participants.

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TERESA A. TREADWELL May 1997

PI - Signature Date

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INTRODUCTION

Today's working environment often demands high productivity and performance versatility from its employees. These demands have arisen from business practices such as just-in-time manufacturing, continuous customer servicing, nearly instantaneous communication connectivity, improved transportation, and a streamlined work force. To maintain these productivity and performance characteristics, several occupations or work situations may require prolonged and continuous work periods. Often, employees must sustain effective cognitive and physical performance beyond 8 to 10 hours' duration, unaware of future rest or work termination times (Englund & Krueger, 1985).

As the use of continuous work periods has become important to the functioning of civilian business, it has become more paramount when conducting military operations. Technological advances in equipment, doctrinal changes, broadened mission requirements, and budgetary constraints have extended soldier performance demands and operational duration. This has been evident during missions in Kuwait, Panama, Haiti, and Somalia. A smaller armed force, deployed according to the force-projection approach to varied humanitarian and war-fighting mission scenarios, may require sustained work periods for pre-deployment, deployment, insertion, mission propagation, and completion phases. The inter-service cooperation and coordination needed to prosecute the "quick decisive" military victory or mission success also uses protracted work periods.

Belenky, Krueger, Balkin, Headley, and Solick (1987) explain that the maintenance of a continuous operations schedule in the military would preclude the usual 6 to 8 hours of sleep per 24 hours of operations. All branches of the armed services have employed continuous operations schedules. With regard to the Army, Field Manual 22-9 (U.S. Army, 1991) explains the use of continuous operations and discusses its implementation. The field manual (U.S. Army, 1991) defines continuous operations (CONOPS) in terms of continuous land combat that affords some opportunity for sleep periods, brief or fragmented in nature.

During sustained operations, time-of-day or circadian factors may also contribute to differences in performance, psychological state, and physiological functioning (Ryman, Naitoh, & Englund, 1984). Generally, circadian rhythms of performance or subjective measures reveal peaks at late morning or afternoon hours and troughs during late evening or early morning hours (Krueger, 1991). Patterns in subjective ratings can help predict performance rhythmicities.

Most information concerning sleep loss and circadian effects from sustained operations have been made through the use of male subjects. The few studies that have been performed with females have been conducted in laboratory settings and produced findings similar to male subjects' results. No research involving a direct comparison of female and male performance during sustained operations has been done.

Many studies have evaluated male soldiers from combat arms occupations during sustained operations (Krueger, 1989; 1991). However, it is not known to what extent these findings can be applied to female soldiers for determining whether Army training and doctrine ensure their military effectiveness. Little field data have been obtained regarding female soldier performance in the combat support or combat service support career fields. Women's progress in the Army, encouraged by recruitment policies and expansion of ground combat assignment policy for various career fields (Tice, 1994; Morganthau, Bogert, Barry, & Vistica, 1994), point to the timely need for information on female performance in extended operations. Therefore, the major objective of this study was to compare the effects of sustained operations of male and female soldiers in a field environment. The field study examined cognitive performance; psychological measurements, fatigue, environmental ratings; and physiological measurements. Sleep deprivation and time-of-testing factors were evaluated for these measures. The study's secondary objective was to describe changes in the soldiers' activity levels and performance assessments of field work.

METHOD

A total of 26 soldiers (13 females and 13 males) from the 180th Transportation Battalion, stationed at Fort Hood, Texas, participated. The study covered 6 days that were delineated into control and experimental sessions. During control sessions, administrative and regulatory tasks were conducted, along with baseline data collection of psychological, performance, and physiological measures. The experimental sessions encompassed 48 hours of sustained operations with training exercise activities and collection of psychological, performance, and physiological measures every four hours. With this testing schedule, there are six non-sleep deprived tests, and thirteen sustained operations test periods.

The first control day of the study included administrative processing and sleep regulation of the test participants. During the in-processing period, experimenters administered a set of psychological trait questionnaires: the General Efficacy Measure (GEM; Sherer et al., 1982), the Multiple Affect Adjective Check List - Revised (MAACL-R; Zuckerman & Lubin, 1985), and the Zuckerman Kuhlman Personality Questionnaire III-Revised (ZKPQ; Zuckerman, Kuhlman, Thornquist, & Kiers, 1991). These psychological trait measures have been designed to periodically assess personality traits, coping resources, and self-perceptions that may relate to performance of cognitive and other soldier tasks (Blewett, Ramos, Redmond, & Fatkin, 1993; Blewett, Redmond, Modrow, Fatkin, & Hudgens, 1994; Fatkin & Hudgens, 1994; Fatkin et al., 1990). They completed the Life Events Form to assess the amount and type of stressors the soldiers may have experienced at the time of the study, along with their available resources, and the General Information Questionnaire which includes demographic information.

Experimental sessions occurred during a training exercise which included field deployment, site preparation, military operations on urban terrain (MOUT), and recovery operations. When soldiers were not participating in the practice and record performance of the standardized test periods, they were engaged in unit scheduled activities.

Standardized test periods were used to regularly examine the effects of sustained operations on soldier performance, psychological perceptions, and physiological functioning. These periods allowed delineation of circadian rhythm and sleep loss contributions to the soldiers' effectiveness. Each test period occurred every four hours, starting at 0800, lasted approximately 60 minutes, and had four components: psychological measures, a cognitive performance battery, a manual dexterity task, and physiological measures. Daily Activity Log sheets were kept by each soldier to track their activity levels, performance effectiveness, and consumption of food, drink, caffeine, and cigarettes. Also, any sleep or rest time was noted.

Psychological measures consisted of a battery of questionnaires designed to examine changes in specific affects in response to stressful situations, sleepiness level, incidence and severity of symptoms associated with physical stressors, and their level of confidence in their ability to do well with reference to anticipation of present experiences. To assess changes in cognitive performance, subjects completed the Cognitive Performance Assessment for Stress and Endurance (CPASE, Mullins, 1996). The cognitive tasks consisted of word recall, logical reasoning, addition, and spatial rotation. A Manual Dexterity Board was used to evaluate fine motor performance. Physiological measures comprised of oral temperature, hand grip strength, and heart rate.

RESULTS AND DISCUSSION

Psychological Measures

Significant correlations obtained between performance and trait anxiety and hostility reinforce the hypothesis regarding individual differences in susceptibility to the effects of sleep deprivation. Individuals who characterized themselves as moderately anxious and somewhat aggressive demonstrated better performance on logical reasoning tasks and on the spatial rotation tasks. During the sustained operations period, soldiers who typically maintain a moderate level of arousal seemed to perform well on logical reasoning and spatial rotation tasks. It is possible that, in spite of their increasing experience of sleepiness and fatigue, these soldiers were able to create an appropriate level of arousal to generate the vigilance necessary to perform well, but not so stressful as to interfere with this process.

There were no significant gender differences for any of the trait measures. Overall life stress was rated relatively high for soldiers who described themselves as generally feeling anxious or disappointed in themselves. Soldiers who reported high life stress perceived the sustained operations as more stressful. Those who reported a willingness to perform well were less fatigued in the late evening hours.

The General Efficacy Measure provides a self-assessment of one's ability to master new situations or ability to adapt to changing circumstances. This ability is considered to be a composite of past success and failure experiences and influences the individual's perception of how they might perform on military tasks (Sherer et al., 1982). Soldiers who reported increases in fatigue on both the ESQ fatigue subscale and the Stanford Sleepiness scale scored lower on General Efficacy. The same soldiers that reported lower levels of General Efficacy perceived the sustained operations periods as more stressful than those who had higher levels of Efficacy.

Throughout the sustained operations period, men reported higher levels of Depression and Negative Affect while women experienced a slightly higher sense of well being then men. All of the stress perception levels with the exception of the SRE, significantly increased on the second day of sleep deprivation. These increases in stress levels and greater variability on SUSOPS day 2 were high enough to override or alter circadian patterns for the MAACL-R Depression, Hostility, and Negative Affect scores. Findings that sleep loss degrades state measures are in congruence with previous research (Krueger, 1989).

The expected overall circadian pattern was found for the psychological measures on baseline day. During the sustained operations period the Subjective Stress Scale and the Stanford Sleepiness Scale showed similar circadian patterns. Circadian patterns were not found for Positive Affect, Depression, Hostility, or Negative Affect. These findings indicate that circadian rhythms did not significantly affect individual's stress levels as measured by the MAACL-R. These scores did worsen across sessions, but significant day by session interactions indicate circadian patterns for the psychological measures were altered by sleep deprivation. The Subjective Stress Scale gives a measure of global stress, indicating the test participants showed some circadian variation overall. In breaking this overall measure into subcomponents, the similarity between the Subjective Stress Scale and the Stanford Sleepiness Scale indicate the overall circadian effect is due to variations in reported sleepiness.

The main objective of this study was to determine if sustained operations affect men and women differently. The lack of any significant gender by sessions interactions indicate there are no circadian differences between males and females, for the psychological measures reported here.

Physiological Measures

All physiological measurements showed an obvious circadian periodicity for both men and women, with rising values during the 0800, 1200 and 1600 measurement periods. Values generally reached a peak at 1600 and declined in subsequent measurement periods (2000 and 2400) with troughs at 0400. The circadian patterns are in consonance with previous studies that have demonstrated rhythms in oral temperature (Froberg, 1977; Harma, Ilmarinen, Knauth, Rutenfranz, & Hanninen, 1988; Ilmarinen, Ilmarinen, Korhonen, & Nurminen, 1980; Reilly, Robinson, & Minors, 1984; Winget, DeRoshia, & Holley, 1985), grip strength (Hislop, 1963; Ilmarinen, et al., 1980; Reilly, 1990; Winget, et al., 1985; Wright, 1959) and resting heart rate (Ilmarinen, et al., 1980; Kleitman, 1923; Winget, et al., 1985).

Numerous studies have examined the influence of sleep deprivation on core temperature, and, with a few exceptions, show a decline in core temperature with sleep deprivation. Core temperature drops to a lower level as the period of sleep deprivation increases. Our study is the first to compare temperature for men and women in the same conditions following sleep deprivation. In both men and women, temperatures on SUSOPS2 were reduced relative to SUSOPS1. While there were no gender differences on SUSOPS1, the women had considerably lower temperatures during SUSOPS2.

One reason for this may have been the body surface area to body mass ratio (BSA/BM). Women generally have a greater BSA/BM than men (Benke & Wilmore, 1974) which allows them to dissipate heat more efficiently. However, in this study the body surface area to body mass ratio did not differ between men and women, thus both presumably had an equal ability to dissipate heat. Further separation of the soldiers into groups of four, with the highest and lowest body surface to mass ratios for each gender, did not reveal any differences in temperature. While it is not clear why, the women's ability to thermoregulate was affected to a greater extent than that of the men on the second day of this scenario.

There were no significant declines in hand grip strength over the course of the study and no alterations in the circadian pattern. Men were significantly stronger than women throughout the test period. Women's right hand grip strength was 58%-62% that of the men. These averages agree with studies comparing the relative grip strength of military men and women (Sharp et al., 1980; Nordesjo & Schele, 1974).

Heart rate is a very labile physiological measure easily influenced by physical activity and the level of physical fitness (Astrand & Rodahl, 1977; McArdle, et al., 1986). In the present study we took some care to reduce physical activity prior to measurements. The heart rate curve does show a circadian pattern that is maintained throughout the scenario. Women maintained a higher heart rate throughout the scenario. It is known that individuals who are less fit maintain higher resting heart rates because of their reduced stroke volume (Astrand & Rodahl, 1977; McArdle et al., 1986). However, there are indications that the cardiorespiratory fitness levels of the men and women in this study are similar since their self-reported endurance and two-mile run percentile rankings were similar. Thus, differences in fitness levels of the men and women cannot explain the higher heart rate of the women.

Performance Measures

As for the psychological and physiological data, performance measures reflected an obvious circadian pattern. All of the tasks, with the exception of logical reasoning, showed significant main effects for sessions with performance showing a tendency to decline to its lowest point at the 0400 test period. These performance trends were as expected from earlier research in the field (Bjerner, Holm, & Swensson, 1955; Krueger, 1991). Froberg (1977) found performance was generally better during the day than at night, but also failed to find this day/night trend for a deductive reasoning task.

Of specific interest to this study are any gender differences in performance, especially during sustained operations. An overall gender difference was found for manual dexterity, with men making more attachments than women. This finding is in congruence with recent research that has found speed advantages for men when the task involved placement of larger objects (Kilshaw & Annett., 1983). This was an overall effect that didn't change as the individuals were deprived of sleep. Logical reasoning was the only cognitive task to show a significant gender difference with sleep deprivation. Males tended to complete more evaluations than females over the course of the study. Women maintained relatively stable levels of accuracy throughout the three performance days while men tended to improve on SOSOPS2. It's important to note that the improved accuracy scores for men on SUSOPS2 were achieved for lower evaluation completion scores. Male accuracy improved but the number of items they completed to obtain this accuracy declined. Accuracy scores were obtained by dividing the number of items completed by the number of items correct. An examination of the raw number of correct responses for men for SUSOPS1 and SUSOPS2 shows mean performance on the second day being lower except for the 1600 and 2000 test periods. There were no significant gender differences in the psychological data to account for these findings. As this is the first research to directly compare female and male performance during sustained operations, further study is needed to understand these gender differences.

CONCLUSIONS

Most of the prior research concerning sustained operations has used male subjects. This groundbreaking research is the first to directly compare male and female performance during sustained operations. One of the main objectives of this study was to determine if sustained operations affected women and men differently. With the exceptions of oral temperature and logical reasoning, gender differences during sleep deprivation were not found. The gender differences for logical reasoning were the result of an increase in the men's accuracy on the second day of sleep deprivation. Therefore the womens' relatively stable levels of accuracy throughout the three performance days indicate there would not be problems during an extended mission. The findings of this study indicate there will be no significant impact on extended military operations attributable to the inclusion of female soldiers.

DEFENSE WOMEN'S HEALTH RESEARCH PROGRAM ANNUAL REPORT: THE EFFECTS OF SUSTAINED OPERATIONS ON FEMALE SOLDIER PERFORMANCE

BACKGROUND

Introduction and Relevance

Today's working environment often demands high productivity and performance versatility from its employees. These demands have arisen from business practices such as just-in-time manufacturing, continuous customer servicing, nearly instantaneous communication connectivity, improved transportation, and a streamlined work force. To maintain these productivity and performance characteristics, several occupations or work situations may require prolonged and continuous work periods. Often, employees must sustain effective cognitive and physical performance beyond 8 to 10 hours' duration, unaware of future rest or work termination times (Englund & Krueger, 1985). These work situations include medical services, fire fighting, civil emergency or disaster operations, search and rescue, or change-over periods in manufacturing plants. The focus on human sleep needs and functioning has become intensified. Even popular literature has reported on these topics: increased melatonin use for sleep regulation and performance enhancement when encountering time zone changes; sleep research clinics characterizing people's sleep disorder patterns; and the adverse effects of sleep deficit on work performance, mood, and social behavior that have been manifested by our society's scheduling constraints (Thomas, 1996).

As the use of continuous work periods has become important to the functioning of civilian business, it has become more paramount when conducting military operations. Technological advances in equipment, doctrinal changes, broadened mission requirements, and budgetary constraints have extended soldier performance demands and operational duration. This has been evident during missions in Kuwait, Panama, Haiti, and Somalia. A smaller armed force, deployed according to the force-projection approach to varied humanitarian and war-fighting mission scenarios, may require sustained work periods for pre-deployment, deployment, insertion, mission propagation, and completion phases. The inter-service cooperation and coordination needed to prosecute the "quick decisive" military victory or mission success also uses protracted work periods.

In the past, the military has examined sustained work through laboratory, simulation, and field studies of combat arms occupations. Therefore, little field data have been obtained regarding female soldier performance or the combat support or combat service support career fields. Women's progress in the Army, encouraged by recruitment policies and expansion of ground combat assignment policy for various career fields (Tice, 1994; Morganthau, Bogert, Barry, & Vistica, 1994), point to the timely need for information on female performance in extended operations.

Sustained Operations in the Military

Belenky, Krueger, Balkin, Headley, and Solick (1987) explain that the maintenance of a continuous operations schedule in the military would preclude the usual 6 to 8 hours of sleep per 24 hours of operations. All branches of the armed services have employed continuous operations schedules. With regard to the Army, Field Manual 22-9 (U.S. Army, 1991) explains the use of continuous operations and discusses its implementation. The field manual (U.S. Army, 1991) defines continuous operations (CONOPS) in terms of continuous land combat that affords some opportunity for sleep periods, brief or fragmented in nature.

Two types of continuous operations may be employed: extended operations (work that proceeds continuously with short breaks during a typical shift system, yet is prolonged in length beyond the normal duty day); and sustained operations (SUSOPS) (planned or unplanned continuous work performance without rest or sleep, during which the worker is expected to function as long as possible) (Englund & Krueger, 1985). While extended operations occur more frequently during military operations, sustained work periods are used sparingly. Because resources of U.S. forces are limited, employment of sustained operations would require units to perform with minimal recovery time. Therefore, it is imperative to examine worker effectiveness in sustained operations and recovery requirements.

Methodological Approaches to Sustained Operations Research

The study of worker performance in extended and sustained operations has progressed in two separate directions (Belenky et al., 1987). Some experimenters have examined continuous operations with regard to shift work issues: productivity levels, work schedule preferences, rest requirements, shift rotations, worker selection and health, and quality of life issues (Alluisi &

Morgan, 1982; Rentos & Shepard, 1976; Tepas, 1979). Other research has focused on sleep deprivation and work performance to include sleep requirements for maintaining sustained operations, sleep stages and mechanisms, circadian rhythms of performance, mood effects, and physiological functions (Dinges, Whitehouse, Orne, & Orne, 1988; Kleitman, 1963; Mackie, 1977; Webb, 1982).

Morgan and Pitts (1985) indicate that the military is the most urgent user of research about sustained operations. Many of these studies for military organizations have examined sleep deprivation and work performance to develop information for prediction of performance capabilities along with accompanying physiological and psychological effects. In addition, they have aided development of methodologies for performance sustainment through specialized work and rest cycles or pharmacological intervention.

This research about sleep deprivation and work performance has employed different study methodologies during sleep loss periods. Many researchers have used laboratory evaluations with periodic testing of performance using selected cognitive tasks (Babkoff et al., 1985; Dinges et al., 1988; Froberg, 1977; Webb, 1985). Other studies involved a simulated work environment providing work-related tasks (Elsmore, 1994; Angus & Heslegrave, 1985; Banderet, Stokes, Francesconi, Kowal, & Naitoh, 1981; Drucker, Cannon, & Ware, 1969) or a field study approach using military operations with performance evaluation (Ainsworth & Bishop, 1971; Banks et al., 1970; Bugge, Opstad, & Magnus, 1979; Haslam, 1981, 1984; Kant, Landman-Roberts, Smith, Cardenales-Ortiz, & Mougey, 1985).

These studies have monitored a variety of performance tasks involving vigilance, short-term memory, computation, search and identification, logical reasoning, reaction time, decision-making, planning, psycho-motor functioning, and military job skills such as marksmanship, driving, and equipment maintenance. Many of these tasks have been standardized and are available from testing services. In addition to performance tasks, sustained operations studies often collect subjective ratings on mood, alertness, sleepiness, and fatigue. Physiological measures often include temperature, heart rate, grip strength, oxygen capacity, brain activity, and electrolyte and hormonal levels in urine and blood. The characterization of performance, psychological state, and physiological functioning during sustained operations affords better understanding of human performance capabilities and opportunities to find predictors of future performance effectiveness.

Sleep Deprivation and Sustained Operations

According to Johnson (1982), work tasks have certain characteristics that determine their sensitivity to sleep deprivation: duration, cognitive work load, operation complexity, amount of previous practice, memory requirements, feedback availability, and task interest. Tasks that are short, well-learned, moderate in complexity and mental workload, interesting, and provide feedback appear more resistant to performance decrement when sleep loss occurs. Paralleling these conclusions, Woodward and Nelson (1974) indicate that performance impairment from sleep loss results in slower reaction times, short-term memory decrement, lowered reasoning and decision-making abilities, degraded learning, attention lapses and omissions, and increased feelings of fatigue, irritability, and depression.

Sleep loss causes performance impairment through three mechanisms (Belenky et al., 1987): lapses in wakefulness or micro-sleep periods; reduced arousal producing a lowered capacity for sustained selective attention; and depressed mood and motivation levels which decrease morale and initiative. Englund, Naitoh, Ryman, and Hodgdon (1983) have indicated that sleep deprivation effects may be tempered by other factors such as physical fitness, prior rest, work and rest cycles, environmental conditions, and motivation.

From these findings on sleep deprivation factors, one can conclude that physical work and endurance experience little decrement (Martin, Bender, & Chen, 1986) as do tasks involving well-learned, basic soldier skills during a sustained operations scenario. Generally, the cognitive tasks along with mood, alertness, and motivation suffer when sleep loss occurs.

Circadian Influence on Sustained Operations

During sustained operations, time-of-day or circadian factors may also contribute to differences in performance, psychological state, and physiological functioning (Ryman, Naitoh, & Englund, 1984). According to Naitoh, Englund, and Ryman (1985), these 24-hour rhythmic effects may be controlled endogenously or exogenously. If endogenous, sleep loss will not affect the rhythmic patterns seen over various times of the day. Many studies have observed a circadian component to performance results for tasks involving logical reasoning, encoding, search and identification, vigilance, reaction time, target planning, and surveillance (Babkoff, Caspy, Mikulincer, & Sing, 1991; Bugge et al., 1979; Dinges et al., 1988; Mullaney, Fleck, Okudaira, &

Kripke, 1985). The 24-hour rhythmicity of performance is task-dependent, as Krueger (1989) notes ultradian rhythms have been seen for other tasks following 90 minute cycles.

Subjective ratings of mood, sleepiness, fatigue, and alertness also have exhibited time-of-day patterns (Babkoff et al., 1991; Bugge et al., 1979; Dinges et al., 1988; Froberg, 1977; Mullaney et al., 1985). Generally, circadian rhythms of performance or subjective measures reveal peaks at late morning or afternoon hours and troughs during late evening or early morning hours (Krueger, 1991). As mentioned earlier, these patterns in subjective ratings can help predict performance rhythmicities.

Physiological measures such as heart rate variability, grip strength, and hormone levels have also exhibited rhythmic patterns during sustained operations (Froberg, 1977; Kant et al., 1985; Opstaad & Aukvang, 1983). In addition, there is a circadian periodicity to both body core temperature (Monk et al., 1985) and human muscle strength (Coldwells, Atkinson, & Reilly, 1994; Hislop, 1963; Wright, 1959). There is some foundation for assuming a causal link between the diurnal variations in strength and core temperature (Monk et al., 1985). Other researchers have also found that elevations in muscle temperature are associated with strength increases (Asmussen, Bonde-Peterson, & Jorgensen, 1976; Bergh & Ekblom, 1979). However, desynchronization of core temperature and strength has been observed in subjects involved in shift work (Reinberg et al., 1988) and altered sleep-wake cycles. It has been suggested that these and possibly other body rhythms may be driven by a number of different, as yet undetermined oscillators (Reinberg et al., 1988).

In one of the few studies of sustained operations involving women, Froberg (1977) was able to demonstrate that temperature rhythms were maintained during 72 hours of sustained operations under strictly controlled conditions. However, Froberg does not report the time period within the female menstrual cycle for test participants. This timing may be a possible confounder in the investigation as body core temperature is known to rise at ovulation and remain elevated during the luteal phase, gradually returning to baseline levels at the end of the cycle (Wolf & Baker, 1993).

Chronic physical activity has been shown to influence some circadian rhythms. Physically active subjects exhibit greater rhythm amplitudes in oral temperature, arousal, alertness, sleepiness, flexibility, muscle strength and self-chosen work rate, and short-term memory (Atkinson, Coldwells, Reilly, & Waterhouse, 1993; Harma, Ilmarinen, Knauth, Rutenfranz, & Hanninen, 1988).

Female Performance During Sustained Operations

Most information concerning sleep loss and circadian effects from sustained operations is derived from studies using male subjects. The few studies that have been performed on females have been conducted in laboratory settings and produced findings similar to male subjects' results. No research involving a direct comparison of female and male performance during sustained operations has been done.

A study by Angus and Heslegrave (1985) required females to maintain continuous task performance in a communications center simulation and periodically complete cognitive tasks. Results indicated cognitive performance and communications' center processing time declined with sleep deprivation. Research by Froberg (1977) and Dinges et al. (1988) only used intermittent task performance. Both studies indicated circadian patterns of cognitive performance and alertness ratings with significant decrement occurring due to sleep loss. In addition, the Froberg (1977) study found significant circadian affects on oral temperature and adrenaline measurements. All three studies, averaging 52 to 72 hours of sleep deprivation, collected subjective ratings.

Research by Goodman, Radomski, Hart, Plyley, and Shepard (1989) examined endurance maintenance and physiological measures (oxygen intake, blood pressure, gas exchange, lactose levels, heart rate, and hematocrit) during 60 hours of sustained operations. Goodman et al. (1989) found a significant decrease in hemoglobin measurements and heart rate variability during the sustained operations period.

OBJECTIVES

Many studies have evaluated male soldiers from combat arms occupations during sustained operations (Krueger, 1989; 1991). However, it is not known to what extent these findings can be applied to female soldiers for determining whether Army training and doctrine ensure their military effectiveness. Therefore, the major objective of this study was to compare the effects of sustained operations of male and female soldiers in a field environment. The field study examined cognitive performance; subjective mood, fatigue, and environmental ratings; and physiological measurements. Sleep deprivation and time-of-testing factors were evaluated for these measures. The study's secondary objective was to describe changes in the soldiers' activity levels and performance assessments of field work.

The following experimental hypotheses were examined:

1. Differences in cognitive performance, subjective ratings, and physiological measures will occur as a function of sleep loss day.

2. Differences in cognitive performance, subjective ratings, and physiological measures will occur as a function of time of testing.

3. Gender differences in cognitive performance, subjective ratings, and physiological measures will occur.

METHODS

Subjects

A total of 26 soldiers (13 females and 13 males) from the 180th Transportation Battalion, stationed at Fort Hood, Texas, participated in this study. All soldiers possessed the same military occupational specialty, 88M (Motor Transport Operator), in the combat service support military career field. The soldiers' mean age (standard deviation) was 30.2 (3.6) years. Military service time averaged 9.1 $\pm$ 3.2 years.

Before the study, each soldier was briefed on the purposes and risks of the study. Volunteers provided written informed consent in accordance with AR 70-25 and completed a stress level questionnaire, the Life Events Form (See Appendix A). A physician reviewed the medical records of each potential test volunteer. Soldiers were precluded from participation for health conditions or history that prevented them from engaging in field exercise activities or sustained operations during 50 hours of sleep deprivation.

Apparatus

The following equipment and test batteries were used for data collection:

Oral Thermometers: A Yellow Springs Model 406 temperature probe interfaced to a dual channel digital meter (Yellow Springs Model 4000A) was used to obtain soldiers' oral temperatures. This equipment afforded a sensitivity of 0.1 degree Celsius over a measurement range of 0 to 50 degrees Celsius.

Hand Dynamometer: Measurement of hand grip strength was made with a Baseline strain gauge hand grip dynamometer. The dynamometer determined grip strength ranging from 0 to 100 kilograms, maintaining an accuracy level of 0.5 kilograms.

Life Events Form: This form, shown in Appendix A, assessed the amount and type of naturally-occurring stressors the soldiers may have experienced at the time of the study, along with their available coping resources.

General Information Questionnaire: This questionnaire included demographic information (age, education, rank, etc.) and questions regarding the participants' health status, physical activity and fitness, menstrual cycle, medications, and subjective ratings (0-100) concerning the importance of successfully completing the study and their willingness to participate in the study (See Appendix B). Male soldiers completed a revised form of the questionnaire which did not include questions regarding menstrual cycle and reproduction. The physical activity and fitness questions were previously evaluated in other performance studies (Knapik, Jones, Reynolds, & Staab, 1992; Siconolfi, Lasater, Snow, & Carleton, 1985; Washburn, Adams, & Haile, 1987).

Daily Activity Log and Peer Rating Sheet: Daily Activity Log sheets were kept by each soldier. Soldiers indicated their activity levels, performance effectiveness, and consumption of food, drink, caffeine, and cigarettes. Also, any sleep or rest time was noted. Each log sheet covered an inter-test period (3 hours). A peer rating was also made for each soldier's performance effectiveness during the inter-test periods by the Safety NCOs. Examples of the log and rating sheets are found in Appendices C and D respectively.

Psychological Trait Measures: The trait measure questionnaires were used to assess personality characteristics on the screening day, C1.

General Efficacy Measure (GEM; Sherer et al., 1982). This measure identifies characteristics the soldier brought to the study, such as a composite of past success and failure experiences (attributed to the self), as well as mastery expectations for new situations. Positive correlations have been obtained between self-efficacy and vocational, educational, and military success.

Multiple Affect Adjective Check List - Revised (MAACL-R; Zuckerman & Lubin, 1985). The General form of the MAACL-R has five primary subscales (Anxiety, Depression, Hostility, Positive Affect, and Sensation Seeking) derived from a one-page list of 132 adjectives. The soldiers checked all words which described how they "generally" felt. An overall distress score, Dysphoria or Negative Affect was calculated by adding the Anxiety, Depression, and Hostility scores.

Zuckerman Kuhlman Personality Questionnaire III-Revised (ZKPQ). This five factor model is recommended for research involving personality correlates because it provides maximal specificity at no loss in reproducibility across gender and populations (Zuckerman, Kuhlman, Thornquist, & Kiers, 1991). The five subscales are: (1) Impulsive-Sensation Seeking; (2) Neuroticism-Anxiety; (3) Aggression-Hostility; (4) Activity; and (5) Sociability. A final subset of ZKPQ items contain statements unlikely to be completely true statements about anyone. A score higher than three on this section may indicate the need to investigate the validity of the test for the particular person achieving that score.

Psychological State Measures. This 10-minute battery of stress perceptions was administered throughout the study at 4-hr intervals.

Multiple Affect Adjective Check List - Revised, Today form (MAACL-R; Zuckerman & Lubin, 1985). The MAACL-R Today form was used to examine changes in specific affects in response to stressful situations. This measure is identical to the General form, except the soldiers were instructed to answer according to how they felt during a specified time period.

Subjective Stress Scale (SUBJ; Kerle & Bialek, 1958). This scale detected significant affective changes in stressful conditions. Soldiers were instructed to select one word from a list of 15 adjectives that best described how they felt during a specified time period.

Specific Rating of Events scale (SRE; Fatkin, King, & Hudgens, 1990). The SRE allowed the soldiers to rate (on a scale of 0-100) how stressed they felt during a specified time period.

Stanford Sleepiness Scale (SLEEP; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973). Soldiers used this defined scale to rate their sleepiness level (ranging from a score of 1 to 7) at a specific time in the study.

Environmental Symptoms Questionnaire (ESQ; Sampson & Kobrick, 1980). The ESQ was used to obtain information about the incidence and severity of symptoms associated with physical stresses frequently encountered by military personnel. Using a 0 to 5 response scale, valuable information about the subjective symptom state of the soldiers was provided by the individual item scores or by the mean scores of separate symptom categories. The symptom categories included general physical distress, fatigue, heat stress, and wellness. Responses are made relative to a specified time period.

Self-Efficacy Scale. The Self-Efficacy Scale (SES; Bandura, 1977; Hudgens, Malto, Geddie, & Fatkin, 1991) asks respondents to rate their level of confidence in their ability to do well with reference to anticipation of "today's experiences." Positive correlations have been obtained between self-efficacy and vocational, educational and military success.

Revised Ways of Coping CheckList.
The Revised Ways of Coping CheckList identifies five individual coping efforts: problem-focused thoughts or behaviors, seeking social support, wishful thinking, blaming self, and avoidance. Raw scores are converted to relative scores to eliminate bias resulting from differences in the number of items on each scale.

Cognitive Performance Assessment for Stress and Endurance (CPASE, Mullins, L.F., 1996). This cognitive performance assessment, emphasizing speed and accuracy, was administered in a paper and pencil format. The following test measures were included:

Verbal Memory. The short-term memory test used lists taken from a word usage text (Thorndike & Lorge, 1944). Each list consisted of twelve one- or two-syllable words with the most common usage rating (100 or more per million). Soldiers were given one minute to study the list and one minute for recall.

Logical Reasoning. The reasoning test evaluated an understanding of grammatical transformations on sentences of various levels of syntactic complexity (Baddeley, 1968). Each item consisted of a true or false statement such as "A follows B----AB" (false) or "B precedes A----BA" (true). The test was balanced for the following conditions: positive versus negative, active versus passive, precedes versus follows, order of statement letter presentation, and order of letters in the pair (equivalent to balancing for true or false condition). Letter pairs were selected to minimize acoustic and verbal confusion. One minute was given to complete the 32 evaluations.

Addition. This task, adapted from Williams and Lubin (1967), tested working memory. Each calculation consisted of a pair of three-digit numbers which were selected from a random number table. The task was subject-paced. Soldiers had thirty seconds to complete as many of the fifteen problems as possible. The second addition segment was implemented in the same manner except that soldiers were required to add a constant of "seven" to the sum.

Spatial Rotation. Spatial ability was tested using a mental rotation task adapted from Shepherd's work (1978). A six-by-six grid was enclosed within a hexagon measuring 2.8 centimeters across the diameter. Portions of the grid were blackened to create random patterns. To the right of each test pattern were three similar patterns. One of the three patterns was identical to the test pattern except that it had been rotated. The task was to select this pattern. Each test consisted of eighteen items balanced for the number of grids blackened (7, 9, or 11), pattern density (adjacent blocks blackened versus a break between blocks), and rotation of the correct answer (90, 180, or 270 degrees). Two minutes were given to complete the 18 evaluations.

Manual Dexterity Board. This wooden board, used to evaluate fine motor performance, had thirty-six screws attached in a square pattern shown in Figure 1. Soldiers affixed the provided 0.25 inch-diameter hex nuts on the screw shaft by turning them with the fore-finger and thumb. Soldiers had one minute to perform this motor task.

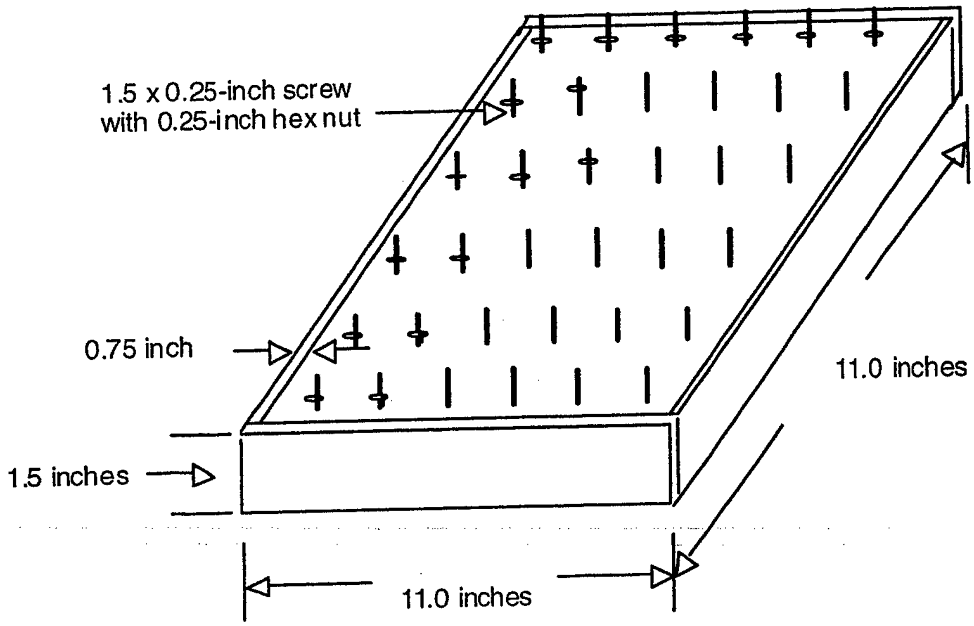

Figure 1. Manual Dexterity Board.

Study Design

As detailed in Table 1, the study covered 6 days. These days were delineated into two types of sessions, control and experimental. During the C0, C1, and C2 control sessions, administrative and regulatory tasks were conducted, along with baseline data collection of the psychological, performance, and physiological measures. The experimental sessions, E1, E2, and E3, encompassed 48 hours of sustained operations with training exercise activities and periodic collection of the psychological, performance, and physiological measures. With this testing schedule, there are 6 non-sleep deprived test periods (B1-B6), and 13 sustained operations test periods (S1-S13). Other experimenters have used similar test plans when performing continuous or sustained operations testing which afford a repeated measures design to examine sleep deprivation and time of day (circadian) effects (Babkoff et al., 1991; Webb, 1985).

Table 1.

Study Design.

Control Day 0	Control Day 1	Control Day 2	Study Day 1	Study Day 2	Study Day 3
Day C0. Inprocessing and Briefing. Screening and Trait Measures. Practice periods 1 & 2 on Cognitive and Psychological State Evaluations. Physiological Tests - 1230[b] and 1600. Free Period. Sleep Period.	Day C1 Baseline Testing-Cognitive, Psychological, Physiological. 0800 B1 Test.[ab] 1200 B2 Test. Lunch. 1600 B3 Test. Dinner. 2000 B4 Test.[a] 2400 B5 Test. Sleep Period.	Day C2 0400 B6 Test. Breakfast. (Released for the day.) Free and Rest Period. Sleep Period.	Breakfast. Start SUSOPS Day 1. Breakfast. 0800 S1 Test.[ab] 1200 S2 Test. Lunch. 1600 S3 Test. Dinner. 2000 S4 Test.[a] 2400 S5 Test. Snack.	0400 S6 Test. Start SUSOPS Day 2. Start Session S2. 0800 S7 Test.[a] 1200 S8 Test. Lunch. 1600 S9 Test. Dinner. 2000 S10 Test.[a] 2400 S11 Test. Snack.	0400 S12 Test. Breakfast. SUSOPS Day 3. 0800 S13 Test.[a] Debrief. Sleep Period.

Environmental Symptoms Questionnaire[a] (ESQ) and [b] Situational Self-Efficacy (SSE) administered only at these selected times.

Screening period measures:

General Information Questionnaire
Life Events Form
Psychological Trait Measures
- GEM
- MAACL-R
- ZKPQ

Testing period measures:

Physiological
- Temperature
- Heart Rate
- Grip Strength

Psychological State Measures
- SSE
- MAACL-R
- SUBJ
- SRE
- SLEEP
- ESQ
- Coping (S13 only)

Cognitive
- Short-Term Memory Recall
- Logical Reasoning
- Mathematical Calculations
- Spatial Rotation

Motor Fine Motor Control

Procedure

The study was performed at Fort Hood, Texas. Weather conditions on the first four test days were sunny and dry with temperature ranges of 60-80°F (day-time) and 40-55°F (night-time). Colder weather began on day 5, producing day-time temperatures of 50-65°F and night-time temperatures ranging between 40-45°F. Rainy conditions also occurred on days 5 and 6. An inside experimental area was used to conduct the in-processing, performance testing, subjective measures, physiological monitoring, and out-processing events of the study.

Control sessions were held at the soldiers' battalion headquarters facilities. Experimental sessions occurred during a training exercise which included field deployment, site preparation, military operations on urban terrain (MOUT), and recovery operations. (Appendix E details the sequence of events and operations orders for this period.) These sessions were conducted at a field site and the unit motor pool. When soldiers were not participating in the practice and record performance of the standardized test periods, they were engaged in unit scheduled activities. Unit safety NCOs monitored the soldier participants during the sustained operations sessions.

Soldiers wore BDUs, boots, and soft caps or helmets throughout the study. During anthropometric measurements and late-night Baseline test periods, soldiers were in their PT uniform and tennis shoes. While participating in MOUT exercises, soldiers wore MILES gear and carried some field equipment including canteens, load-bearing equipment belts and suspenders, M16s, training grenades, and flashlights.

Control Sessions

The first day of the study, Control Day C0, included administrative processing and sleep regulation of the test participants. The experimental procedure along with certain behavioral restrictions were fully explained to the participants. For example, they learned that no liquid or food intake would be allowed during testing periods to avoid subtle influences on oral temperature and heart rate. Soldiers then completed the Volunteer Agreement Affidavit and Volunteer Data Registry forms along with the General Information Questionnaire (Appendix B), providing demographic, education, health, and fitness information. In addition, soldiers filled out the Life Events Form (Appendix A) to assess the amount and type of naturally occurring stressors experienced at the study's onset, along with the soldier's available resources. Anthropometric measurements of stature and weight were made on each test participant using techniques in the 1988 Anthropometric Survey of U.S. Army Personnel (Gordon et al., 1989).

During the last segment of the in-processing period, experimenters administered the set of psychological trait questionnaires: the General Efficacy Measure (GEM; Sherer et al., 1982), the Multiple Affect Adjective Check List - Revised (MAACL-R; Zuckerman & Lubin, 1985), and the Zuckerman Kuhlman Personality Questionnaire III-Revised (ZKPQ; Zuckerman, Kuhlman, Thornquist, & Kiers, 1991). These psychological trait measures have been designed to periodically assess personality traits, coping resources, and self-perceptions that may relate to performance of cognitive and other soldier tasks (Blewett, Ramos, Redmond, & Fatkin, 1993; Blewett, Redmond, Modrow, Fatkin, & Hudgens, 1994; Fatkin & Hudgens, 1994; Fatkin et al., 1990). The in-processing tasks lasted approximately 1.5 hours.

Following in-processing, study participants were given a detailed instruction and practice period on the psychological state measures, the Cognitive Performance Assessment for Stress and Endurance (CPASE), the manual dexterity task, and the physiological measures. This practice period, given at 1230, lasted approximately 75 minutes. It was used to familiarize the soldiers with the standardized test measures, and ensure correct data collection procedures were established. After this first practice period, soldiers were released for personal time. A second practice of the standardized test period began four hours later, lasting from 1600 to 1700 hours. Following this practice, the soldiers were released for the rest of the day, and instructed to go to sleep no later than 2400 hours, thus affording at least 6 hours of sleep.

Control Days C1 and C2 comprised the study's baseline data collection segment. Soldiers came to the battalion headquarters testing room every four hours beginning at 0800 to complete the measures of the standardized test session. Each session lasted 1 hour and always included the daily log questions, psychological state measures (10-15 minutes), cognitive battery and manual dexterity task (10-15 minutes), and the physiological measures (20-30 minutes). During each portion of testing, soldiers were given brief instructions and monitored to prevent eating, drinking, or smoking. On the Daily Log sheet, soldiers indicated food, drink, and cigarette consumption along with any rest time, their activity levels, and a self-performance rating. Soldiers were instructed that the consumption questions were to be answered providing a description and amount. The daily log, psychological state measures (listed in Table 1), and the cognitive battery were administered to all participants at one time. Following these tasks, two groups of 12 soldiers, and one group of 2 soldiers were given the 1-minute manual dexterity test.

After completion of their manual dexterity task, soldiers proceeded to the physiological testing area. Here, there were two testing stations: oral temperature and heart rate collection, and hand grip performance. Assigned groups of 6 soldiers were tested simultaneously at these stations. Soldiers were directed to rotate through these stations or remain in the waiting area.

During the inter-test segments of Control Day C2, soldiers worked in their motor pool area, preparing for deployment to the field site. As listed in the Sequence of Events in Appendix E, these deployment tasks of equipment inspection and maintenance, along with loading occurred between 0630 and 1600 hours. Following test session B3, soldiers were released for personal time between the test sessions. Most soldiers had some rest during the inter-test segments preceding tests B5 and B6. With completion of the baseline assessment, soldiers attended to some company administrative tasks and were then released for the day for personal time and sleep until the beginning of the SUSOPS Day 1 at 0800 hours. The soldiers were instructed to get at least 6 hours of sleep before beginning the SUSOPS assessment period.

SUSOPS Sessions

The SUSOPS portion of the study extended over three days (SUSOPS Day 1, 2, 3) lasting approximately 52 hours. Monitoring by experimenters and unit safeties ensured soldiers did not sleep during this time. As with the baseline sessions, testing occurred every four hours starting at 0800 hours of SUSOPS Day 1. The standardized testing sessions were identical to those used during the Baseline Control days, lasting approximately one hour. Soldiers always began these testing periods by filling out the Daily Log sheets for the previous inter-test segment. For test session S1, soldiers were told to provide their hours of sleep prior to the start of the SUSOPS period. As indicated in Table 1, some of the psychological trait measures were administered selectively: the Environmental Symptoms Questionnaire, the Situational Self-Efficacy Measure, the General Rating of Events, and the Comparative Rating of Events. Assessments conducted from 0800 hours (test session S1) through 1600 hours on SUSOPS Day 2 (test session S9) were conducted in a building at the MOUT field site. Tables and chairs were set up for this testing along with lighting established with military lighting kits. Meals along with healthy snacks were also provided at this location according to the schedule found in Appendix E.

Unit Safety NCOs monitored the soldiers during the entire SUSOPS part of the study. They also periodically completed performance rating forms for a set of assigned soldiers. This form, included in Appendix D, allowed performance to be categorized as (1) poor, (2) below average, (3)average, (4) excellent, or (5) superior.

Throughout this SUSOPS time period (0800 hours of SUSOPS Day 1 through 1600 hours of SUSOPS Day 2), soldiers completed various training exercises at the MOUT site (See Appendix E.) These training tasks focused primarily on operations within Bosnia by troops engaged in providing transportation support. The participants performed scenarios of refugee and sniper engagements, ambushes, and attacks on training runs of supply convoys throughout the MOUT site's streets. During these training runs, some soldiers fired rifles and threw smoke grenades. Each of these runs lasted about 1 hour and was followed by after-action reviews. Soldiers also attacked the encampment of the transportation unit participating in the convoy training runs and had to put out a brush fire near the MOUT site. Following these operations, soldiers engaged in weapons cleaning and personnel hygiene tasks from 0500 to 0800 hours at the end of SUSOPS Day 1.

During SUSOPS Day 2, at the MOUT site, soldiers again ran the training lanes for another transportation unit. Then, soldiers prepared for deployment to another site. This preparation period occurred from 1300 to 1600 hours. Following testing session S9 and dinner, soldiers were then directed to move to the company motor pool because of adverse weather conditions in the field. Here, they completed the rest of the SUSOPS portion of the study.

Testing sessions S10 through S13 occurred at the soldiers' motor pool building. Soldiers received a midnight snack and breakfast here. Between testing, soldiers performed field recovery operations including equipment clean-up and inventory, along with preventive maintenance. With field recovery complete at 0600 hours of SUSOPS Day 2, soldiers breakfasted and underwent the last testing session S13 at 0800 hours of SUSOPS Day 3. As this testing session was at the end of the sustained operations period, it was used as a control period to mitigate the effects of motivation experienced when soldiers are aware a prolonged work period has ended. This test period included all the psychological, performance, and physiological measurements along with post-study evaluations of coping strategies and generalized stress ratings. At this time, the daily activity logging and field performance ratings also ceased. Soldiers were then debriefed about the study and released to complete a regulated rest period for sleep recovery (Woodward & Nelson, 1974).

Standardized Test Periods

Standardized test periods were used to regularly examine the effects of sustained operations on soldier performance, psychological perceptions, and physiological functioning. These periods allowed delineation of circadian rhythm and sleep loss contributions to the soldiers' effectiveness. Each test period lasted approximately 60 minutes and had four components: psychological measures, a cognitive performance battery, a manual dexterity task, and physiological measures.

Psychological Measures

Once soldiers were quietly seated at the testing location, the set of psychological state measures were administered first. Soldiers were instructed to quietly respond to these measures according to how they felt since previously tested. Generally, the administration order for these measures was the Multiple Affect Adjective Check List, the Subjective Scale, the Specific Rating of Events, and the Stanford Sleepiness Scale. This portion of the standardized test period lasted approximately 10 minutes. At selected times (See Table 1), soldiers also completed the Situational Self-Efficacy Scale, the Environmental Symptoms Questionnaire, and the Coping Questionnaire. The Situational Self-Efficacy Scale was administered only at the beginning of the baseline data collection and the beginning of the sustained operations period in order to obtain a "self-assessed prediction" of how the soldiers believed they would perform. Selective administration of the Environmental Symptoms Questionnaire, and the Coping Questionnaire allowed sufficient data to be collected from these rather lengthy measures, without sacrificing reliability or response validity due to "questionnaire overload."

Cognitive Performance Tasks

The 10-minute Cognitive Performance Assessment for Stress and Endurance (CPASE) examined aspects of short-term memory, logical reasoning, calculation, perception, and spatial processing functioning. This assessment, administered as a test booklet, had the five timed tests discussed in the Apparatus section: Verbal Memory (1 minute study, 1 minute recall), Logical Reasoning (1 minutes), Addition (30 seconds), Addition with a Constant (30 seconds), and Spatial Rotation (2 minutes). Performance of these tests was subject-paced.

During the practice sessions, soldiers were given detailed instructions on the performance of each task. Special attention was directed to three of the tasks: Verbal Memory, Addition with a Constant, and Spatial Rotation. With the Verbal Memory test, soldiers were instructed to study the printed word list and copy each word, thus ensuring the entire list had been reviewed. The Addition with a Constant test required each soldier to write two answers: the first sum of the two addends and the second sum comprising the first sum plus the constant "7". Explanation of the

Spatial Rotation task afforded a review of practice problems which focused on pattern recognition and rotation concepts of the task. On all tests, both speed and accuracy were emphasized, as was working in a set order through the presented problems. Soldiers had to write the recalled word list (Verbal Memory test), circle the correct true or false evaluation (Logical Reasoning test), print the sums (Addition tasks), or write the letter of the matching spatial rotation figure (Spatial Rotation). Minimal time was given between tasks. Experimenters carefully monitored the test periods to ensure strict adherence to the task requirements. During the experimental test periods, minimal instructions were given on the tasks.

Manual Dexterity Task

Following the cognitive battery, soldiers performed the manual dexterity test using the boards shown in Figure 1. During the practice sessions, soldiers were shown how to attach the hex nuts to the screws with the fore-finger and thumb. Correct performance of this turning technique and emplacement of the nut on the screw (tightened within a half turn of the screw's base) were emphasized to the soldiers. Soldiers were instructed to affix the nuts by column or row. They were not allowed to touch the board or pick up screws before the task start was called by the experimenter. One minute was given to perform this task. Following completion, experimenters checked the affixed screws for a tight fit. The number of completed attachments along with the board number was made on the assessment booklet cover sheet. A maximum of twelve soldiers could be tested at a time.

Physiological Measures

Prior to physiological testing, soldiers had been seated quietly for approximately 30 minutes. During this time, they were not allowed to consume food or drink. Experimenters closely monitored the soldiers for compliance with these restrictions.

Oral Temperatures (To)

Oral temperatures were measured with a temperature probe interfaced to a digital meter. Soldiers were assigned to the same probe and meter for all their temperature measurements. Steritemp® plastic covers were placed over the probes and discarded after each temperature measurements. Probes were wiped with 70% isopropyl alcohol after each use.

During the practice sessions, soldiers were given a briefing on how to hold the probes and place them sublingually. Technicians supervised probe placement and recorded Celsius temperature measurements given by the digital meters. Four minutes were allowed for temperature stabilization before values were recorded.

Heart Rate

Heart rates were obtained at the same time as oral temperatures after subjects had been quietly seated for about 1 minute. Technicians used the four fingers of their dominant hand to palpate the radial artery for a pulse. They obtained a 15-second count which was verbally called out to a recorder who transcribed the value. Fifteen second counts were later converted to minute pulse values. A group of six soldiers were evaluated at a time.

Hand Grip Strength

Maximal voluntary hand grip strengths of the right and left hands were measured with a strain gauge hand grip dynamometer. The device was adjusted to produce an approximate angle of 150 degrees at the third metacarpalphalangeal joint and 110 degrees at the proximal interphalangeal joint of the third finger (Mundale, 1970). Soldiers used the same adjusted dynamometer for all measurements.

Soldiers were told the goal of the test was to examine their maximal hand grip strength. They were instructed to build up to their maximal force in 1-2 seconds of effort. Subjects stood upright with their arms fully extended and the dial of the device facing the ground. They were given the verbal command: "Ready? One, two, three, squeeze". Contractions were held for 3-5 seconds, and then soldiers were told to "relax". Maximal force applied by the soldier was read off the dial gauge in kilograms. At least 15 seconds of rest was given between trials. The right hand was tested first.

During the practice periods, joint angles were adjusted and dynamometer settings established. Soldiers completed three practice trials for each hand. After the practice periods, only two trials were administered in each period. If the value of these two trials were not within 10%, a third trial was administered. The two highest trials were averaged for data analysis.

RESULTS

Data Analysis

For statistical evaluation, the repeated measures approach was used to minimize individual soldier differences. (Table 1 indicates the study's test schedule followed by each participant.) Three-way analyses of variance (ANOVAs) were used to examine the effects of gender, field day, and test session on the psychological perceptions, performance tasks, and physiological measures during the field study. In these analyses, gender was a between-subjects factor, while field day and test session were within-subjects factors. The field day factor had three levels: Baseline, sustained operations day 1 (SUSOPS1), and sustained operations day 2 (SUSOPS2). Test session levels included the six testing times: 0800, 1200, 1600, 2000, 2400, and 0400 hours. (Table 1 indicates labeling of each test period by a letter-number combination denoting field day and test session.) A 0.05 criterion level for significance was employed throughout the analyses. The homogeneity of variance assumption for these analyses was confirmed. If this assumption was not met, the Greenhouse-Geiser correction was applied before significance was determined. Post hoc comparisons were also made for significant results through Scheffe's Test or Tukey's Honestly Significant Differences (HSD) Test.

As the soldiers' schedules began at 0400 hours on the Baseline and Sustained Operations Periods, the 24-hour periods needed for circadian testing commenced at this hour. Thus, the last test period at 0800 hours on Study Day 3 acted as a post-test period to control for end-of-test motivation effects typically seen with sustained operations performance. Data from this period was scored but was not used in the statistical analyses.

Demographic data collected from anthropometric measurements and the General Information Questionnaire were evaluated for the two gender groups by the generation of descriptive statistics (mean, standard deviation, and percentile ranking). Some of these measures were analyzed using the independent groups t-test (continuous variables) or the Wilcoxon test when comparing men and women on ordinal variables obtained only once. Appendix F includes a portion of the demographic data for the test participants

Correlation analyses were also employed to determine the relationship of environmental factors, personal characteristics, work schedule events, and field performance to cognitive performance, subjective ratings, and physiological measurements.

Other subjective data were obtained through administration of the Daily Log and Peer Rating forms. At the beginning of the testing session, soldiers completed the daily log to indicate activity level, food, drink, and caffeine consumption along with rest or sleep hours and cigarette usage. In addition, the soldier participants and test safeties made ratings of work performance. Many of the daily log notations were evaluated with nonparametric statistics. Concordance of soldier performance ratings was also determined. Using analysis of variance, we examined possible gender, day, and session differences for rest hours and cigarettes usage.

Participant Demographics

A portion of the demographic data for test participants is included in the Table 2.

Table 2
Demographic Information for Males and Females

	Males		Females	
	M	SD	M	SD
	(years)			
Age	28.0	1.8	32.0	7.0
Length of Service	7.0	2.9	11.0	5.1
Education	12.9	0.8	13.2	1.7
Time in MOS	7.8	2.4	10.8	4.8

Psychological Measures

Because of the interdependence of the psychological measures, multivariate analyses of variance (MANOVA) were employed on the dependent variables obtained from the subjective questionnaires. Scores from the Multiple Affect Adjective CheckList-Revised subscales (anxiety, depression, hostility, positive affect, and negative affect) were analyzed together in one

MANOVA. Data from the other stress-related measures, the Specific Rating of Events Scale (overall stress rating), the Subjective Stress Scale, and the Standford Sleepiness Scale, were also analyzed together. Another separate MANOVA was conducted on physical distress, fatigue, temperature sensitivity, and wellness ratings from the Environmental Symptom Questionnaire.

Trait Measures

Multivariate analyses of variance (MANOVA) indicated that there were no significant differences between men and women on any of the trait measures (Wilks' $\lambda = .822$; $F(6, 19) = .685$; $p = 0.664$). When trait data were included in subsequent analyses and correlations of personality characteristics and performance or subjective mood, the data for the men and the women were pooled.

Overall Life Stress

As indicated in Table F-1 (see Appendix F), soldiers who responded on trait measures as typically feeling anxious or disappointed, also described their levels of overall life stress as relatively high. Subsequent correlations conducted between overall life stress and stress ratings of the field exercise (from the SRE) were also significantly and positively correlated. In other words, soldiers who recently experienced of a relatively high level of life stress considered the sustained operations period as more stressful than those soldiers who reported lower levels of life stress.

General Efficacy Measure (GEM)

Participants who scored higher on the GEM reported being less sensitive to pain during their initial routine operations period. Those who acknowledged their ability to master new situations or deal with changing circumstances reported fewer headaches, cramps, etc., during both the morning hours (0800 hours, $r = -.483$, $p<0.05$) and the evening hours (2000 hours, r= -.529, p<0.01). These individuals also reported recently experiencing a lower level of overall life stress (r= -.606, p<0.01).

There were also significant negative correlations between general efficacy with subjective ratings of fatigue during the evening hours of the routine operations period, as well as the first evening of the sustained operations period (see Table F-1). Other variables that were significantly correlated with the soldiers' efficacy scores are also included in Table F-1. For example, significant negative correlations were found with reports of sleepiness and overall subjective stress levels, while significant positive correlations were found between soldiers scoring high in general efficacy and the those who maintained a sense of well-being throughout the entire study.

Motivation Level

To obtain a measure of the soldiers' motivation to participate in the sustained operations portion, each participant was asked to rate the importance of successfully completing the field exercise (0 to 100), along with rating their willingness to complete the field exercise. Soldiers who were willing to perform well during the field exercise reported experiencing less fatigue in the late evening hours of their routine operations period than did soldiers who were not as motivated (r= -.503, p<0.01).

Stress Perception Measures

Baseline Day

Multivariate analysis of variance (MANOVA) indicated that there were no significant differences between men and women on any of the stress perception measures administered on Baseline Day ($F(1, 24) = .455$; $p= 0.506$). A three-way MANOVA (Gender x Sessions x Measures) revealed no Gender by Session interaction effect (Wilks' $\lambda = .866$; F (5, 20)

= .618; p= 0.688), and no Gender by Measures interaction (Wilks' λ = .814; F (7, 18) = .588; p= 0.757).

There was a significant Sessions main effect indicating the expected rhythmic pattern during Baseline Day (Wilks' λ = .255; F (5, 20) = 11.665; p< 0.001).

Sustained Operations Period

When analyzing for possible gender differences in stress perceptions during the sustained operations period, no gender main effects were found (F(1,21)= .344; p=0.564). It is important to note that the only differences between stress perceptions of the men and women were reflected in a Measures by Gender interaction effect (Wilks' λ = .333; F (7, 15) = 4.289; p= 0.009), whereas the Sessions by Gender interaction was not significant (Wilks' λ = .576; F (11, 11) = .736; p= 0.690). Table 3 illustrates how men and women responded differently on two of the stress perception measures, although their patterns across sessions remained similar.

Table 3

Stress Perceptions (Means and SEMs) of Men and Women During the Sustained Operations Period

		Negative Affect		Positive Affect	
Day	Time	Men	Women	Men	Women
SUSOPS1	0800	48.3(1.5)	47.8(1.7)	45.8(1.4)	48.2(2.4)
	1200	50.5(2.3)	44.9(0.6)	45.5(1.0)	49.8(2.1)
	1600	48.3(1.9)	45.4(0.7)	46.2(1.3)	48.0(2.0)
	2000	49.8(3.4)	46.4(1.5)	46.8(1.6)	46.7(1.2)
	2400	64.2(7.0)	54.3(4.2)	43.0(0.7)	43.7(0.4)
	0400	65.2(7.4)	51.7(1.8)	44.7(1.4)	43.5(0.3)
SUSOPS2	0800	61.6(5.1)	61.0(5.2)	44.6(1.3)	46.2(1.5)
	1200	55.7(4.4)	46.4(1.1)	44.3(1.0)	47.5(2.4)
	1600	67.3(7.5)	51.9(2.4)	44.0(0.8)	47.4(3.1)
	2000	55.2(3.9)	50.8(2.4)	45.2(1.1)	48.2(3.1)
	2400	53.6(4.2)	49.3(1.7)	44.9(1.1)	46.4(2.6)
	0400	48.2(2.2)	50.8(2.1)	44.3(0.9)	54.8(3.7)

INDEPENDENT CONTROL GROUP*	Negative Affect	Positive Affect
Pre Stress Levels	47.1(2.2)	57.1(1.2)
Post Stress Levels	51.8(2.8)	56.7(1.7)

Men reported consistently higher dysphoria, or negative affect, levels than women throughout the sustained operations period. When reporting levels of positive affect, women experienced a slightly higher sense of wellness than men.

The state appraisals of both the men and the women were also compared with responses obtained from an independent control protocol representing a condition ranging from no stress to low stress. **As indicated in Table 3, the soldiers experienced positive affect levels during the first testing session that were significantly lower from the referent independent control** group "pre-stress" levels. The negative affect levels were not significantly higher than the independent control group, particularly at the beginning and end of the sustained operations period. While differences did exist between the men and women, it is important to note their similar pattern of responses throughout the sustained operations period. Previous stress evaluations using the same measures have demonstrated a similar utility of referent protocol comparisons for estimating the relative stress experienced in a given situation (Blewett et al., 1993; Blewett et al., 1994; Fatkin & Hudgens, 1994; Fatkin, King, & Hudgens, 1990; Hudgens, Malto, Geddie, & Fatkin, 1991).

Since there was no main effect for gender in the MANOVA with the psychological variables, the data for men and women were pooled for the succeeding analyses. A MANOVA conducted with the same stress perception variables (MAACL-R Subscales) for the combined group revealed a significant Days by Sessions interaction effect (Wilks' $\lambda = .549$; $F(5, 21) = 3.452$; $p = 0.02$), and a Days main effect ($F(1, 25) = 7.211$; $p = 0.013$). Subsequent analyses revealed the Days by Sessions interaction effect was significant for the subscales discussed below.

MAACL-R Depression Subscale

Figure 2 illustrates the significant Days by Session interaction effect for the Depression Subscale ($F(5, 21) = 2.948$; $p = 0.036$).

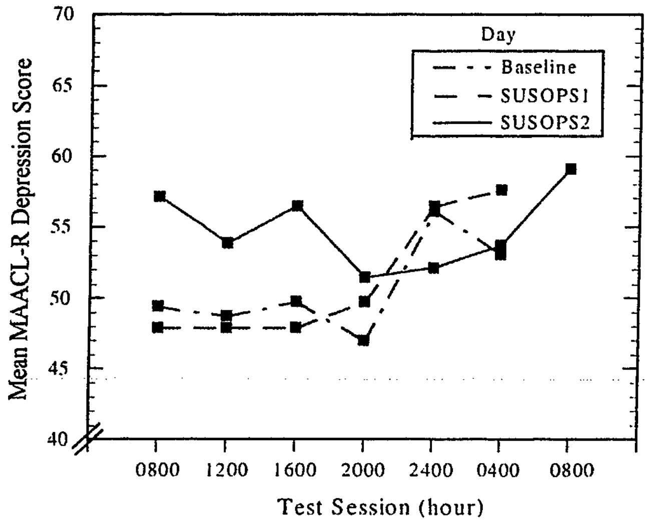

Figure 2. Mean MAACL-R Depression Score by Field Day and Test Session.

Soldiers reported moderate levels of depression during the 2400 hours and 0400 hours sessions of the Baseline Day and SUSOPS Day 1. Depression remained at this level throughout most of SUSOPS Day 2. Figure 3 provides an extended days and sessions perspective of the mean depression scores and their standard errors.

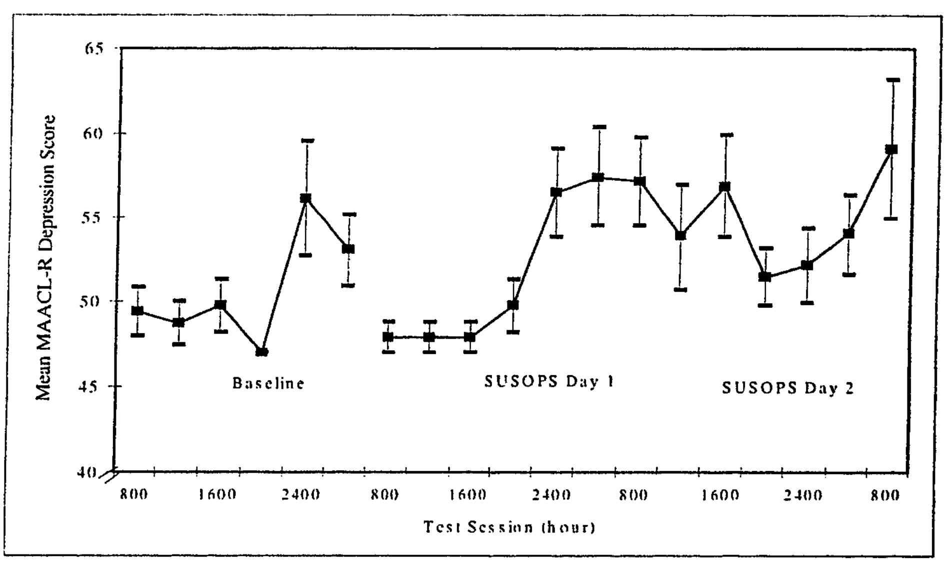

Figure 3. Mean (±SEM) MAACL-R Depression Score across sessions.

MAACL-R Hostility Subscale

The significant Days by Session interaction effect for Hostility ($F(5, 21) = 3.783$; $p = 0.013$) is shown in Figure 4.

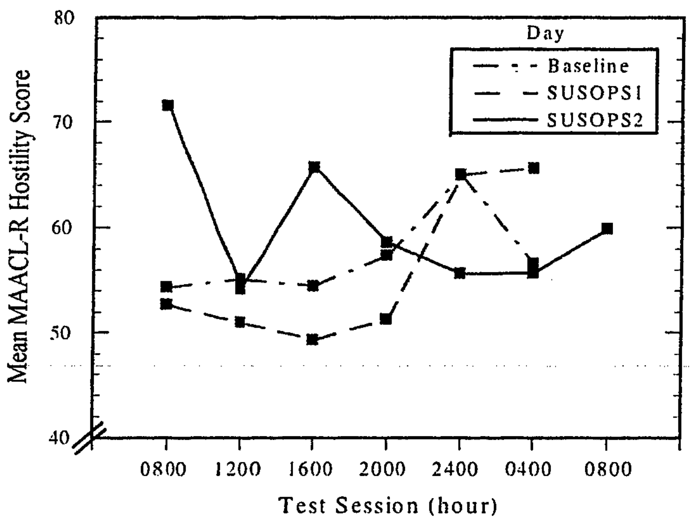

Figure 4. Mean MAACL-R Hostility Score by Field Day and Test Session.

Soldiers expressed moderately high levels of hostility at the 0400 hours session of Baseline Day, at 2400 and 0400 hours sessions of SUSOPS Day 1, and at the 1600 hours session of SUSOPS Day 2. The significant drop in hostility during the 1200 hours session of SUSOPS Day 2 is portrayed in the extended days and sessions chart, Figure 5.

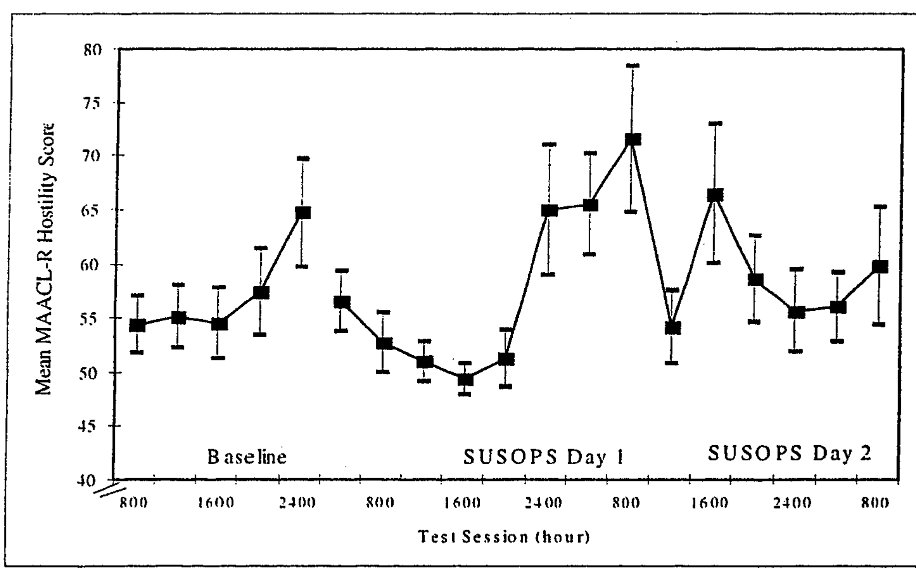

Figure 5. Mean (±SEM) MAACL-R Hostility Score across sessions.

MAACL-R Negative Affect Subscale

Figure 6 illustrates the significant Days by Sessions interaction effect for the subscale ($F(5, 21) = 3.502$; $p= 0.019$). The pattern of results is almost identical to the Hostility Subscale result pattern depicted in Figure 4 and Figure 5.

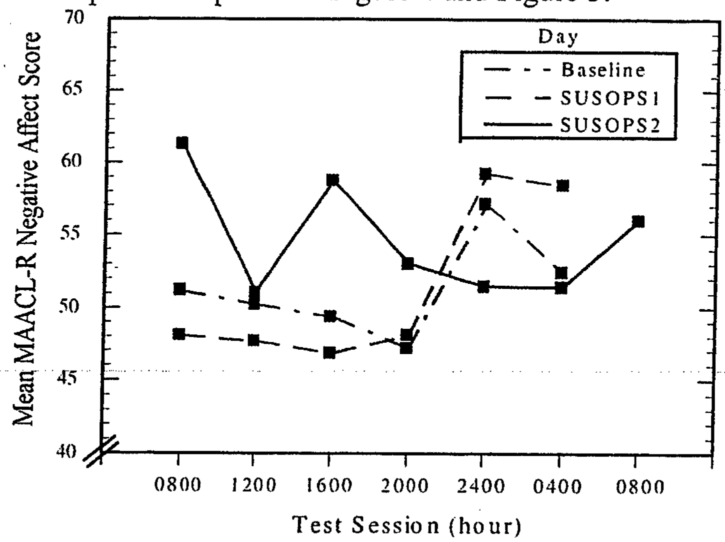

Figure 6. Mean MAACL-R Negative Affect Score by Field Day and Test Session.

Figure 7 allows for a more distinct visual inspection of the standard errors of the means from the Negative Affect Subscale. The variability of the negative affect scores increases noticeably during the late evening hours of SUSOPS Day 1.

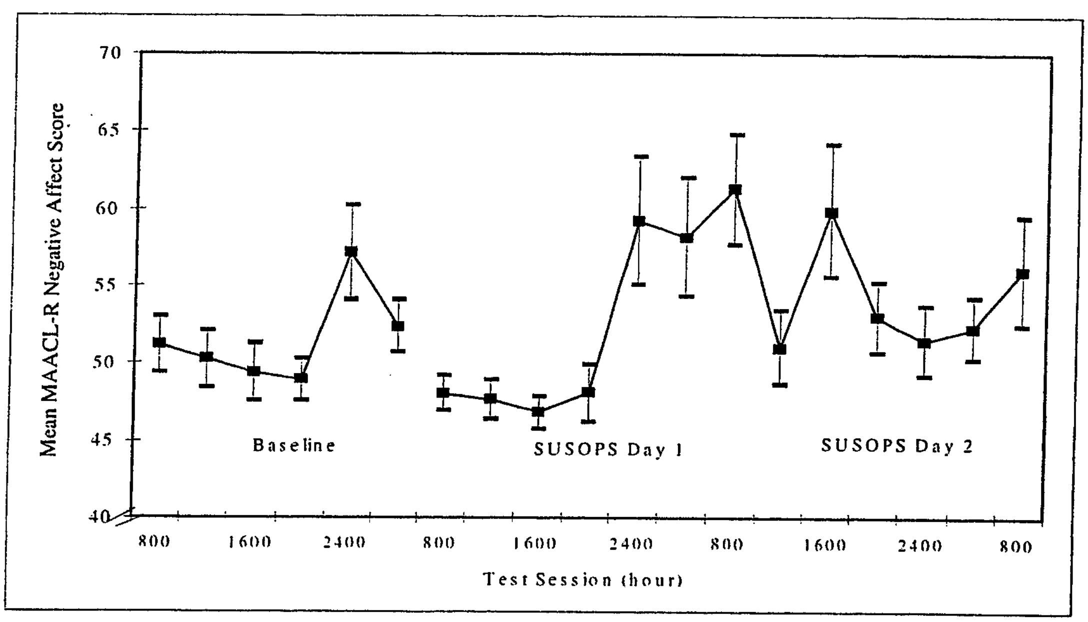

Figure 7. Mean (±SEM) MAACL-R Negative Affect Score across sessions.

MAACL-R Positive Affect

Soldiers reported moderate levels of positive affect (or sense of wellness) throughout the study, except for significant drops on Baseline Day at the 1600 hours and 2000 hours sessions. Figure 8 illustrates this significant Days by Sessions interaction effect (F (5, 21) = 2.95; p= 0.036).

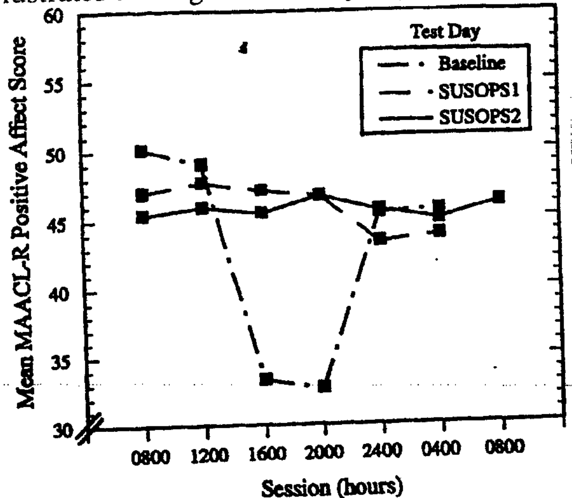

Figure 8. Mean MAACL-R Positive Affect Score by Field Day and Test Session.

In addition to the interaction effect, the analysis revealed a significant Sessions main effect (F (5, 21) = 5.620; p= 0.002) and a significant Days main effect (F (1, 25) = 5.580; p= 0.026). Figure 9 illustrates the small amount of variability in Positive Affect scores throughout the study, regardless of the dramatic drop in positive affect at 1600 hours and 2000 hours on Baseline Day.

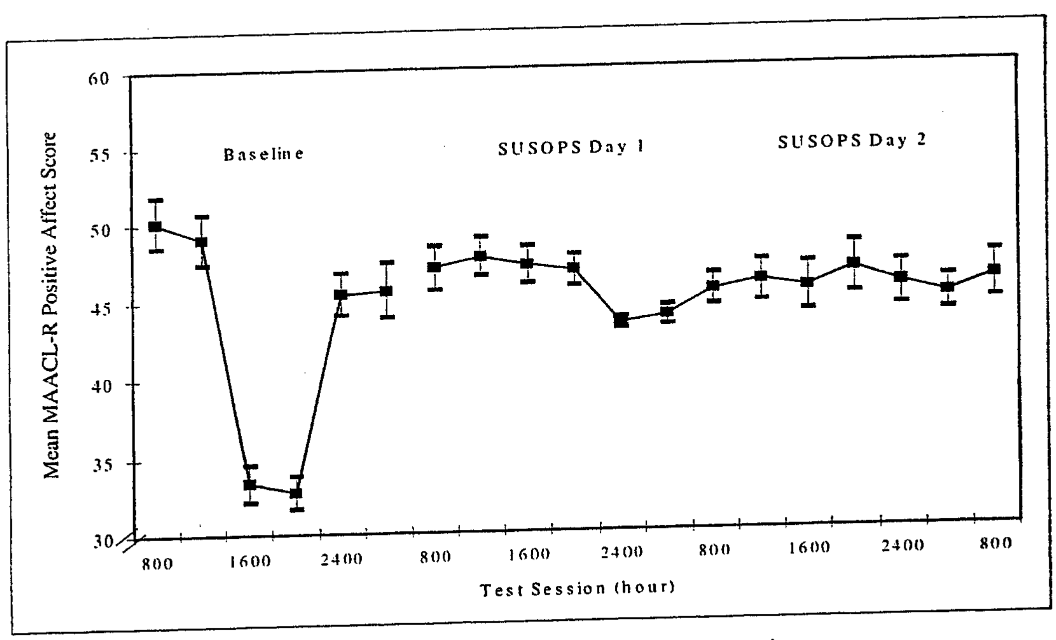

Figure 9. Mean (±SEM) MAACL-R Positive Affect Score across sessions.

A MANOVA conducted on the remaining stress-related variables, the Subjective Stress Scale, the Specific Rating of Events, and the Standford Sleepiness Scale, for the combined group revealed a significant three-way interaction effect for Days by Sessions by Stress Measures (Wilks' $\lambda = .339$; $F(10, 16) = 3.125$; $p = 0.021$), a significant Days by Sessions interaction effect (Wilks' $\lambda = .561$; $F(5, 21) = 3.290$; $p = 0.024$), a Sessions main effect ($F(5, 21) = 3.936$; $p = 0.011$), a Days main effect ($F(1, 25) = 6.200$; $p = 0.02$), and a Measures main effect ($F(2, 24) = 39.733$; $p < 0.001$).

To explain the nature of the significant interaction effects involving the stress variables, repeated measures ANOVA (Days x Session) was performed for each variable.

Subjective Stress Scale

As shown in Figure 10 and Figure 11, there was a Days by Session interaction effect (Wilks' $\lambda = .464$; $F(5, 21) = 4.849$; $p = 0.004$) for Subjective Stress levels, as well as a Days main effect ($F(1, 25) = 5.352$; $p = 0.029$), and a Sessions main effect (Wilks' $\lambda = .502$; $F(5, 21) = 4.174$; $p = 0.009$).

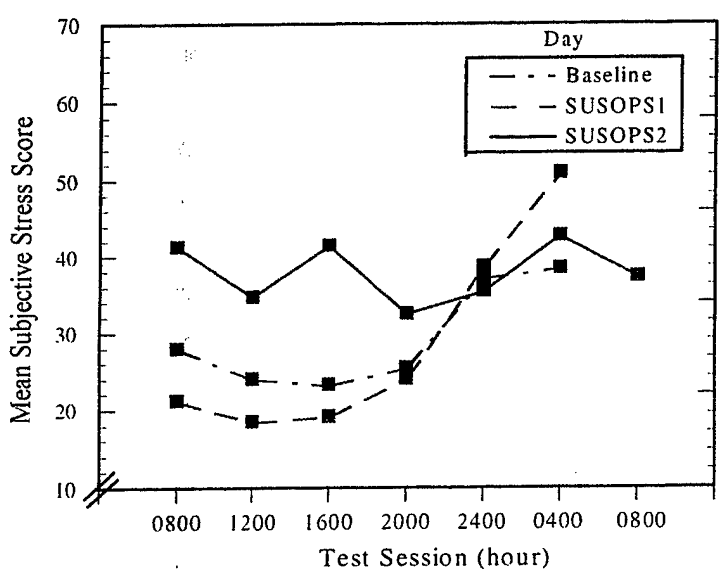

Figure 10. Mean Subjective Stress Score by Field Day and Test Session.

Soldiers reported experiencing higher levels of subjective stress during the 2400 hours and 0400 hours sessions of Baseline Day and SUSOPS Day 1. Stress levels remained just below these moderate levels throughout the remainder of SUSOPS Day 2.

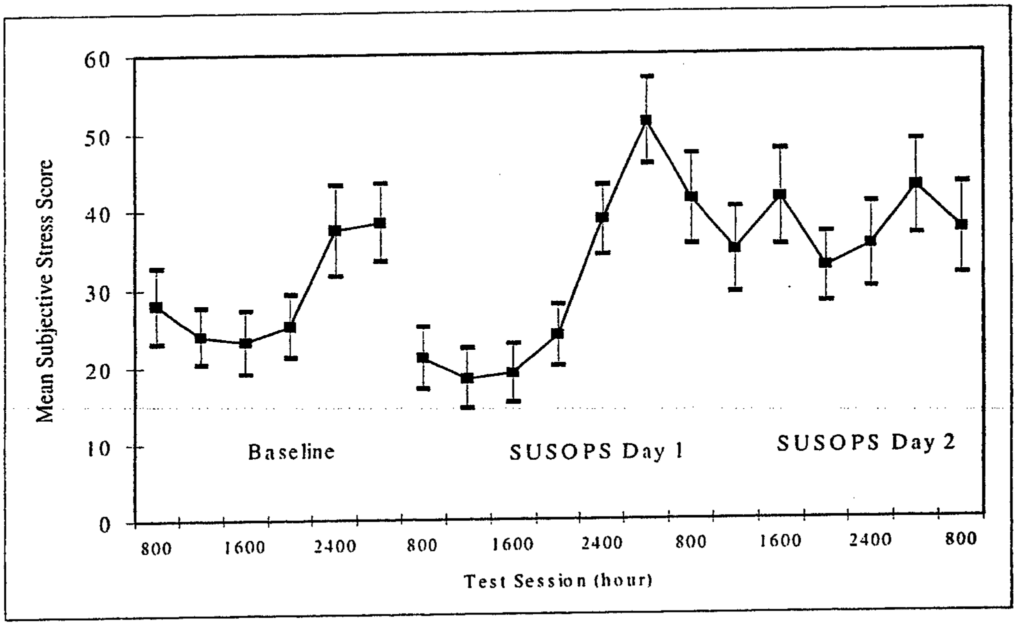

Figure 11. Mean (±SEM) Subjective Stress Score across sessions.

Specific Rating of Events

There was no significant interaction effect for Days by Session (Wilks' λ = .717; F (5, 21) = 1.660; p= 0.188) for the Specific Rating of Events. There was also no main effect for Days (F(1,25) = 2.694; p=0.113) and no significant main effect for Session (Wilks' λ = .919; F (5, 21) = .371; p= 0.863).

Stanford Sleepiness Scale

The Sleepiness Scale scores are illustrated in Figure 12. There was a significant Sessions main effect due to the increased sleepiness after the midnight testing session and at 0400 hours for Baseline Day (Wilks' λ = .352; F (5, 21) = 7.748; p< 0.001).

During the sustained operations period, a similar circadian pattern is demonstrated for SUSOPS Day 1 and SUSOPS Day 2. However, when examining the sleepiness scores beginning at 0800 hours on SUSOPS Day 2, the soldiers did not return to baseline levels for the remainder of the study.

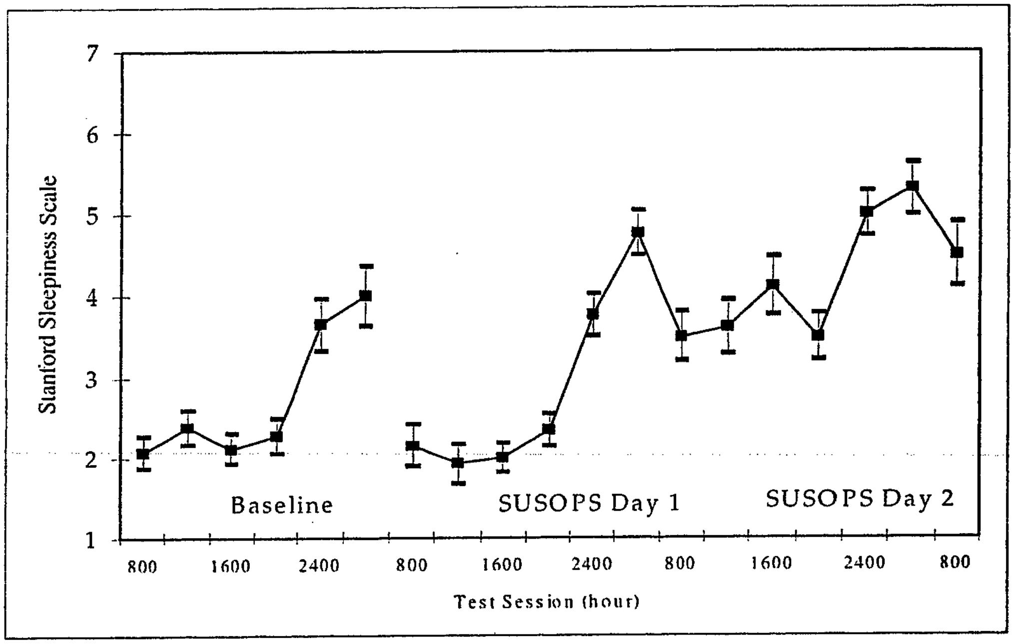

Figure 12. Mean (±SEM) Stanford Sleepiness Scale across sessions.

As indicated in Table F-2, the soldiers' Sleepiness scores were significantly and negatively correlated with their total scores from the General Efficacy Measure (GEM). Soldiers who considered themselves able to adapt to changing circumstances seemed to have less difficulty staying awake than those who have lower levels of adaptability. This relationship was seen in virtually every session beyond the 1600 hours session of SUSOPS Day 1.

Environmental Symptom Questionnaire (ESQ)

A repeated measures MANOVA (Gender x Sessions x ESQ Subscales) was performed on the data from the subscales of the ESQ administered during one morning and one evening session on Baseline Day (0800 hours and 2000 hours). There was no significant interaction effect for Gender by Sessions by ESQ Subscales (Wilks' $\lambda = .887$; $F(5, 20) = 511$; $p = 0.764$). There were also no significant Gender by Sessions interaction or Gender by ESQ

Subscale interaction effects. No Gender main effect was found for the subjective ratings of physical symptoms ($F(1,24) = 2.058$, $p= 0.164$).

For the sustained operations period, a repeated measures MANOVA was conducted with the ESQ data from SUSOPS Day 1 and SUSOPS Day 2. Once again, there were no significant gender differences in the soldiers' physical symptoms ratings ($F(1,24) = 2.174$, $p= 0.153$).

Pearson's correlation coefficients were computed with data from the ESQ Subscales, psychological trait data, and the situational stress ratings for the combined group. As discussed earlier in the report, soldiers who rated themselves as able to master new situations and deal with changing circumstances reported fewer physical symptoms than those who scored lower on general efficacy. There were also significant negative correlations between general efficacy as a trait characteristic and ratings from the Fatigue Subscale of the ESQ during evening test sessions (see Table F-2).

Physiological Measures

The ANOVA results for the physiological measures are presented in Appendix G.

Oral Temperature (T_0)

As shown in Figure 13, oral temperature (T_o) varied significantly because of the interaction between gender and test day ($F(2,23)=4.21$, $p=0.028$). Both the men and women had lower temperatures on SUSOPS1 and SUSOPS2 compared to the Baseline day ($p<0.05$). The women's temperature continued to decline on SUSOPS2 compared to SUSOPS1 ($p<0.01$); while the men's temperature average also continued to decline on SUSOPS2 but this value was not different from SUSOPS1 ($p>0.05$).

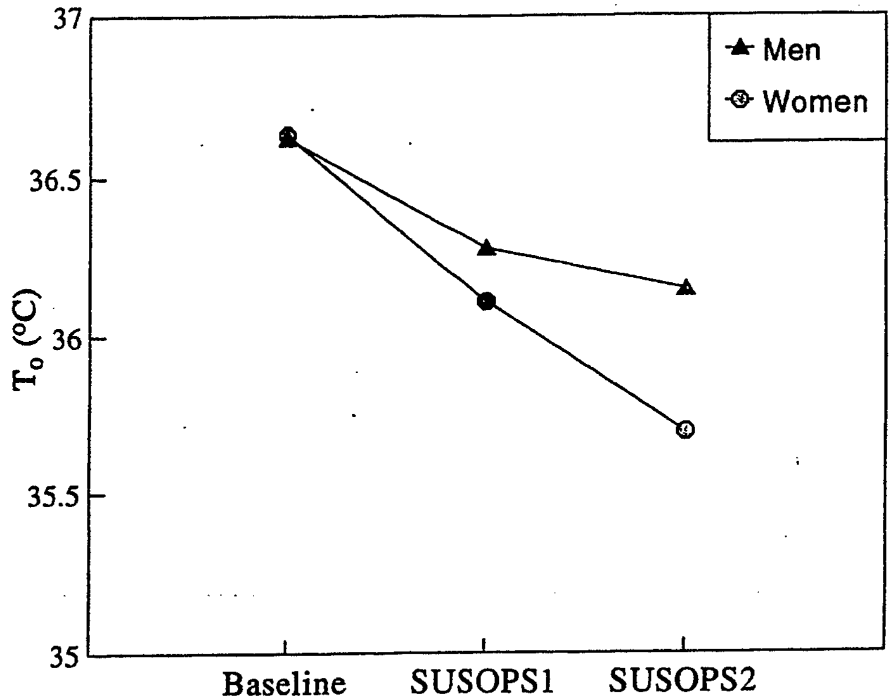

Figure 13. Mean Oral Temperature (T_O) by Gender and Field Day.

Figure 14 reveals the significant interaction effect of the gender and session ($F(5,20)=4.03$, $p=0.011$) on oral temperature measures. Post hoc testing determined significant differences between the measures taken for men and women occurred only at 0800 ($p<0.01$).

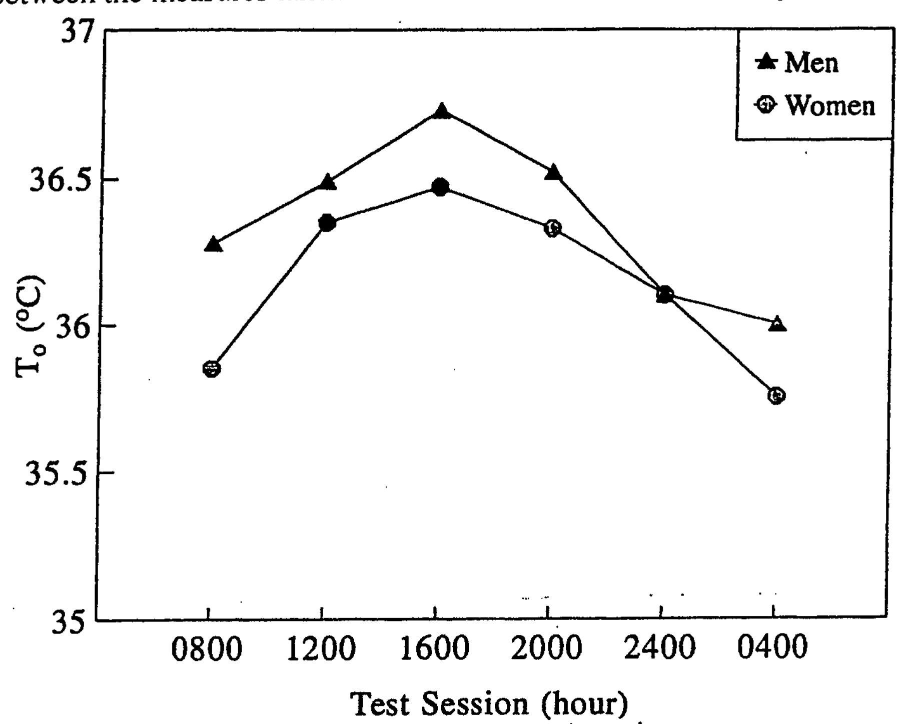

Figure 14. Mean Oral Temperature (T_O) by Gender and Test Session.

The session by day interaction effects ($F(10,15)=2.84$, $p=0.033$) were driven by the larger temperature variations during SUSOPS1. (See Figure 15.) SUSOPS1 began with a lower temperature value at 0800 ($p<0.01$), and rose to the same level as the Baseline day by 1600. The decline in temperature later on SUSOPS1 reached the level of SUSOPS2 by 2400 ($p>0.05$). T_O measured on SUSOPS2 were consistently lower ($p<0.01$) than on the Baseline day, but followed a similar pattern.

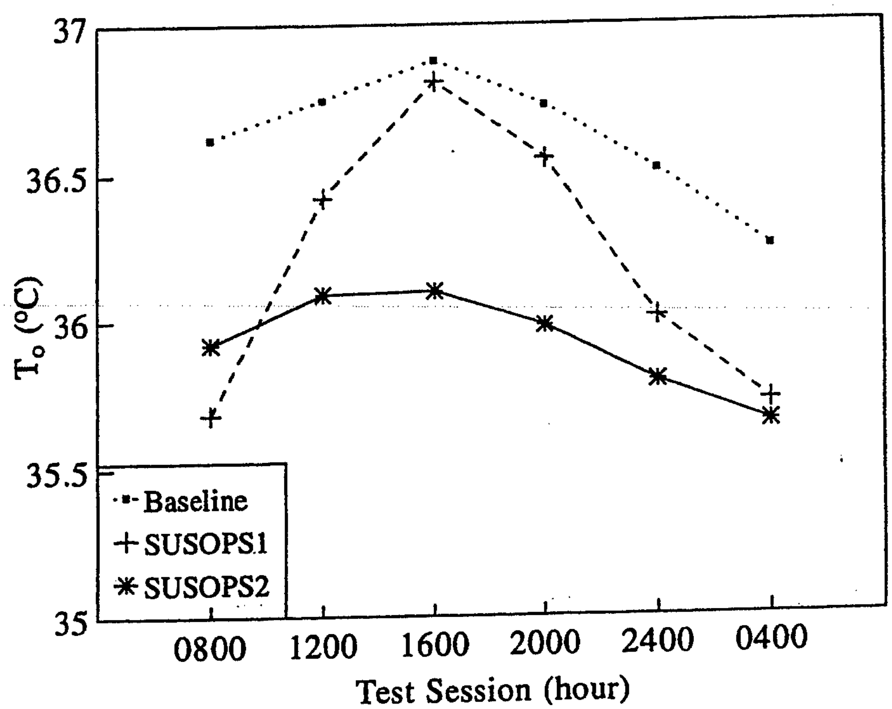

Figure 15. Mean Oral Temperature (T_O) by Field Day and Test Session.

Three women reported taking oral contraceptives. Figure 16 shows the oral temperature of these women (denoted contraceptive users "CU") compared to the other ten women in the study (contraceptive non-users "CNU"). The contraceptive users tended to have higher temperatures throughout the study. A three-way ANOVA (contraceptive usage group x days x sessions) was run on the women to further examine this effect. No significant effects were found for the interaction between contraceptive usage group and days ($F(2,10)=1.52$, $p=0.265$), the interaction of contraceptive usage group and sessions ($F(5,7)=0.19$, $p=0.959$), nor contraceptive group usage ($F(1,11)=1.41$, $p=0.261$).

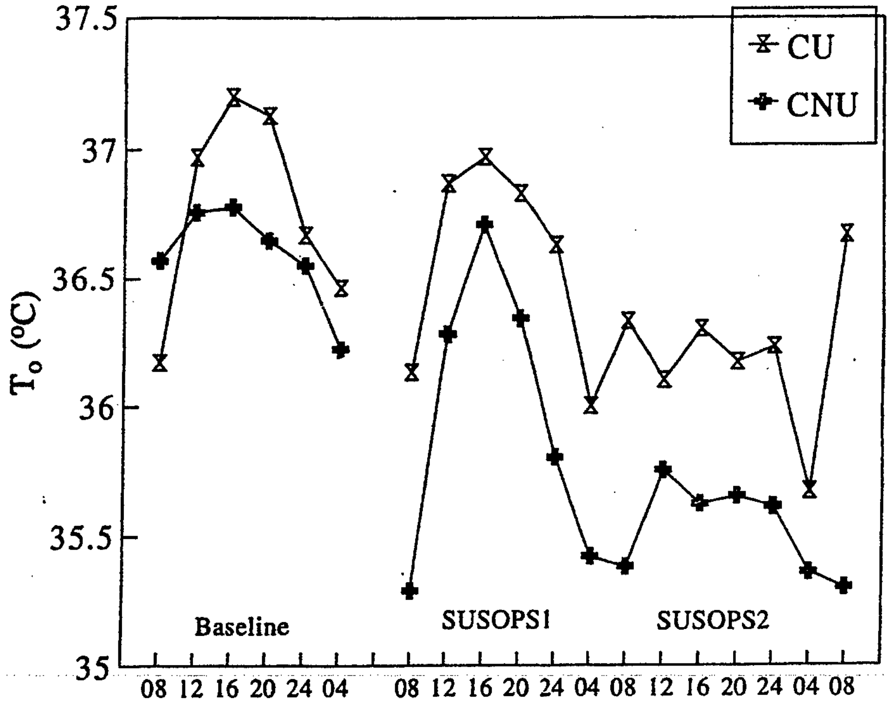

Figure 16. Mean Oral Temperature of Contraceptive Users (CU) and Contraceptive Non-Users (CNU) by Field Day and Test Session.

In order to analyze the effects of the menstrual cycle on oral temperatures, the women not using oral contraceptives were separated into those who were 12-21 days into their cycle (mid-cycle) at any time during the study (n=6) and those who were not (n=4). This time period was selected to include the time women may have had elevated body temperatures as a result of ovulation (Landgren, Unden, & Diczfalusy, 1980; Treloar, Boynton, Behn, & Brown, 1967). Mean temperature values for the two groups are shown in Figure 17. There was no obvious pattern in the data with both groups having higher temperatures at different times. A three-way ANOVA (menstrual group x days x sessions) revealed no group by day interaction effect ($F(2,7)=0.29$, $p=0.755$), no group by session interaction ($F(5,4)=1.79$, $p=0.296$), nor any main effect of menstrual group ($F(1,8)=0.09$, $p=0.776$) on oral temperature measures.

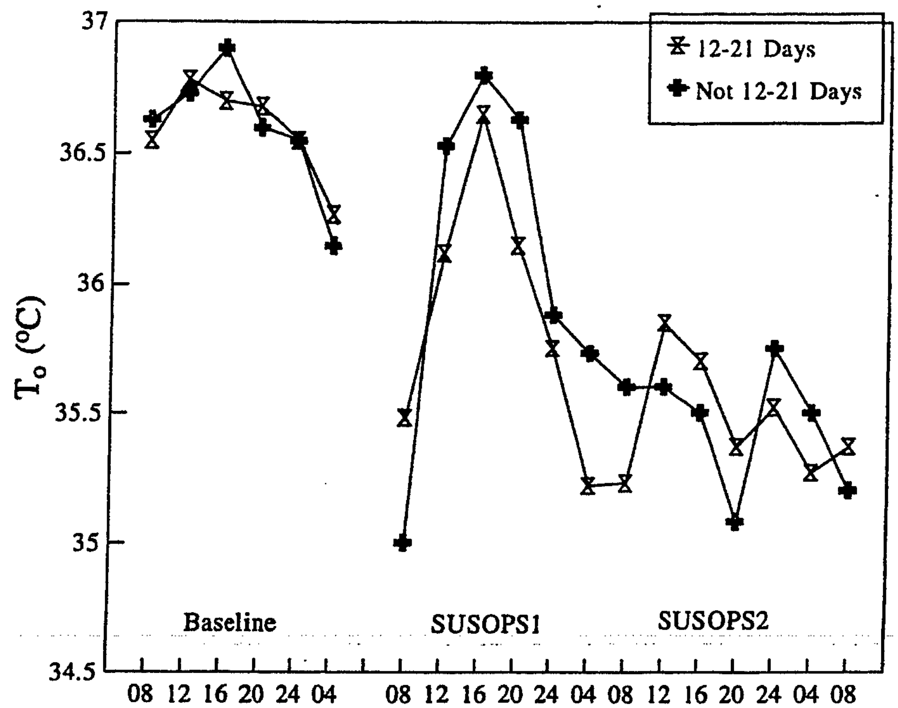

Figure 17. Mean Oral Temperature for Women in Luteal and Non-Luteal Phases of Menstrual Cycle.

Body surface area (BSA) was calculated as BSA = $M^{0.425} * S^{0.725} * 0.007184$, where: M=body mass (kg) and S=stature (cm) (DuBois & Dubois, 1916). The body surface area of the men was greater than the BSA of the women (1.92 ± 0.20 m^2 verses 1.71 ± 0.12 m^2, respectively, ($t(24)=3.12$, $p<0.01$). When the BSA to body mass ratio was compared, men and women had similar values (0.0249 ± 0.0026 m^2/kg verses 0.0253 ± 0.0020 m^2/kg, respectively, ($t(24)=0.41$, $p=0.69$).

Hand Grip Strength

Figure 18 shows the average (standard error) dominant hand grip strength measures for men and women. The statistical analysis confirmed that patterns for right, left, and dominant hand grip data were similar.

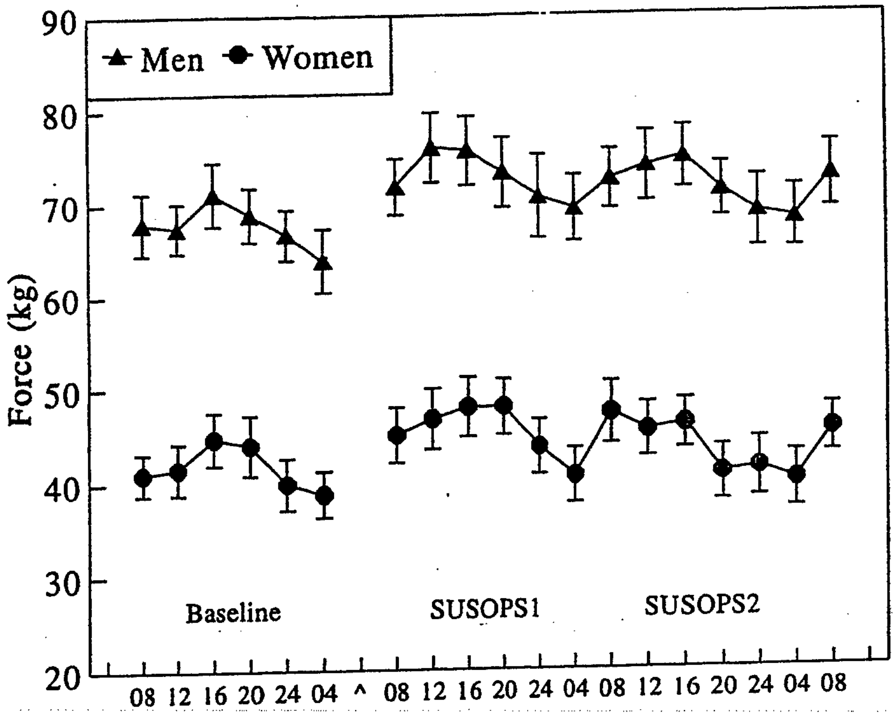

Figure 18. Dominant Hand Grip Strength for Men and Women during the entire study.

There were significant gender main effects for both right, left and dominant hand grip strengths: (F(1,24)=51.59, p<0.001) for right, (F(1,24)=52.59, p<0.001) for left and (F(1,24)=47.31, p<0.001) for dominant. The average grip strength of the women was 60%, 58% and 62% that of the men for the right, left and dominant hand, respectively.

Statistical analyses revealed significant main effects for Days with respect to results for the right (F(2,23)=8.83, p=0.001), left (F(2,23)=8.28, p=0.002), and dominant hand grip strengths (F(2,23)=9.70, p=0.001). In all three measures, the Baseline values were lower than SUSOPS1 (p<0.05), but there were no significant differences between SUSOPS1 and SUSOPS2.

The Sessions main effect was also significant for all three hand grip measures: (F(5,20)=8.79, p<0.001) for right, (F(5,20)=15.67, p<0.001) for left, and (F(5,20)=7.54, p<0.001) for dominant hands. Hand grip readings increased to a maximum at 1600 and then decreased to the lowest readings at 2400 and 0400.

Heart Rate

The average (standard error) changes in resting heart rate were collected during the test sessions. The significant Days by Session interaction is shown in Figure 19 ($F(10,15)=4.62$, $p=0.004$). The heart rate change from 0800 to 1200 is much greater on SUSOPS1 compared to Baseline and SUSOPS2. At 1600, resting heart rate on SUSOPS1 and SUSOPS2 decline while the Baseline heart rate does not. There was a significant main effect of gender ($F(1,24)= 11.16$, $p=0.003$) as women averaged higher resting heart rates and men, 76.3 versus 71.5 beats/min.

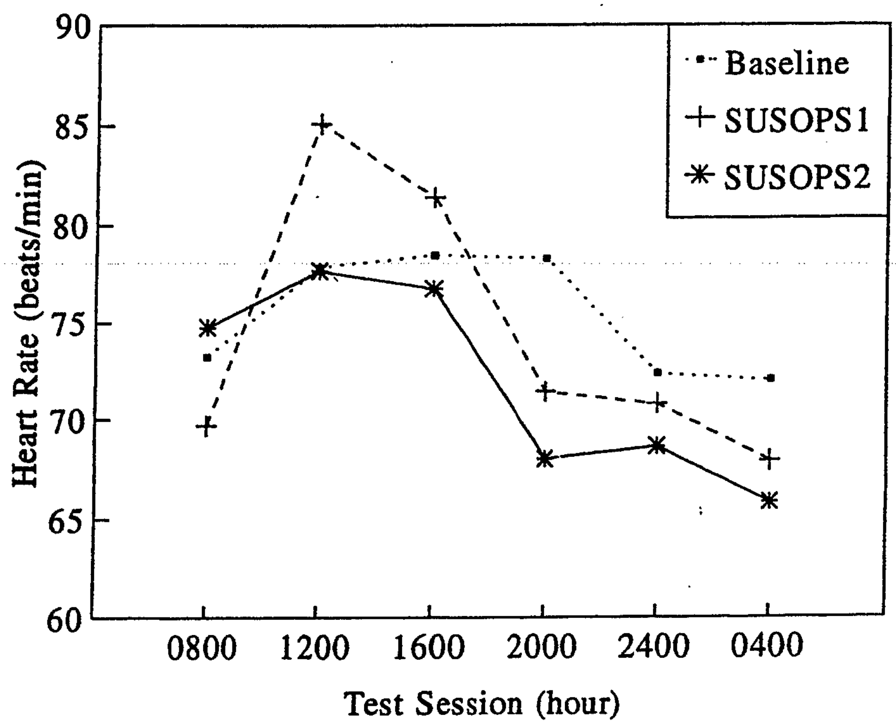

Figure 19. Resting Heart Rate by Field Day and Test Session.

Physical Activity and Physical Fitness

Table 4 shows the self-reported and calculated physical activity and physical fitness variables of the men and women. For the two self-reported activity questions (overall activity and weekly activity) there were no differences between the men and the women. Also when men and women were asked to self-rate their fitness components (i.e., endurance, sprint speed, strength, and flexibility) relative to others of their age and gender, there were no gender differences. Men did report more push-ups and faster two-mile run times than the women, but sit-ups performance was similar. The percentile rankings of the men and women relative to their Army peers were also similar.

Table 4

Physical Activity and Physical Fitness Measures.

Measure	Men (Mean, SD)	Women (Mean SD)	*p*-value
Overall Activity (5-point scale)	3.5 (1.1)	3.5 (1.1)	0.999[a]
Weekly Activity (8-point scale)	4.1 (1.2)	3.8 (4.1)	0.357[a]
Endurance (5-point scale)	3.5 (0.7)	3.3 (0.8)	0.368[a]
Sprint Speed (5-point Scale)	3.4 (0.5)	3.0 (0.6)	0.092[a]
Strength (5-point scale)	3.5 (0.5)	3.4 (0.7)	0.547[a]
Flexibility (5-point scale)	3.2 (0.4)	3.5 (0.7)	0.356[a]
Push-ups (repetitions)	64.6 (3.3)	36.2 (10.1)	<.001[b]
Sit-Ups (repetitions)	64.0 (2.9)	61.4 (6.6)	0.67[b]
Two-Mile Run (minutes)	14.6 (1.8)	18.1 (1.7)	<.001[b]
Percentile Ranking of Push-ups	81.0 (16.0)	77.1 (19.4)	0.589[b]
Percentile Ranking of Sit-Ups	62.3 (27.0)	62.5 (30.4)	0.987[b]
Percentile Ranking of Two-Mile Run	59.5 (28.6)	56.3 (25.7)	0.765[b]

[a] From Wilcoxon Test

[b] From t-test

Performance Tests

All performance data were analyzed with three-way analyses of variance testing. Performance tasks comprised manual dexterity, verbal memory, logical reasoning, simple addition, addition with a constant, and spatial rotation. Before running ANOVAs on the performance variables, select correlation analyses were calculated for the results of the logical reasoning, addition, and spatial rotation tests. These analyses determined whether significant linear relationships existed between the each task's performance measures with respect to given testing period (day x session). Due to the lack of significant results for the Pearson correlations (α=0.05 criterion level), separate ANOVAs were run for each performance variable.

During the sustained operations' portion of the study, a test participant was not available for one test period. Therefore, the average performance scores for that session, male group, were used for his scores. However, since responses to the daily log sheets were somewhat individualistic, answers typical of that soldier's responses were substituted for the missing test period information.

To delineate performance differences which may occur during sustained operations, we examined both work accomplished and its accompanying accuracy level. Therefore, performance on each test was evaluated as to the number of items completed or attempted. On the logical reasoning, addition, and spatial rotation tasks in which multiple answers could be given to the completed item, we evaluated the number of correctly completed items. This count was divided by the number of attempted items and then converted to a percentage, becoming the accuracy score for the performance test. In the following discussions, variables with ATT or PC appended respectively indicate completion or accuracy scores.

The complete listing of the ANOVA results for the performance tasks can be found in Appendix H.

Manual Dexterity

Little sustained operations research has examined manual dexterity. During this one-minute task involving fine motor control, soldiers could achieve a maximum score of 36 attachments. Scores for this subject-paced task generally ranged between 1 and 13 attachments. Overall, the dexterity scores were significantly greater for male participants than females ($F_{1,24}$)=12.23, p=.002): 8.03 attachments versus 6.46 attachments.

As shown in Figure 20, the interaction between field day and testing sessions (F10,15)=4.56, p=.004) significantly affected the manual dexterity scores. Generally, performance during SUSOPS2 was lower than the other days except for the 0800 test session. Dexterity scores for both SUSOPS days declined to their troughs at 0400 hours which were significantly lower than the corresponding Baseline session (p<.01). The significantly lower performance averages during the 0400 and 0800 sessions as compared to 2000 hours testing also explained the statistically significant main effects of session time (F(5,20)=4.20), p=.009).

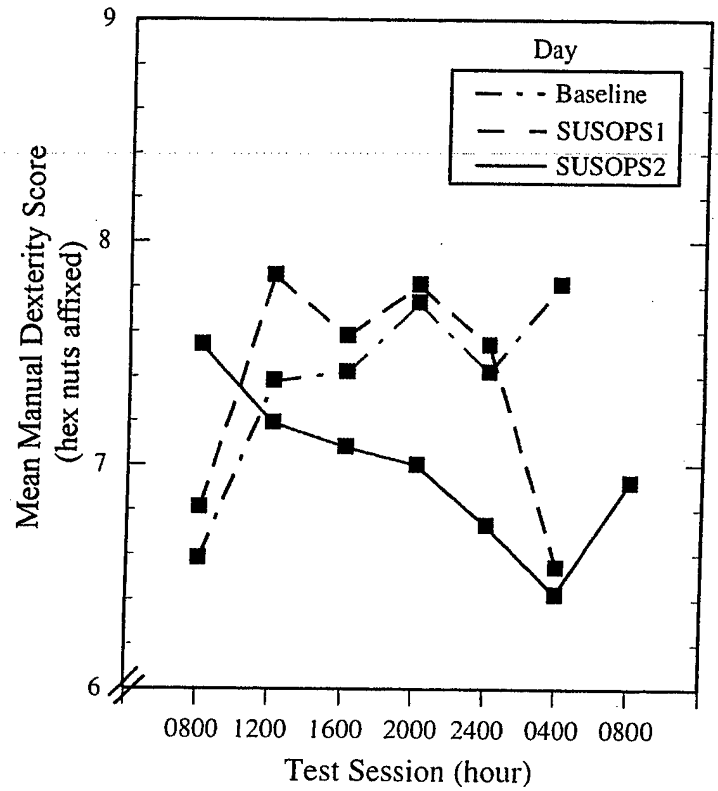

Figure 20: Mean Manual Dexterity Score by Field Day and Test Session.

Verbal Memory

This short-term memory test required written recall of twelve single and double syllable words. Analysis of variance results for the recall scores determined significant main effects of day and session, (F(2,23)=5.23, p=.013) and (F(5,20)=13.00, p<.001) respectively. Word recall was significantly worse (6.41 words) on SUSOPS2 compared to the Baseline and SUSOPS1 days, 6,87 and 7.13 words respectively (p<.05). As illustrated in Figure 21, soldiers maintained consistent recall scores between from 0800 through 1600 hours with performance declining to significantly lower levels at 2400 and 0400 hours (p<.01).

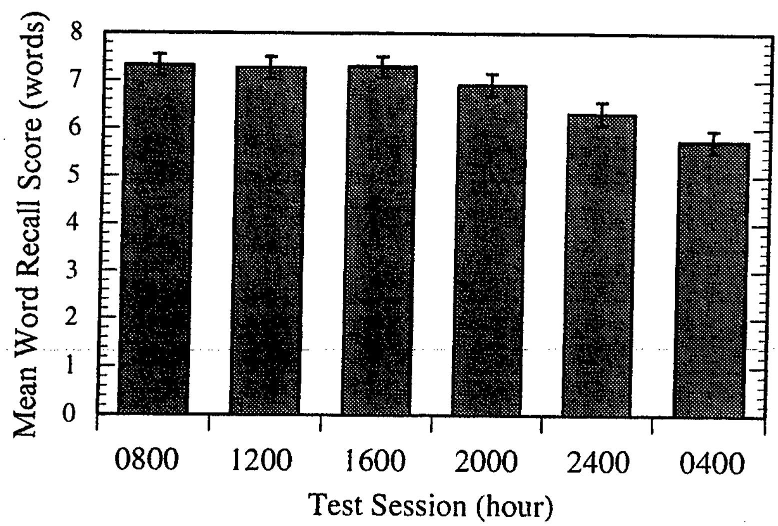

Figure 21. Mean Verbal Memory Score by Test Session.

Logical Reasoning

This reasoning task (Baddeley, 1968) involved 32 evaluations of two-letter pairs and a phrase describing the letter pair ordering. Each evaluation was judged as "true" or "false". Two scores determining completion and accuracy, LRATT and LRPC were generated for this logical reasoning task.

Figure 22 illustrates the significant interaction of gender, day, and session present for the LRATT scores (F(10,15)=4.95, p=.003). In general, men completed more evaluations than the women over the study. Tukey testing of female and male completion scores for corresponding sessions over the three days revealed several significant three-way interactions (p<.05): female B1 versus male S1 scores (0800 hours); female B3 versus male S3 scores (1600 hours); and female S6 versus male B6 and S6 scores (0400 hours). Periodically, the two groups' LRATT scores did converge: 0400 hours on the Baseline day, 0800 hours on SUSOPS1, and 2400 hours on SUSOPS1. Commencing with the end of SUSOPS1 through SUSOPS2, women did periodically have higher evaluation scores.

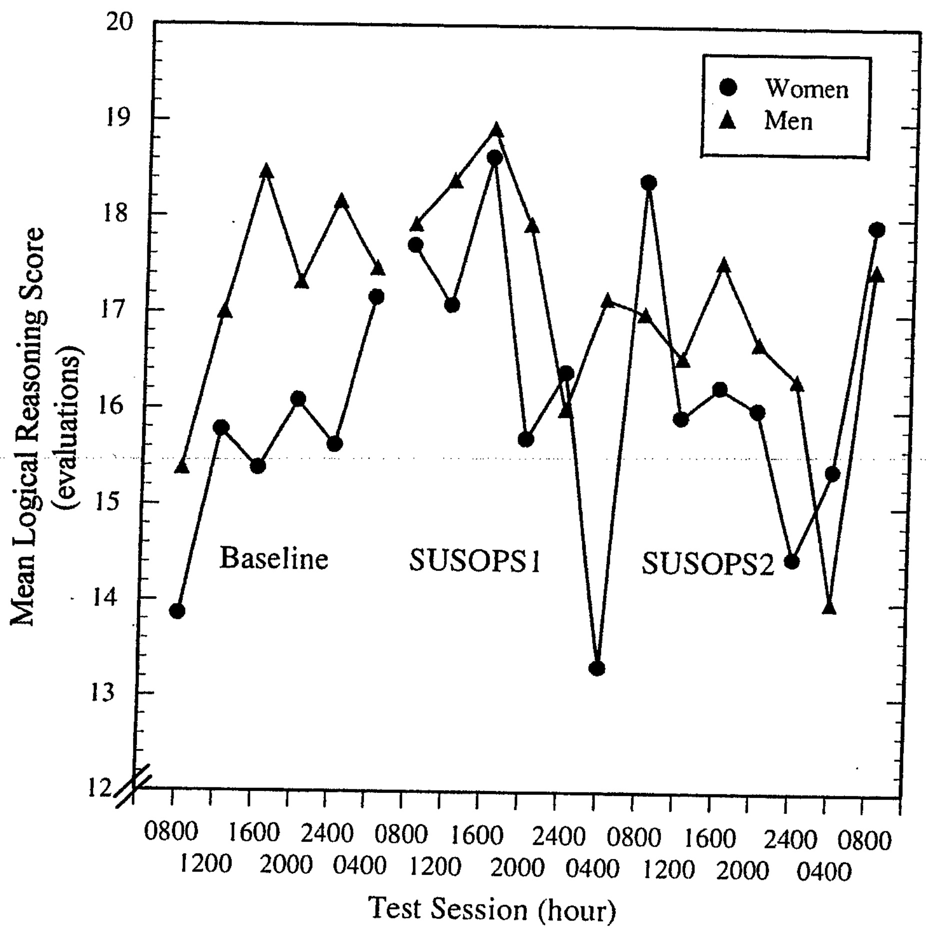

Figure 22. Mean Logical Reasoning Score for Men and Women during Entire Study.

Analysis of variance results demonstrated significant interactions between gender and day ($F(2,23)=3.42$, $p=.050$) for logical reasoning accuracy scores, LRPC. Over the three performance days, female soldiers maintained relatively equal levels of accuracy, while male soldiers had increased scores. Thus, these levels diverged by SUSOPS2 to 74.55% and 67.39% for the men and women respectively ($p<.05$). However, these male accuracy averages were achieved for lowered evaluation completion scores. Male LRPC levels on SUSOPS2 elevated this day's average, 70.97%, significantly over the Baseline LRPC average ($p<.05$), 67.39%, resulting in a significant main effect of day on logical reasoning accuracy ($F2,23)=3.46$, $p=0.049$).

As seen in Figure 23, accuracy levels for logical reasoning performance revealed a significant interaction between day and test session (F(10,15)=2.77, p=.037). The relatively stable accuracy levels during SUSOPS2 coupled with the variability of SUSOPS1 and Baseline performance did contribute to these results. However, accuracy levels did converge at 0400 hours testing. Post hoc testing indicated the high level of accuracy attained at 2400 hours of SUSOPS1 was significantly greater than that achieved for Baseline test periods 1200 hours, 1600 hours, and 2400 hours along with SUSOPS1 performance at 1200 and 1600 hours (p<.01).

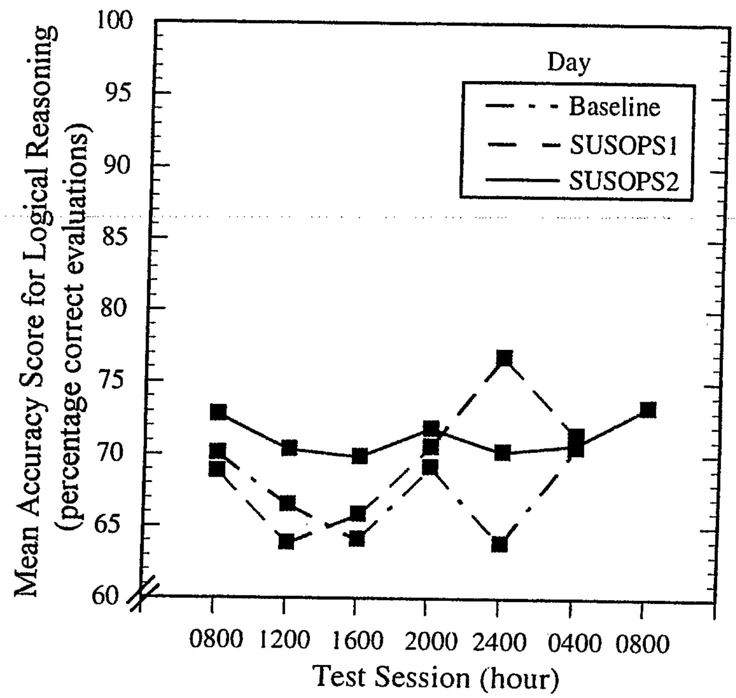

Figure 23. Mean Accuracy Score for Logical Reasoning by Field Day and Test Session.

Simple Addition

For this computation task, soldiers were given 30 seconds to complete 15 problems adding two three-digit numbers together. Completion scores, ADATT, ranged from 2 to 15 problems. Figure 24 illustrates the significant interaction effect between day and session on the soldiers' addition performance. During the study's three days, mean addition scores were relatively stable except for the Baseline day at 2400 and 0400 hours, SUSOPS1 at 0400 hours, and SUSOPS2 at 1200 hours. The variability of performance at these periods produced several significant Scheffe comparisons (p<.01) for corresponding session times. Main effects of day (F(2,23)=13.80, p<.001) and session (F(5,20)=21.72, p<.001) were also seen for addition completion results. The soldiers averaged significantly higher addition scores on SUSOPS2 compared to Baseline and SUSOPS1 days (p<.01). As seen in Figure 25, session ADATT values ranged from 9.56 to 10.96 problems with performance during 1200 and 1600 hours bettering that at 2400, 0800, and 0400 hours (p<.01).

Examination of the accuracy levels maintained during the simple addition testing, revealed no significant statistical results. (See Appendix H.) Accuracy level scores, ADPC, averaged 90.94% $\pm$ 12.67%.

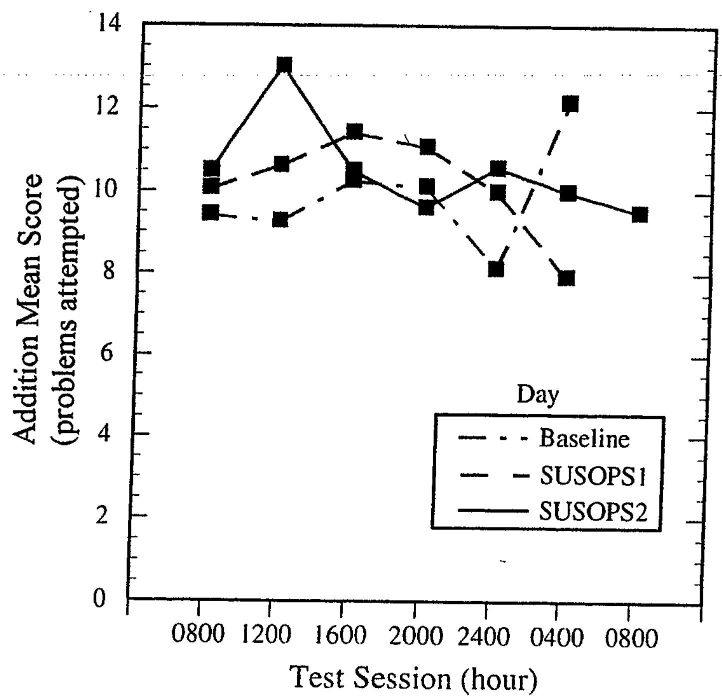

Figure 24. Mean Addition Score by Field Day and Test Session.

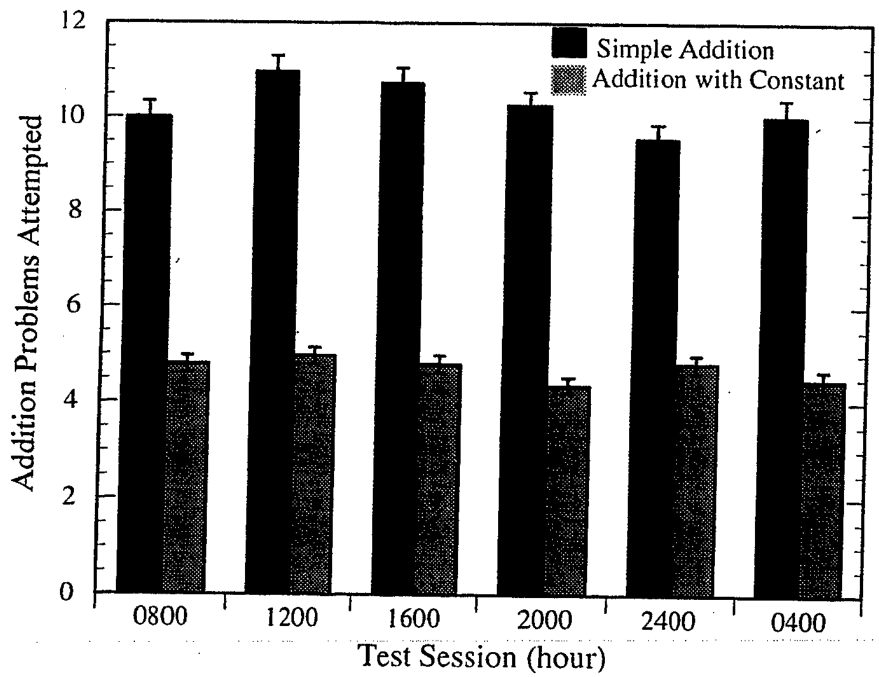

Figure 25. Mean Addition Performance Test Scores by Test Session.

Addition with Constant

This second computation task involving addition was similar to the first, yet required an additional step, the adding of a constant addend "7" to the first sum. Soldiers were instructed to write the resulting sums for both steps. Performance was scored according to the number of problems completed (CAATT), along with the accuracy levels for the two sums, S1PC and S2PC respectively. We were unable to delineate performance on some soldiers' task performance with respect to first and second sum accuracy, so only 24 soldiers' data were analyzed.

Like the previous addition task, soldier's performance on this two-step addition test exhibited a significant interaction of day and test session (($F(10,13)=7.05$, $p=.001$). As expected, completion scores were about half of the simple addition scores. Patterns in Figure 26 for the three days' test sessions are similar to those in Figure 24, especially the performance during SUSOPS1. The exceptions to the pattern similarities are seen in the elevation in scores during the Baseline 2400 hours session and the Final test period at 0800 hours. Post hoc testing indicated significant differences between the higher addition scores during periods B5, B6, S7, and S8 in comparison with the other Baseline and latter SUSOPS2 test periods ($p<.01$).

As seen in Figure 25, the session main effect ((F(5,18)=10.30, p<.001) on completion scores for CAATT was driven by the performance trough experienced at 2000 hours, as compared to higher levels at 0800, 1200, 1600, and 2400 hours (p<.01). These session averages ranged from 4.35 to 4.96 problems.

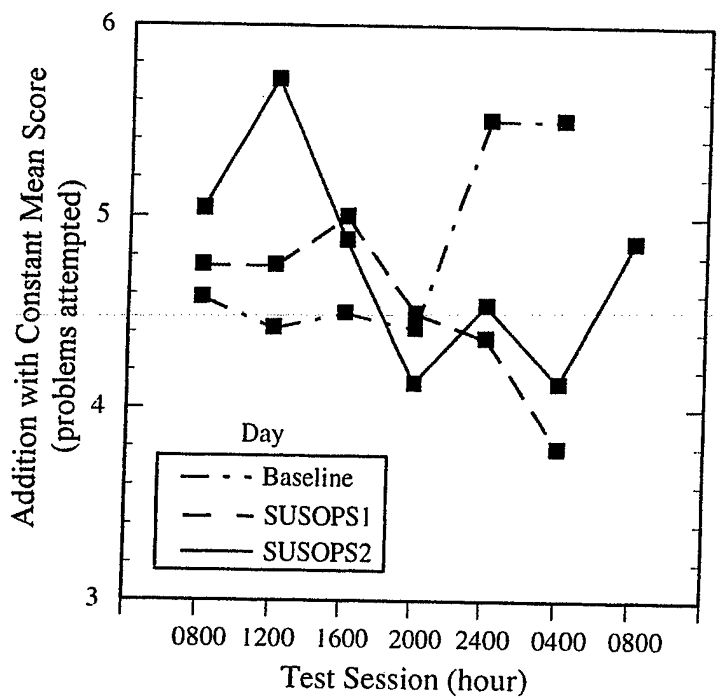

Figure 26. Mean Addition with Constant Score by Field Day and Test Session.

Evaluation of the accuracy levels for the first and second sums, S1PC and S2PC, determined statistically significant differences only occurred between second sum accuracy levels. (Appendix I details these ANOVA results for the S1PC measures.) S2PC results were significantly affected by the interaction between day and session (F(10,13)=2.90, p=.038). Examination of Figure 27 indicates large variability in the S2PC scores especially on the SUSOP2 and Baseline sessions. Tukey test results point to significant differences between the troughs at the Baseline 1600 and SUSOPS2 0400 sessions with respect to SUSOPS2 peaks at 1600 and 2400 (p<.01). At 1200 and 2000 hours, the SUSOPS1 and SUSOPS2 values converged. Generally, the direction of the accuracy level results for the two sustained operations days behave oppositely, with some convergence at their respective 1200 and 2000 testing periods.

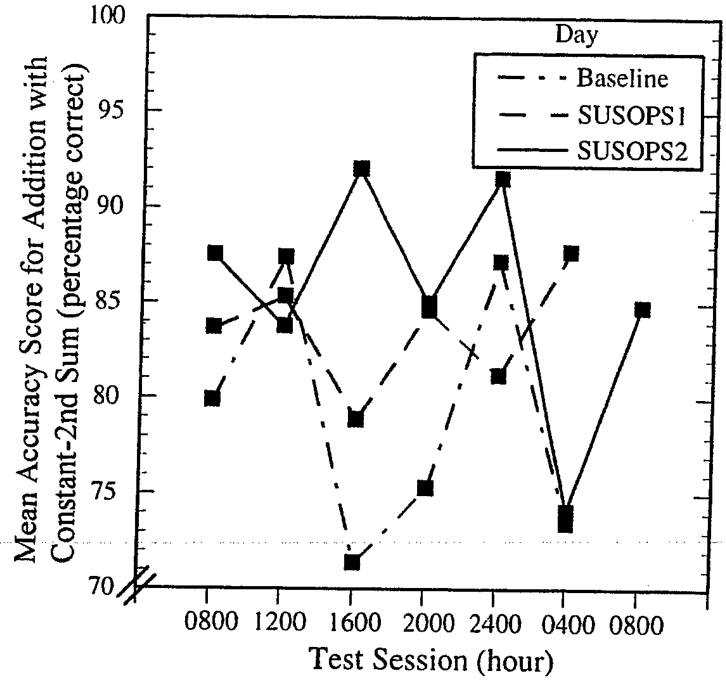

Figure 27. Mean Accuracy Score for Addition with Constant-2nd Sum.

As this computation task examined both cognitive and perceptual processing through the initial two-addend sum, followed by the constant addend calculation. We further delineated performance accuracy on the second sum into two components: the percentage of incorrect 2nd sums attributed to an incorrectly added first sum (CAAPC), and the percentage of incorrect 2nd sums attributed to incorrect addition of the constant (CAIPC). These categories were mutually exclusive. Paired t-tests were computed with respect to gender, days, sessions, and day-session combinations. Significant results for these tests are shown in Table 5. These comparisons indicated incorrect computation of the 1st sum contributed significantly more towards 2nd sum accuracy levels than addition of the constant number.

Table 5. Significant Paired T-Tests on Error Delineation for Incorrect 2nd Sum Results.

Controlling Effect	Sample Size	Significant Paired Comparisons	CAAPC Mean (%)	CAIPC Mean (%)	t-value	Significance
Overall	n=24		18.66	31.11	4.18	p<.001
Gender	n=24	Male	17.82	28.01	2.43	p=.016
	n=24	Female	19.49	34.21	3.47	p=.001
Day	n=24	SUSOPS1	14.81	35.19	3.98	p<.001
Session	n=24	0800 hours	16.55	32.06	2.18	p=.033
	n=24	2400 hours	9.26	33.80	3.76	p<.001
	n=24	0400 hours	18.75	35.42	2.24	p=.028
Day x Session	n=24	Baseline 2400	9.03	32.64	2.13	p=.044
	n=24	SUSOPS1 0800	10.07	39.93	2.59	p=.016
	n=24	SUSOPS1 2400	12.50	41.67	2.29	p=.032

Spatial Rotation

Soldiers' performance on the spatial rotation task involved pattern recognition and figure rotation. Eighteen evaluations were presented for this task. The significance of the interaction of day and session (F(10,15)=2.89, p<.031) on mean spatial rotation scores, SRATT, can be seen in Figure 28. Baseline performance at 0800 hours is significantly less than nearly all the other test periods (p<.01). Tukey testing also revealed the Baseline completion score at 0400 averages much less than test periods S3 through S10 (p<.01), while performance during the SUSOPS2 1600 hours period greatly exceeds Baseline 1200, 1600, and 2000 hours levels. Figure 28 also shows that testing day greatly affected the mean spatial rotation score (F(2,23)=7.14, p=.004). The Baseline average, 14.81 evaluations, was significantly lower than those for the two SUSOPS days, 15.86 and 16.03 evaluations respectively.

The spatial rotation completion scores at 1600, 2000, and 2400 hours (16.21, 15.90, and 15.88 respectively) as compared to poorer morning averages at 0400 and 0800 hours (15.05 and 14.96) establish the significant session main effects (F(5,20)=4.39, p=.007).

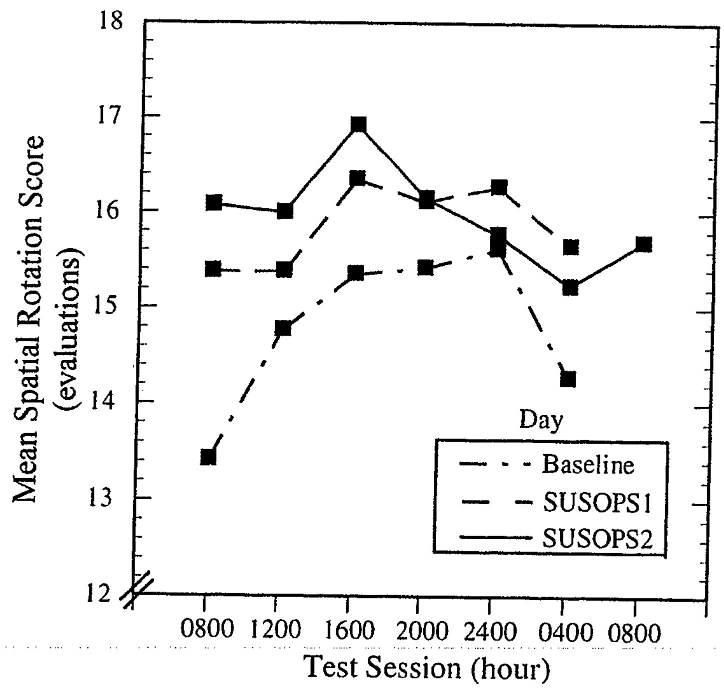

Figure 28. Mean Spatial Rotation Score by Field Day and Test Session.

As shown in Figure 29, accuracy levels for the spatial rotation task also exhibited significant interactions between day and session ($F(10,15)=3.83$, $p=0.01$.) Generally, accuracy scores during SUSOPS2 and Baseline days exceeded the corresponding periods of SUSOPS1, except during 2000 and 0400 hours. The Baseline accuracy levels at these times, were significantly lower than most of the SUSOPS2 performance averages. This maintenance of high accuracy levels during SUSOPS2 versus the other two performance days, 74.01% versus 65.69% and 65.89% respectively, produced significant main effects with respect to test day ($F(2,23)=17.19$, $p<.001$).

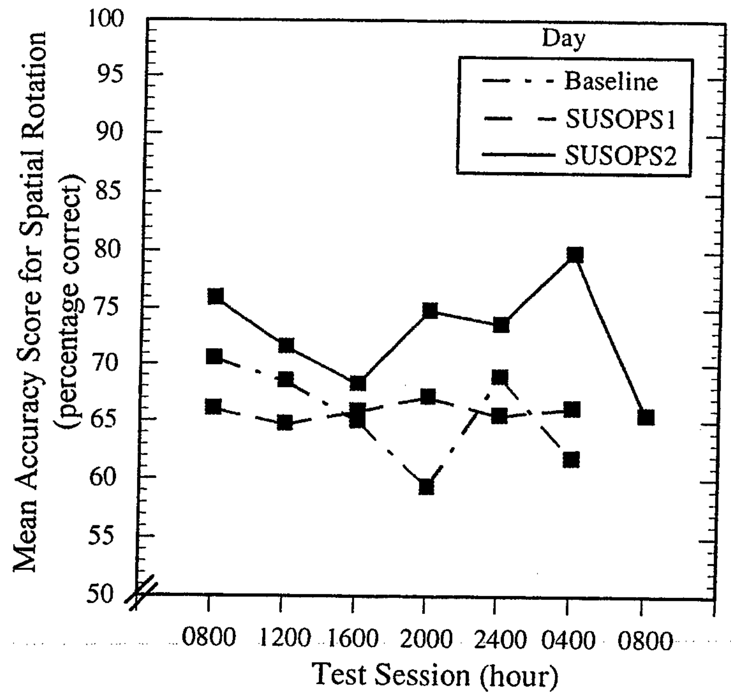

Figure 29. Mean Accuracy Score for Spatial Rotation by Field Day and Test Session.

Daily Log Information

The Daily Log sheets (Appendix C) were used to examine food, drink, caffeine, and cigarette consumption during the baseline and sustained operations testing days. In addition, the soldiers noted any rest or sleep hours along with their activity levels for the three-hour period prior to testing. Periodically, the job performance of the test participants was rated by the study safeties and by the soldiers themselves.

Food, drink, and caffeine consumption was tabulated according to categories of participant gender, study day, and test session. Cross tabulation results were examined using the Pearson X^2 statistic. Calculated residual errors determined the significant departures from expected response frequencies.

Food Consumption

Generally, soldiers were fed according to the schedule shown in Table 1. Breakfast and dinner were hot meals, while lunches were Meals-Ready-to-Eat (MREs). The late-night snack often included hot soup along with a beverage. Snacks including juice, cereal, breakfast bars, crackers, and fruit were along with water, a koolaid drink, and coffee. As mentioned earlier, food and drink consumption was curtailed prior to the testing periods. Statistical evaluation of men and women's food consumption overall revealed no significant deviations in reported frequencies of eating. However, a breakdown of gender reporting by session times did reveal a higher frequency level for "no food" consumption by men versus women, 48.7% versus 25.6%, prior to testing at 1600 hours.

No significant departures from expected reporting frequencies for food consumption were determined when reporting data were tabulated according to day and session.

Cross tabulation results regarding food consumption with respect to separate session and day categorizations exhibited significant deviations in reporting levels. Soldiers reported a higher expected frequency with respect to no eating during the Baseline day (52.3%) and lowered frequencies (32.7%) on the SUSOPS2 day. Tabulation of eating by session revealed soldiers ate less often than expected prior to the 0400 hours testing, while eating frequencies were higher than expected before 1200 and 2000 hours as soldiers snacked during the morning and ate dinner at 1700. These results are illustrated in Figure 30.

Drink and Caffeine Consumption

Drink consumption reports categorized by gender indicated significant departures from the expected frequencies as female soldiers noted higher "no drink" frequencies (27.6%) while male soldiers had lower frequencies of "no drink" responses (16.7%). Tabulation of drink consumption according to gender and session time paralleled these results as the men had a lower no drink frequency than women between 0500 and 0800.

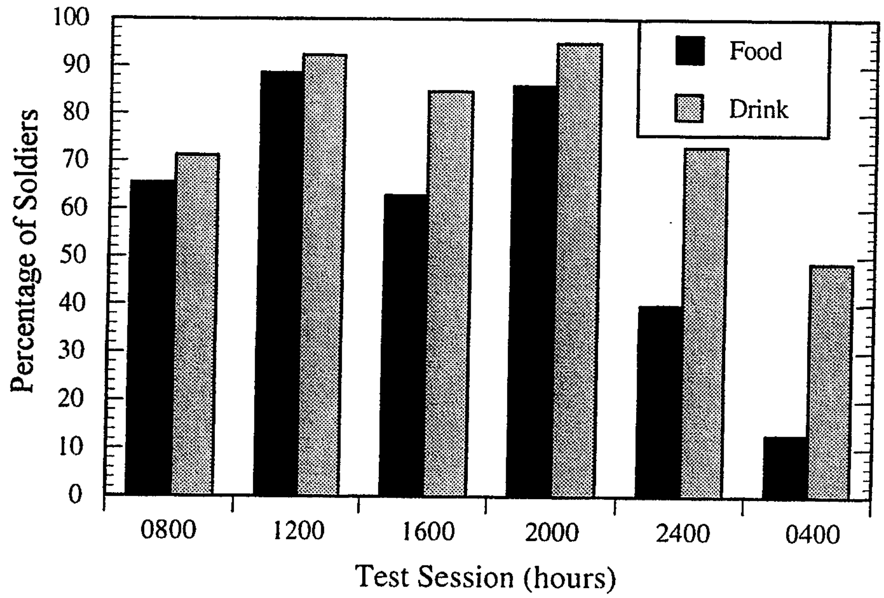

Figure 30. Food and Drink Consumption by Test Session.

Significant session-day results revealed lower than expected drink consumption before 0400 on both Baseline and SUSOPS1 days. Opposite to the increased no drink frequency reported at 0400, session times of 1200 and 0200 produced fewer reports of no drink consumption. Figure 30 shows these drink consumption frequencies.

Generally, soldiers consumed caffeine through drinking coffee. Cross-tabulation results did not indicate any significant trends in caffeine consumption according to gender. However, grouping caffeine reports according to gender and session times did indicate that between 1300 and 1600, the frequency of male caffeine consumption was elevated (46.2%), while female consumption declined (23.1%). Session-day categorization of caffeine consumption indicated a lower frequency of caffeine use before B6 and S3 testing. Only on the first sustained operations day did soldiers' caffeine intake deviate from expected levels, revealing less caffeine consumption (28.8%) when compared to Baseline and SUSOPS2 levels of 45.4% and 42.9%.

Rest hours

As soldiers were not allowed sleep during the study's sustained operations days, recorded sleep or rest hours occurred almost exclusively during the inter-test periods prior to the B2 through B6 sessions (0800 through 0400). When soldiers completed their Daily logs at 0800 on

SUSOPS1, they noted the number of hours of sleep they had before starting the sustained operations portion of the study. An abbreviated ANOVA examined differences in sleep hours prior to the 5 Baseline test periods with respect to gender and test period times. Rest or sleep time ranged from 0.10 hour to 1.8 hours, exhibiting a main effect of test time ($F(4,21)=22.89$, $p<.001$). As expected, soldiers obtained a significantly longer rest time prior to the 0400 period as compared to the other 4 pre-testing periods ($p<.05$). No significant gender differences in rest time were determined ($F(1,24)=0.12$, $p=.737$).

Examination of the number of sleep or rest hours soldiers experienced before undergoing sustained operations revealed no significant differences between the women and men ($F(1,24)=0.77$, $p=.39$). These times averaged 5.71 ± 2.57 hours.

Cigarette Usage

As with the other recorded items, soldiers noted the number of cigarettes smoked prior to the each test session. Nine soldiers were regular smokers. As smoking levels were not recorded for the time prior to test period B1, a balanced design was not possible to evaluate day by session interaction effects. Separate ANOVAs evaluated the main effects of day and session, along with the between-subjects effect of gender. Evaluation of all soldiers logs produced ANOVA results indicating no significant interaction effects between gender and day ($F(2,23)=2.26$, $p=.127$) or gender and session ($F(5,20)=1.79$, $p=.161$). Similarly, the main effects of day and session did not significantly affect cigarette usage levels. Among the 26 soldiers, average cigarette usage during the three hour inter-test period was 1 ± 2 cigarettes, with regular smokers using 2.4 ± 1.3 cigarettes.

Statistical examination of cigarette usage by this regular smoker group with respect to main and interaction effects of gender, day, or session revealed no significant differences.

Activity Levels

Soldiers characterized their activity levels according to intensity: "low" (tasks included weapons cleaning, police call, radio watch, eating, television viewing, driving, video game playing, and typing), "medium" (tasks included shopping, jogging, cleaning, clearing a building, refugee movement, and slow-paced ambush maneuvers; and "high" (strenuous tasks such as fire fighting, running, equipment loading, equipment moving, road marching, and quick ambush movements). Cross-tabulation results indicated significant departures from expected rating frequencies with respect to day, session, gender-day, and day-session groupings. On the Baseline and SUSOPS1 days, rating frequencies for three activity characterization levels differed significantly from expected values: Baseline activity had a greater number of low intensity ratings accompanied by lower medium and high intensity characterizations; while SUSOPS1 brought more medium and high intensity activity characterizations. Examining gender-day tabulations of activity ratings, indicated the men rated activity less frequently as "medium" (9.2%), while women denoted this level (30.8%) more frequently on the Baseline day. Session-day groupings indicated soldiers' activity evaluation for the early morning period prior to S12 testing had significantly more "low" than "medium" intensity responses. These results contributed to the greater low intensity ratings for the 0400 test sessions. Figure 31 shows the response frequencies for the three activity level categories according to test session.

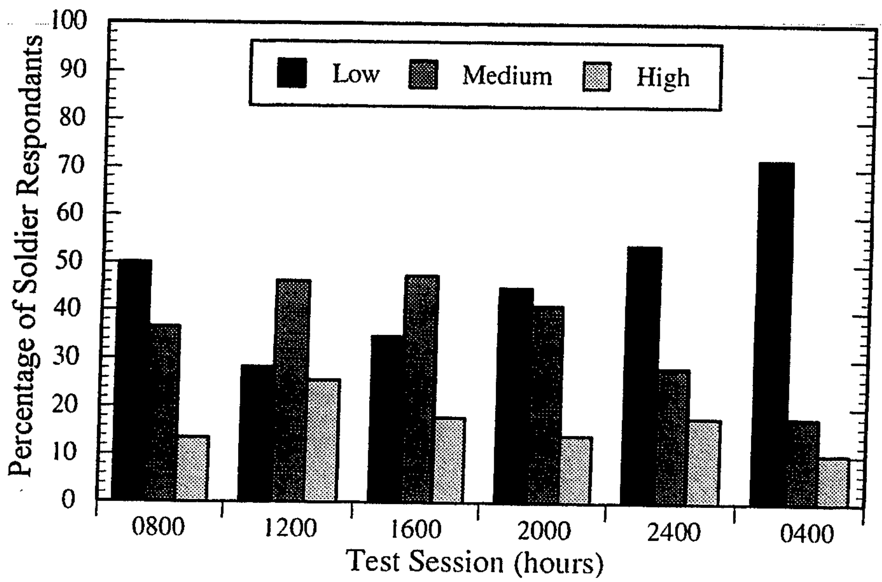

Figure 31. Activity Level Classification by Test Session.

Performance Ratings

Beginning with the Baseline test session at 1200 hours, soldiers made ratings of their own work performance for each 3-hour period prior to the test session. They annotated their daily log sheets, classifying their performance as (1) poor, (2) below average, (3) average, (4) excellent, or (5) superior. The study safeties also rated the soldier participants' performance during selected periods on sustained operations days 1 and 2. These peer ratings used the same five rating level classifications. Cross-tabulation of the soldiers' ratings revealed minimal use of the outlier classification levels. As a result, nonparametric analysis required a compression of these levels into three categories: below average, average, and above average.

Self Ratings

Cross-tabulation analyses revealed the male soldiers classified their performance more frequently as above average than predicted (36.7%), while females used this rating category less frequently (18.1%). This trend is paralleled when examining gender-day tabulations for Baseline and SUSOPS2 daily log data. Session-gender groupings of self ratings revealed work prior to 1200 hours testing was characterized less frequently as below average by women than men. (0% versus 7.7%). Overall, soldiers indicated that maintenance of higher performance quality was not possible, as higher frequencies of "below average" ratings occurred at 0400, especially for Baseline and SUSOPS1 days. (See Table 6.)

Table 6. Self-performance Ratings for Work Periods Prior to Test Sessions.

		Percentage of Soldiers' Ratings		
Test Session	**N**	**Below Average**	**Average**	**Above Average**
0800 hours	52	11.5	59.6	28.8
1200 hours	78	3.8	64.1	32.1
1600 hours	78	3.8	61.5	34.6
2000 hours	78	3.8	60.3	35.9
2400 hours	78	14.1	66.7	19.2
0400 hours	78	29.5	56.4	14.1

Peer Ratings

Most of the six peer-rated test periods occurred on one performance day because of limitations in safety observation of the soldiers for the inter-test periods. Examination of the peer ratings on the two sustained operations days (n=94 and n=51 ratings respectively) revealed significant departures from expected frequencies: SUSOPS1 had more "above average" ratings (69.1%) and fewer "below average" ratings (7.4%) than expected; while SUSOPS2 ratings were more prevalent in the "below average" category than the "above average" and "average" categories. Session time also affected the peer rating levels as work prior to 0800 hours received fewer "above average" ratings, and evening work before 2400 had a greater frequency of "above average" classifications. During the sustained operations days, the study safeties generally gave male test participants fewer than expected "below average" ratings than females

A total of 145 performance ratings pairs, self and peer, were made during the study. Results of the Friedman test revealed no significant difference between the mean self and peer performance ratings [$X^2(1, \underline{N}=145)=1.77, \underline{p}=0.184$]: 1.44 and 1.56 respectively. Examination of Kendall's Coefficient of Concordance [$X^2(1, \underline{N}=145)=3.12, \underline{p}=0.077$] concerning agreement between the pairs of soldier and peer ratings indicated low agreement ($\underline{W}=.02$).

DISCUSSION

Psychological Characteristics

Since no significant differences between men and women were found for the psychological trait variables, Pearson's correlation coefficients were computed between these variables and the cognitive performance measures for the combined group. Upon examining the significant correlations obtained between performance and trait anxiety and hostility, the hypothesis regarding individual differences in susceptibility to the effects of sleep deprivation is reinforced. Individuals who characterized themselves as moderately anxious and somewhat aggressive demonstrated better performance on logical reasoning tasks and on the spatial rotation tasks.

It is important to acknowledge the role of significant moderating variables as possible links between traits and performance. In other words, it is necessary to consider the kind and intensity of stress and the time of measurement, along with the personal factors that might account for the individual variability in performance. Appley and Trumbull (1977) found that relatively consistent intra-individual, but varied inter-individual, psychobiological response patterns occur in stressful situations. The impact of this response pattern on performance is not readily predictable from a knowledge of the situational conditions alone (e.g., sustained operations), but requires an analysis of the extent if individual variability in the context in which the stressor is applied.

During the 52-hour period of sustained operations, soldiers who typically maintain a moderate level of arousal seemed to perform well on logical reasoning and spatial rotation tasks. It is possible that, in spite of their increasing experience of sleepiness and fatigue, these soldiers were able to create an appropriate level of arousal to generate the vigilance necessary to perform well, but not so stressful as to interfere with this process.

Trait measures

There were no significant gender differences for any of the trait measures. Overall life stress was rated relatively high for soldiers who described themselves as generally feeling anxious or disappointed in themselves. Soldiers who reported high life stress perceived the sustained operations as more stressful. Those who reported a willingness to perform well were less fatigued in the late evening hours.

The General Efficacy Measure provides a self-assessment of one's ability to master new situations or ability to adapt to changing circumstances. This ability is considered to be a composite of past success and failure experiences and influences the individual's perception of how they might perform on military tasks (Sherer et al., 1982). Soldiers who reported increases in fatigue on both the ESQ fatigue subscale and the Stanford Sleepiness scale scored lower on General Efficacy. The same soldiers that reported lower levels of General Efficacy perceived the sustained operations periods as more stressful than those who had higher levels of Efficacy.

Bandura (1977, 1982, 1986) contends that individuals are constantly assessing their range of capabilities and that these assessments significantly guide and influence behavior. When individuals perceive a circumstance or task as exceeding their ability, they tend to minimize their efforts, perform less effectively, or avoid these situations altogether. On the other hand, when individuals believe the tasks or adjustment is within their range of capabilities, they invest more effort and tend to persevere even in the face of obstacles or adverse circumstances.

State Measures

Throughout the sustained operations period, men reported higher levels of Depression and Negative Affect while women experienced a slightly higher sense of well being than men. All of the stress perception levels with the exception of the SRE, significantly increased on the second day of sleep deprivation. These increases in stress levels and greater variability on SUSOPS day 2 were high enough to override or alter circadian patterns for the MAACL-R Depression, Hostility, and Negative Affect scores. It's noteworthy that the elevated Hostility and Negative Affect levels on SUSOPS day 2 dipped at the 1200 hour session. This was likely due to a personal hygiene break immediately preceeding this session. Findings that sleep loss degrades state measures are in congruence with previous research (Krueger, 1989).

The significant drop in Positive Affect during the baseline day stands out. Typically the pattern for Positive Affect is an inverse of one or more of the Negative Affect components (Anxiety, Depression, or Hostility) *if* the individuals appraise their situation as stressful (Fatkin & Hudgens, 1994; Fatkin, King, & Hudgens, 1990; Hudgens, Malto, Geddie, & Fatkin, 1991). However this pattern was not seen for the 1600 hours and 2000 hours time periods. While the soldiers reported a drop in Positive Affect during this time, the Negative Affect components of stress remained at stable and relatively low levels. Observational records indicate that during the late afternoon and early evening, soldiers' conversations were dominated by argumentative comments and concerns about the local team having lost a National Football League playoff game that Sunday afternoon. This 'significant external event' may have prompted the decrease in the soldiers' sense of well being for that afternoon.

Circadian Effects

The expected overall circadian pattern was found for the psychological measures on baseline day, as indicated by the significant sessions main effect. During the sustained operations period the Subjective Stress Scale and the Stanford Sleepiness Scale showed similar circadian patterns. A significant sessions main effect for Positive Affect, a measure of an individual's feeling of well being, is due to low measures during the 1600 hours and 2000 hours baseline day sessions. At all other times, Positive Affect measures appear stable. Circadian patterns were not found for Depression, Hostility, or Negative Affect. These findings indicate that circadian rhythms did not significantly affect individual's stress levels as measured by the MAACL-R. These scores did worsen across sessions, but the significant day by session interactions discussed above in the state measures section indicate circadian patterns were altered by sleep deprivation. The Subjective Stress Scale gives a measure of global stress, indicating the test participants showed some circadian variation overall. In breaking this overall measure into subcomponents, the similarity between the Subjective Stress Scale and the Stanford Sleepiness Scale indicate the overall circadian effect is due to variations in reported sleepiness.

The main objective of this study was to determine if sustained operations affect men and women differently. The lack of any significant gender by sessions interactions indicate there are no circadian differences between males and females, for the psychological measures reported here.

Physiological Measures

In all physiological measurements there was obvious circadian periodicity for both the men and the women; the highly significant main effects of the sessions reflected this. Examination of the physiological results' graphs reveals rising values during the 0800, 1200 and 1600 measurement periods. Values generally reached a peak at 1600 and declined in subsequent measurement periods (2000 and 2400) with troughs at 0400. There are some variations, especially for resting heart rate, but the general pattern is clear. The circadian patterns are in consonance with previous studies that have demonstrated rhythms in oral temperature (Froberg, 1977; Harma, Ilmarinen, Knauth, Rutenfranz, & Hanninen, 1988; Ilmarinen, Ilmarinen, Korhonen, & Nurminen, 1980; Reilly, Robinson, & Minors, 1984; Winget, DeRoshia, & Holley, 1985), grip strength (Hislop, 1963; Ilmarinen, et al., 1980; Reilly, 1990; Winget, et al., 1985; Wright, 1959) and resting heart rate (Ilmarinen, et al., 1980; Kleitman, 1923; Winget, et al., 1985).

Circadian cycling was well maintained during the scenario despite the lack of sleep. There were day by session interactions for oral temperature and heart rate but these did not indicate a lack of the circadian pattern but rather some alterations in the patterns as discussed below.

Winget et al. (1985) analyzed maximal values in circadian oscillations, acrophases, for a number of different studies. Comparisons of these data with our Baseline day show similar peaks. For oral temperature, acrophase times reported by Winget ranged from 1542 to 1739 in consonance with the 1600 found in our investigation. For right hand grip strength, Winget reports the highest values at times ranging from 1416 to 1826 and for left hand grip strength from 1508 to 1829. In our study, peak hand strength grip strength most often occurred at 1600 although the right hand grip strength of the women peaked at 2000. For heart rate Winget et al. (1985) reports peak times between 1546 and 1710 and in the present study peak values are found in the 1600 and 2000 time frame.

Oral Temperature

Any consideration of the body temperature of women must take into account the influence of the menstrual cycle. Body temperature rises of 0.2°C to 0.4°C are associated with ovulation (Moghissi, 1992) and are presumably due to the thermogenic effect of progesterone (DeMouzon, Testart, Lefevre, & Pouly, 1984; Israel & Schneller, 1950; Meyboom, 1991; Rothchild & Barnes, 1952). However, accurate monitoring of this temperature rise generally requires 6 to 8 hours of uninterrupted sleep (Moghissi, 1992). Further, about 20% of otherwise normally cycling women do not show temperature elevations (Bauman, 1981) despite the fact that the rise in progesterone appears to be very predictable in most women (Landgren, et al., 1980; Moghissi, 1992).

In our study, examination of individual temperature curves for each woman did not reveal any sudden rise in temperature during the course of the study. We were also unable to detect a difference in temperature between women 12-21 days into their cycle and those who were not. We failed to ask women about the actual length of their cycle and thus had to tenuously assume a wide range in which ovulation may have occurred. Ninety-four percent of women exhibit cycle lengths (defined as the first day of menstrual bleeding to the last day before the next menstrual bleeding) of 24 to 35 days (Landgren, et al., 1980).

Progesterone or their synthetic analogs are common components of oral contraceptives (Meyboom, 1991). Thus, we separated the female subjects on the basis of contraceptive users and non-users. There were no statistical differences between users and non-users but with only 3 users, statistical power was obviously low (Cohen, 1977). The users demonstrated the same pattern in oral temperatures as the non-users but their temperatures were consistently higher throughout, averaging 0.5°C for the entire study.

Table 7 shows studies that have examined the influence of sleep deprivation on core temperature (Fiorica, Higgins, Imapietro, Lategola, & Davis, 1968; Froberg, 1977; Kleitman, 1923; Kolka, Jones, & Elizonda, 1984; Kolka & Stephenson, 1988; Kreider, 1961; Martin & Chen, 1984; Savourey & Bittel, 1994; Sawka, Gonzalez, & Pandolf, 1984). Regardless of the method of measurement, most (Fiorica, et al., 1968; Froberg, 1977; Kleitman, 1923; Kolka, et al., 1984; Kolka & Stephenson, 1988; Kreider, 1961) but not all (Martin & Chen, 1984; Savourey & Bittel, 1994; Sawka, et al., 1984) studies show a decline in core temperature with sleep deprivation. Core temperature drops to a lower level as the period of sleep deprivation increases. Three of the studies had men and women subjects but did not separate them out in the data analysis. Thus, the present study is the first to compare men and women in the same conditions following sleep deprivation.

In both men and women, temperatures on SUSOPS2 were reduced relative to SUSOPS1. While there were no gender differences on SUSOPS1, the women had considerably lower temperatures during SUSOPS2. One reason for this may have been the body surface area to body mass ratio (BSA/BM). Women generally have a greater BSA/BM than men (Benke & Wilmore, 1974) which allows them to dissipate heat more efficiently. This is because per unit of body mass, more body surface area is exposed to the environment (McArdle, Katch, & Katch, 1986). While this is a favorable characteristic in a hot environment where thermoregulation requires heat loss, it is an unfavorable characteristic in a cold environment because thermoregulation requires heat retention.

Table 7

Studies Examining the Effect of Sleep Deprivation on Core Temperature.

Study	Subjects	Temp[a] Monitor[b]	Time of Day	BSA/ Body Mass (m^2/kg)	Lab Temp[a]	Length of Sleep Deprivation - Temperature(°C)
Kleitman (1923)	1 Male	T_o	1800			24h - 0.1 48h - 0.3 72h - 0.4 96h - 0.5
Kreider (1961)	8 men	T_{re}				87h - 0.5 to 0.7
Fiorica et al. (1968)	12 men	T_{re}	1500	0.0260		34h - 0.1 58h - 0.3 82h - 0.5
Froberg (1977)	31 women	T_o	1600		23	24h - 0.0 48h - 0.2
Kolka et al. (1984)	6 men 1 woman	T_{re}	0800	0.0256		50h - 0.5
Sawka et al. (1984)	5 men	T_{es}	1500	0.0264	28	33h - 0.1 (not significant, $p>0.05$)
Martin and Chen (1984)	5 men 3 women	T_{re}	0900			50 h - 0.0
Kolka and Stephenson (1988)	3 men 3 women	T_{es}	1400	0.0260	25	33h - 0.3
Savourey and Bittel (1994)	12 men	T_{re}	1200	0.0269	25	27h - 0.0

a TEMP=Temperature
b T_{re}=Rectal Temperature, T_{es}=Esophageal Temperature, T_o=Oral Temperature

In this study the body surface area to body mass ratio did not differ between men and women, thus both presumably had an equal ability to dissipate heat. Further, separation of the soldiers into groups of four with the highest and lowest body surface to mass ratios for each gender did not reveal any differences in T_O. Thus, while it is not clear why, it is apparent that the women's ability to thermoregulate was affected to a greater extent than that of the men on the second day of this scenario.

There was an altered pattern of temperature response on SUSOPS1, relative to the Baseline Day. This could have been due to the lower environmental temperature experienced in the field compared to the garrison environment. Acute exposure to moderately cold temperature (10°C) can result in a decrease in rectal temperature (Fiorica, et al., 1968). In addition, ambient temperature can accentuate the circadian temperature curve, resulting in higher peaks and lower troughs (Aschoff & Heise, 1972). It should be noted that these studies (Aschoff & Heise, 1972; Fiorica, et al., 1968) were conducted in laboratory conditions where clothing was controlled. In the present study, subjects were able to adjust their clothing in any way they chose. Generally, free-living humans will adjust to create a microclimate around themselves consistent with comfort and the maintenance of body temperature (Askew, 1989; Buskirk & Mendez, 1967).

Hand Grip Strength

There is no evidence that menstrual cycle phase affects maximum voluntary strength (Davis, Elford, & Jamieson, 1991; Dibrezzo, Fort, & Brown, 1991; Lebrun, McKenzie, Prior, & Taunton, 1995) so the effects of the menstrual cycle were not considered.

There was consistency among the types of hand grip strength measured. Right, left and dominant hand grip strength all produced similar results. There were no significant declines in hand grip strength over the course of the study and no alterations in the circadian pattern as evidenced by the lack of a day by session interaction. Previous studies on the influence of sleep deprivation on muscle strength have shown no decrement in performance after 36 hours (Bond, et al., 1988) or after 48 hours, even if subjects perform heavy physical exertion during the sleep deprivation period (Rodgers et al., 1995). Hand grip strength appears to be highly resistant to the effects of sleep loss (Reilly, 1990).

There was a 6% to 8% increase in grip strength when Baseline was compared to SUSOPS1. This is unlikely due to a familiarization effect. Previous studies show high reliability for the hand grip test (Ramos & Knapik, 1979). Further, subjects had two practice sessions before any measurements were taken and the Baseline Day provided additional practice. Had a familiarization effect occurred, an increase in strength would have been expected on the Baseline Day, however, a normal circadian variation can be seen. It would appear that some characteristic of the field environment accounted for the strength increase on SUSOPS1.

Men were significantly stronger than women throughout the test period. Women's right hand grip strength was 58%-62% that of the men. These averages agree well with studies comparing the relative grip strength of military men and women which report that women have 64% the strength of men (Nordesjo & Schele, 1974) and 63% (Sharp et al., 1980). Overall, women's upper body strength has been reported to be about 55% that of men (Knapik, Wright, Kowal, & Vogel, 1980; Laubach, 1976). Much of this difference may be accounted for by the lower muscle mass of women (Baumgartner, Rhyne, Troup, Wayne, & Garry, 1992; DeKoning, Binkhorst, Kauer, & Thijssen, 1986; Knapik, Staab, & Harman, 1996; Knapik, et al., 1980; Wilmore, 1974), since the major determinate of strength appears to be the cross-sectional area of muscle tissue (Ikai & Fukunaga, 1968; Maughan, 1984).

Heart Rate

Heart rate is a very labile physiological measure easily influenced by physical activity and the level of physical fitness (Astrand & Rodahl, 1977; McArdle, et al., 1986). In the present study care was taken to reduce physical activity prior to measurements by having subjects seated quietly for 30 minutes prior to measurements while they completed the questionnaires. Subjects did get up from the test area to walk to the area where the heart rate measures were obtained but this was a short distance and a one-minute equilibration period was allowed before measures were obtained. The heart rate curve does show a circadian pattern that is maintained throughout the scenario.

The higher heart rate at 1200 hours on SUSOPS1 probably reflects elevated sympathetic activity as a result of beginning the field exercise scenario (Hansen, Stoa, Blix, & Ursin, 1978; Holmboe, Bell, & Norman, 1975). Subjects experienced a great deal of physical activity between 0800 and 1200 hours and were excited at the success of their efforts at that point. Likewise, the higher heart rate at 2000 hours on the Baseline day may reflect some excitement at the novelty of the test situation.

Women maintained a higher heart rate throughout the scenario. It is known that individuals who are less fit maintain higher resting heart rates because of their reduced stroke volume (Astrand & Rodahl, 1977; McArdle et al., 1986). However, there are indications that the cardiorespiratory fitness levels of the men and women in this study are similar since their self-reported endurance and two-mile run percentile rankings were similar (Table 2). Thus, differences in fitness levels of the men and women cannot explain the higher heart rate of the women.

Performance Tests

Circadian Effects

As for the psychological and physiological data, performance measures reflected an obvious circadian pattern. All of the tasks, with the exception of logical reasoning, showed significant main effects for sessions with performance declining to its lowest point at the 0400 test period. These performance trends were as expected from earlier research in the field (Bjerner, Holm, & Swensson, 1955; Krueger, 1991). Froberg (1977) found performance was generally better during the day than at night, but also failed to find this day/night trend for a deductive reasoning task.

Manual Dexterity

The number of attachments for manual dexterity were significantly greater for male participants than for females. At first glance this seems to go against other findings regarding gender differences and dexterity. Since early research by Tiffin and Asher (1948), experimental findings seem to support the notion that women perform better on fine motor control tasks. Most of these findings are based on procedures that use the Perdue peg-board task, a task that requires subjects to pick up thin pegs. Recent research seems to indicate that finger size rather than manual dexterity may account for these gender differences. Peters, Servos, and Day (1990) found that significant sex differences disappeared when finger size was controlled for as a covariate. Kilshaw and Annett (1983) tested subjects in a peg-placing task using pegs that were thick and easier to grasp, and found a speed advantage for men. Peters and Campagnaro (1996), after testing men and women on six different motor tasks, concluded that the general claim that women are superior in fine motor performance could not be supported.

The task used in this study required subjects to pick up square nuts and attach them to bolts embedded on a board. The square nuts are easier to grasp and pick up then a peg, and would have been less difficult for larger fingers to manipulate. The task itself was also different, requiring subjects to repeatedly turn the nut to attach it to the bolt board, so that the overall task relied less on grasping and picking up an object. The gender difference found for manual dexterity can be explained by differences in the nature of the task used in this study and recent experimental findings.

With the exception of the 0800 test period, dexterity performance was lower for SUSOPS2 than for the baseline and SUSOPS1. During this task, test participants were instructed to perform attachments using the thumb and index finger, requiring fine motor control. The steady decline of dexterity scores during SUSOPS2 may indicate a sensitivity of fine motor control to sleep deprivation.

Verbal Memory

For this task, test participants studied the word list and were immediately required to recall as many words as possible. Word recall significantly declined on SUSOPS2. This is in correspondence with earlier finding in which Williams, Gieseking, and Lubin (1966) found significant impairment on word recall after one night of sleep loss. There were no significant gender differences for the effect of sleep deprivation on this memory task.

Logical Reasoning

Of the four cognitive tests, logical reasoning was the only one to show interactions with gender. Males tended to complete more evaluations than females over the course of the study. Women maintained relatively stable levels of accuracy throughout the three performance days while men tended to improve on SOSOPS2. It's important to note that the improved accuracy scores for men on SUSOPS2 were achieved for lower evaluation completion scores. Male accuracy improved but the number of items they completed to obtain this accuracy declined. Accuracy scores were obtained by dividing the number of items completed by the number of items correct. An examination of the raw number of correct responses for men for SUSOPS1 and SUSOPS2 shows mean performance on the second day being lower except for the 1600 and 2000 test periods. There were no significant gender differences in the psychological data to account for these findings. As this is the first research to directly compare female and male performance during sustained operations further study is needed to understand these gender differences.

Addition

The addition procedure used here was a self-paced task. Previous studies using self-paced addition have found that sleep deprivation causes decrements in speed over accuracy (Patrick & Gilbert, 1896; Weiskotten & Ferguson, 1930; Wilkinson, 1961a). Findings for addition show significant day by session interactions on the number attempted, a measure of speed, but no significant effects for accuracy. The stability in the accuracy scores are consistent with previous research. The findings for the speed variable are not as clear. Although there were significant effects for the number attempted, they were not in the expected direction. Overall, subjects tended to complete more addition problems on the second day of sleep deprivation. This was more than likely due to practice effects. Williams and Lubin (1967) found the addition task to be especially susceptible to practice. Familiarity with a task may reduce the effects of sleep loss (Wilkenson, 1961b)

Spatial Rotation

Completion scores for the spatial task were significantly lower on the baseline day then on the two SUSOPS days. Accuracy scores were higher on the second SUSOPS day. An examination of the the raw number of correct responses indicate that subjects got more items correct on SUSOPS2. This improved performance, on the second day without sleep, is an unexpected finding. As with the addition, it may be due to practice. This is unlikely however, because other research using this spatial task has not demonstrated practice effects (Mullins, Fatkin, & Patton, 1997). How, Foo, Low, Wong, Vijayan, Siew, & Kanapathy (1994) found improvements in performance on various tasks, including spatial tasks, from 48 to 60 hours. They attribute this finding to individual adaptations to fatigue effects. It is likely that this accounts for the results found for spatial rotation in this study.

CONCLUSIONS

Most of the prior research concerning sustained operations has used male subjects. The present research is the first to directly compare male and female performance during sustained operations. One of the main objectives of this study was to determine if sustained operations affected women and men differently. With the exceptions of oral temperature and logical reasoning, gender differences during sleep deprivation were not found. The gender differences for logical reasoning were the result of an increase in the men's accuracy on the second day of sleep deprivation. Therefore the womens' relatively stable levels of accuracy throughout the three performance days indicate there would not be related problems during an extended mission. The findings of this study are generally consistent with established findings regarding sustained operations as well as gender differences. Based on the relatively few differences observed, results indicate there would be minimum impact on extended military operations involving women participants.

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APPENDIX A

LIFE EVENTS FORM

LIFE EVENTS FORM I

1. Check the appropriate response: "I have recently experienced:"

   Unusually low stress ______
   Mild stress ______
   Moderate stress ______
   High stress ______
   Unusually high stress ______

2. Have you recently experienced any events having an impact on your life? Yes ____ No ____
   Please list them and indicate them as positive or negative by placing them in the corresponding column:

POSITIVE	DATE EVENT OCCURRED

NEGATIVE	DATE EVENT OCCURRED

3. How would you rate the way you handled any events that occurred?

   Very well ______
   Well ______
   Adequate ______
   Poorly ______
   Very Poorly ______

4. "Considering all that has happened recently, my resources for responding to the events were:"

   More than adequate ______
   Adequate ______
   Less than adequate ______

APPENDIX B

GENERAL INFORMATION QUESTIONNAIRE

FS,95

ID # ___________

GENERAL INFORMATION QUESTIONNAIRE

Please answer all questions by filling in the blanks as completely as possible. All information will be kept strictly confidential. The information is important for test purposes and will not be used for any other purpose.

1. SSN ______________

2. Today's Date ___________

3. Time ___________

4. MOS Primary _______ Time in MOS _____ (years) _____ (months)

   Secondary _______ Time in MOS _____ (years) _____ (months)

5. Length of service _____ (years) _____ (months)

6. Date of Birth ___________

7. Present Pay Grade _________

8. Education completed:
   High School _____ (years)
   College _____ (years)
   Grad School _____ (years)

9. Height ________

   Weight ________

10. On the scale below, place a mark on the line to indicate how important the completion of the study requirements are to you.

|___|___|___|___|___|___|___|___|___|___|

0 10 20 30 40 50 60 70 80 90 100

not important at all — extremely important

Please explain why:____

____

11. On the scale below, please rate how willing you are to participate in this study:

|___|___|___|___|___|___|___|___|___|___|

0 10 20 30 40 50 60 70 80 90 100

not at all — very willing

12. PHYSICAL ACTIVITY

a. In regard to overall physical activity, how would you describe your life?

Very Inactive	Somewhat Inactive	Average	Active	Very Active
____	____	____	____	____

b. How many times per week do you engage in any regular physical activity (like jogging, bicycling, etc.) long enough to work up a sweat?

None	1	2	3	4	5	6	7 or more
__	__	__	__	__	__	__	__

13. PHYSICAL FITNESS: Compared to others of your age and sex, how would you rate your:

	Far Below Average	Below Average	Average	Above Average	Far Above Average
a. Endurance	____	____	____	____	____
b. Sprint Speed	____	____	____	____	____
c. Strength	____	____	____	____	____
d. Flexibility	____	____	____	____	____

14. To the best of your recollection, list your most recent Army Physical Fitness Test (APFT) raw scores and APFT total points:

a. Number of Push-ups ________

b. Number of Sit-ups ________

c. Two-mile run time (min : sec) ____:____

d. Total APFT Points ________

15. Present overall health: (check one)

(1) ____ excellent

(2) ____ good

(3) ____ fair

(4) ____ poor

16. Have you experienced any of the following health symptoms?:

	Yes	(Time Occurred)	No	Don't Know
Frequent or severe headaches	___	__________	___	___
Dizziness or fainting spells	___	__________	___	___
Sinusitis (Sinus headache)	___	__________	___	___
Head injury	___	__________	___	___
Palpitation or heart pounding	___	__________	___	___
Heart trouble	___	__________	___	___
High or low blood pressure	___	__________	___	___
Loss of memory or amnesia	___	__________	___	___
Black-outs	___	__________	___	___
Excessive worrying or anxiety	___	__________	___	___

17 List any other health problems currently affecting you:

____

____

____

18. Are you **presently** taking any medicines or drugs for medical reasons?

_____ yes _____ no

If yes, what kind(s)?

____

For what condition?

____

Date you began using this medicine or drug ______________________

19. Other than those listed in question 18, have you taken medicines or drugs for medical reasons at any time during the past 3 months?

_____ yes _____ no

If yes, what kind(s)?

____

For what condition?

____

____

20. Are you presently receiving any hormone treatments (not including birth control pills)? ______ yes ______ no

If yes, what kind(s)?

For what condition?

21. Other than those listed in question 20, have you received any hormone treatments at any time during the past 3 months?

_____ yes _____ no

If yes, what kind(s)?

For what condition?

22. How many hours of sleep do you normally get on week nights? ______

on weekends? ______

23. Are you following any special diet right now? (check one)

_____ yes _____ no

If yes, explain:

24. Have you ever had any surgery that affected your reproductive system? (check one)

_____ yes _____ no

If yes, explain:

25. Do you find you are over tired: (check one)

(1) _____ never
(2) _____ occasionally
(3) _____ frequently

26. Do you consider yourself: (check one)

(1) _____ right-handed
(2) _____ left-handed
(3) _____ ambidextrous (right for some tasks, left for others)

27. Which hand do you use to write with: (check one)

_____ right _____ left

28. Do you smoke cigarettes? (check one) _____ yes _____ no

If yes, approximately how many per day? _____

29. Are you pregnant? (check one) _____ yes _____ no

30. At what age did you have your first period? ________

31. Are you taking birth control pills? _____ yes _____ no

32. If you are presently taking birth control pills:
(1) what brand of pills are you taking: ____________________
(2) how long ago did you start taking birth control pills __________

33. If your are not presently taking birth control pills:
Have you recently stopped taking birth control pills
(within the last 3 months): _____ yes _____ no

34. Have you ever had a child? _____ yes _____ no
If yes, how many? ________

35. Are your periods: (check one)
(1) _____ always regular and predictable
(2) _____ usually regular and predictable
(3) _____ irregular and unpredictable
(4) _____ other. Explain:

36. Have you missed a period during the last 3 months?
_____ yes _____ no
Do you miss periods: (check one) (1) _____ never
(2) _____ occasionally
(3) _____ frequently

37. Do you usually keep track of when your next period will start? (check one)
______ yes ______ no

If yes, what method(s)
Do you use?
(1) _____ memory
(2) _____ mark calendar
(3) _____ count birth control pills
(4) _____ other. Explain

38. What was the starting date of your most recent menses (first day of your period)?
____

39. Do you suffer from menstrual cramps or other menstrual symptoms that are severe enough to keep you from performing your regular duties? (check one)
(1) _____ never
(2) _____ occasionally
(3) _____ frequently

40. Do you use an I.U.D. (intra-uterine device)? _____ yes _____ no

APPENDIX C

DAILY LOG SHEET

Daily Log Sheet

Roster # __________

Date __________

Time __________

Activity: Type, Intensity (High, Medium, Low)

Food (what, how much)

Drinks (what, how much)

Sleep/Rest (when, how long)

Place an **X** in the box which best describes your performance since you last completed the questionnaires.

Field Performance Rating

Poor 1	Below Average 2	Average 3	Excellent 4	Superior 5

APPENDIX D

PEER RATING SHEET

SUSTAINED OPERATIONS STUDY
INDIVIDUAL FIELD PERFORMANCE RATING

Data Collector:____________________ Unit Id:____________________

Date (DDMMYY):________________ Field Location:____________________

Performance Session:__________

Period of Observation (HRMN-HRMN):____________________

INSTRUCTIONS

Select the single most appropriate rating (by placing an "X" in the corresponding column) which best describes the over-all field performance of each soldier while carrying out his duties/tasks during the period of your observation.

It should reflect such attributes as: how energetic or active she performs her tasks, her ability to handle the physical and cognitive demands of the job, the ability to "keep-up", signs of fatigue versus "freshness", and initiative and aggressiveness in performing MOS duties.

	Field Performance Rating					
Subject Number	Poor 1	Below Average 2	Average 3	Excellent 4	Superior 5	Comments

APPENDIX E

SEQUENCE OF EVENTS AND OPERATIONS ORDER

SEQUENCE OF EVENTS

The Operations Orders' sequence of events followed by the experimental group the Control Days and SUSOPS Days are given below.

(4 December 95) Control Day 1
0630-0700 Formation
0800-1630 MP/Load Equipment/Coordination/OPORD/Begin Baseline Period
0800-0900 Test B1
1200-1300 Test B2
1300 Load out/Final Preparations/MP
1600-1700 Test B3
2000-2100 Test B4

(5 December 95) Control Day 2
2400-0100 Test B5
0400-0500 Test B6
0730 Formation/Motor Pool
0800 Off
0815-1630 Finish Coordination/Combat checks (Safeties only)
1130-1230 Lunch
1300 TASC Pickups/Sign for mout site (Safeties only)
1400 Off (Safeties)

(6 December 95) SUSOPS Day 1
0400-0500 Draw Weapons/PMCS
0500-0600 Load Equipment/Communication checks/Convoy Brief
0600 SP
0630-0800 Set up site/Tents/Commo-Priority to test equipment
0800-0900 Test S1
0900-1000 418-Lane 1 - 1st Convoy
1000-1100 418-Lane 1 - 2nd Convoy
1100-1200 418-Lane 1 - 3rd Convoy
1200-1300 Test S2
1300-1400 Lunch
1400-1500 418-Lane 2 - 1st Convoy
1500-1600 418-Lane 2 - 2nd Convoy
1600-1700 Test S3
1700-1800 Dinner
1800-1900 418-Lane 2 - 3rd Convoy
1900-2000 Prep for attack/AAR
2000-2100 Test S4
2100-2400 Attack 418/HHD Lanes 1 and 2 (Fought brush fire)
*Lane 1 Refugees and Sniper Attack
Lane 2 Sniper Attack and Ambush
Lane 3 Attack

(7 December 95) SUSOPS Day 2
2400-0100 Test S5
0100-0200 Midnight Meal
0200-0400 Clear an occupied building
0400-0500 Test S6
0500-0600 Weapons cleaning, personal hygiene
0600-0700 Breakfast
0700-0800 Weapons cleaning
0800-0900 Test S7
0900-1100 2nd Transportation, 1st Platoon Lane 1
1100-1200 Lunch
1200-1300 Test S8
1300-1400 Begin site clean-up
1400-1600 Finish clean-up/Tear down/Clean weapons
1600-1700 Test S9
1700-1730 Dinner/Call for Range Clearance
1730-2000 Clear/Move to Company Motor Pool/Set up for next test
2000-2100 Test S10
2100-2400 Inventory and clean equipment, Field recovery

(8 December 95) SUSOPS Day 3
2400-0100 Test S11
0100-0200 Midnight Meal
0200-0400 Clean weapons/Mask/PMCS
0400-0500 Test S12
0500-0600 Complete field recovery
0600-0700 Breakfast
0800-0900 Final test S13
0900 Debriefing
0900-1500 Release, required rest time

OPERATIONS ORDER

1. Situation:

a. Enemy Situation: Our potential enemies are the cold weather, fatique, and spotty leadership that allows soldiers to commit unsafe acts. Fatigue will play a critical role in this exercise as soldiers will be submitted to 48 hours of continuous sleep-deprived work 6-8 December.

b. Friendly Situation: The Human Research and Engineering Directorate, Army Research Laboratory, collects data on soldier performance in continuous operations at Fort Hood, Texas, 4-8 December as part of the Defense Women's Health Research Program (DWHRP) field study. This study has the attention of the 64th CSG and 13th COSCOM Commanders and the III Corps Deputy Commanding General.

2. Mission: The 180th Transportation Battalion supports the Army Research Laboratory in collecting data on soldier performance in continuous operations at Fort Hood, 4-8 December 1995.

3. Execution:

a. Commander's Intent: The results of this effort will have Army and DOD wide impact for years to come. We will commit the battalion's assets to ensure we fully support this mission. We will provide a minimum of 12 male and 12 female soldiers. Intent to mazimize use of Red cycle platoons (2d Transportation Company). The desired endstate is to collect baseline and field data on 13-14 male and female soldiers and have the entire unit back safely in the company area by 081700 December.

b. Concept of the Operation: The ARL data collecting team consisting of ten soldiers and DA civilians will arrive at Fort Hood 2 December. The focus of this study is on performance under combat-like stress conditions.

Day 0 Complete administrative forms and conduct two practice sessions (3 hours, 1 hour).

Day 1 Begin 0800 conduct baseline tests every four hours for 2400 hours: 040800, 041200, 041500, 042000, 042400, 050400. This requires test soldiers report to the baseline test area (location TBD by company commander) every four hours for testing. This "baseline data" is used as a point of comparison against data collected in the field. It will take approximately 45 minutes to 1 hour to conduct the baseline tests. It evaluates performance during different periods of soldiers' daily cycles.

Day 2 Conduct baseline tests until 0500. Upon conclusion, the test platoon prepares to depart to the training area. Soldiers are encouraged to get maximum sleep this night.

Day 3 NLT 0800 the test platoon must be in their field position. For the next 48 hours these soldiers must remain awake conducting Common and MOS 88 related tasks. Beginning 0800 they will conduct a battery of tests every four hours: 060800, 061200, 061600, 062000, and 062400.

Day 4 The testing every fours during the sleep deprivation period continues: 070400, 070800, 071200, 071500, 072000, and 072400.

Day 5 The testing every four hours during the sleep deprivation period continues 080400 and 080800. Upon conclusion of the testing period, the platoon will be released in the company area. **Ensure soldiers who have been awake ≥ 24 hours without 6 hours sleep do not drive.**

4. Service Support: N/A

5. Command and Signal:

a. Signal: Range Control Frequency is 30.45; Fort Hood Lifesaver frequency is 38.30, call sign "DUSTOFF."

b. Command: The battalion TOC will be located in TA 30 4-7 December.

APPENDIX F

STATISTICAL RESULTS FOR PSYCHOLOGICAL MEASURES

Table F-1

CORRELATIONS BETWEEN LIFE STRESS AND PSYCHOLOGICAL TRAIT AND STATE MEASURES

	Life Events: Stress Recently Experienced
Trait	
General Efficacy	-0.606**
Anxiety	0.642**
Depression	0.605**
Dysphoria	0.616**
SUSOPS1 Situational Stress	
0800	0.540**
1200	0.539**
1600	0.494*
2000	0.554**
2400	0.657**
0400	0.710**
SUSOPS2 Situational Stress	
0800	0.668**
1200	0.574**
1600	0.612**
2000	0.658**
2400	0.720**
0400	0.331

n=25
*p<.05; **p<.01

Table F-2

CORRELATIONS BETWEEN GENERAL EFFICACY AND STATE STRESS VARIABLES

		Measure			
Day	Time	Sleepiness	Fatigue	Subj Stress	Pos Aff
Baseline	0800	-0.389*	-0.095	-0.573**	0.273
	1200	-0.296		-0.452*	0.432*
	1600	-0.511**		-0.393*	0.455*
	2000	-0.462*	-0.474*	-0.302	0.564**
	2400	-0.125		-0.177	0.140
	0400	-0.436*		-0.181	0.412*
SUSOPS1	0800	-0.263	-0.271	-0.309	0.423*
	1200	-0.270		-0.258	0.442*
	1600	-0.298		-0.356	0.410*
	2000	-0.565**	-0.607**	-0.438*	0.179
	2400	-0.586**		-0.586**	0.489*
	0400	-0.470*		-0.417*	0.461*
SUSOPS2	0800	-0.477*	-0.063	-0.468*	0.334
	1200	-0.635*		-0.489*	0.473*
	1600	-0.516**		-0.614**	0.572**
	2000	-0.399*	-0.364	-0.335	0.274
	2400	-0.467*		-0.343	0.330
	0400	-0.122		-0.292	0.396*

n=26

*p<.05; **p<.01

Subj Stress - Subjective Stress; Pos Aff - Positive Affect

Table F-3

CORRELATION RESULTS FOR PSYCHOLOGICAL TRAIT ANXIETY AND HOSTILITY WITH PERFORMANCE SCORES (TOTAL CORRECT)

Day	Session	Memory		Log. Reas		Addition		Spacial	
		T-Anx	T-Hos	T-Anx	T-Hos	T-Anx	T-Hos	T-Anx	T-Hos
Baseline	0800	.263	.259	.567*	.327	.460*	.225	.151	.449*
	1200	.070	.154	.345	.140	.375	.228	.442*	.468*
	1600	.217	.241	.456*	.319	.194	.002	.495*	.606*
	2000	.214	.195	.283	.117	.156	.054	.393*	.578*
	2400	-.085	.188	.512*	.214	.247	-.058	.404*	.278
	0400	.304	.342	.412*	.088	.379	.242	.295	.460*
SUSOPS1	0800	-.042	.015	.403*	.181	.297	.130	.366	.252
	1200	.046	.271	.435*	.007	.169	.132	.101	.420*
	1600	.169	.274	.493*	.160	.198	.130	.519*	.514*
	2000	.041	.304	.422*	.092	.208	.229	.263	.421*
	2400	.124	.158	.281	-.003	.468*	.059	.352	.510*
	0400	.114	.215	.158	.033	.232	.051	.365	.225
SUSOPS2	0800	.142	.298	.442*	-.023	.175	-.004	.402*	.415*
	1200	-.083	.189	.463*	.154	.306	.141	.234	.323
	1600	.041	.033	.237	-.118	-.006	-.161	.345	.167
	2000	.003	-.011	.491*	.121	.212	.129	.574*	.596*
	2400	-.363	-.153	-.199	-.390*	.031	.062	.078	.381
	0400	-.181	-.082	.511*	-.068	.343	-.127	.436*	.246

n=26
*$p < .05$

Table F-4

CORRELATIONS BETWEEN "WILLINGNESS TO PERFORM WELL" AND SIMPLE ADDITION PERFORMANCE

		Simple Addition		
		# Attempted		# Correct
Baseline	0800	0.401*	0800	0.370
	1200	0.456*	1200	0.474*
	1600	0.415*	1600	0.366
	2000	0.526**	2000	0.453*
	2400	0.347	2400	0.329
	0400	0.223	0400	0.222
SUSOPS1	0800	0.313	0800	0.321
	1200	0.416*	1200	0.232
	1600	0.354*	1600	0.332
	2000	0.562**	2000	0.554**
	2400	0.304	2400	0.225
	0400	0.302	0400	0.163
SUSOPS2	0800	0.532**	0800	0.557**
	1200	0.392	1200	0.432
	1600	0.420*	1600	0.372
	2000	0.456**	2000	0.444*
	2400	0.201	2400	0.070
	0400	0.435	0400	0.393

n=25

*p<.05; **p<.01

APPENDIX G

ANOVA RESULTS FOR PHYSIOLOGICAL MEASURES

ANOVA RESULTS FOR PHYSIOLOGICAL MEASURES

Variable	Effect	F-ratio	p-value
Oral Temperature	Gender	F(1,24)= 1.24	p=.277
	Gender x Day	F(2,23)= 4.21	p=.028
	Day	F(2,23)=34.39	p<.001
	Gender x Session	F(5,20)= 4.03	p=.011
	Session	F(5,20)=19.55	p<.001
	Gender x Day x Session	F(10,15)= 0.96	p=.509
	Day x Session	F(10,15)= 2.84	p=.033
Right Hand Grip Strength	Gender	F(1,24)=51.59	p<.001
	Gender x Day	F(2,23)= 0.44	p=.646
	Day	F(2,23)= 8.83	p=.001
	Gender x Session	F(5,20)= 1.06	p=.412
	Session	F(5,20)= 8.79	p<.001
	Gender x Day x Session	F(10,15)= 0.61	p=.785
	Day x Session	F(10,15)= 2.01	p=.107
Left Hand Grip Strength	Gender	F(1,24)=52.59	p<.001
	Gender x Day	F(2,23)= 1.36	p=.276
	Day	F(2,23)= 8.28	p=.002
	Gender x Session	F(5,20)= 0.38	p=.857
	Session	F(5,20)=15.67	p<.001
	Gender x Day x Session	F(10,15)= 0.98	p=.499
	Day x Session	F(10,15)= 1.96	p=.116
Dominant Hand Grip Strength	Gender	F(1,24)=47.31	p<.001
	Gender x Day	F(2,23)= 0.55	p=585
	Day	F(2,23)= 9.70	p=.001
	Gender x Session	F(5,20)= 0.39	p=.852
	Session	F(5,20)= 7.54	p<.001
	Gender x Day x Session	F(10,15)= 0.58	p=.807
	Day x Session	F(10,15)= 1.65	p=.184
Resting Heart Rate	Gender	F(1,24)=11.16	p=.003
	Gender x Day	F(2,23)= 2.16	p=.139
	Day	F(2,23)= 7.95	p=.002
	Gender x Session	F(5,20)= 0.52	p=.756
	Session	F(5,20)=42.18	p<.001
	Gender x Day x Session	F(10,15)= 2.01	p=.108
	Day x Session	F(10,15)= 4.62	p=.004

APPENDIX H

ANOVA RESULTS FOR PERFORMANCE TESTS

ANOVA RESULTS FOR PERFORMANCE TESTS

Variable	Effect	F-ratio	p-value
Manual Dexterity (DXATT)	Gender	F(1,24)=12.23	p=.002
	Gender x Day	F(2,23)= 2.29	p=.123
	Day	F(2,23)= 3.13	p=.063
	Gender x Session	F(5,20)= 0.46	p=.800
	Session	F(5,20)= 4.20	p=.009
	Gender x Day x Session	F(10,15)= 1.98	p=.113
	Day x Session	F(10,15)= 4.56	p=.004
Verbal Memory (VRATT)	Gender	F(1,24)= 0.54	p=.468
	Gender x Day	F(2,23)= 0.55	p=.587
	Day	F(2,23)= 5.23	p=.013
	Gender x Session	F(5,20)= 0.70	p=.631
	Session	F(5,20)= 13.00	p<.001
	Gender x Day x Session	F(10,15)= 0.80	p=.633
	Day x Session	F(10,15)= 1.51	p=.227
Logical Reasoning (LRATT)	Gender	F(1,24)= 0.32	p=.577
	Gender x Day	F(2,23)= 0.82	p=.451
	Day	F(2,23)= 2.47	p=.107
	Gender x Session	F(5,20)= 1.41	p=.264
	Session	F(5,20)= 1.99	p=.124
	Gender x Day x Session	F(10,15)= 4.95	p=.003
	Day x Session	F(10,15)= 2.13	p=.091
Logical Reasoning (LRPC)	Gender	F(1,24)= 0.32	p=.576
	Gender x Day	F(2,23)= 3.42	p=.050
	Day	F(2,23)= 3.46	p=.049
	Gender x Session	F(5,20)= 0.61	p=.690
	Session	F(5,20)= 1.49	p=.237
	Gender x Day x Session	F(10,15)= 0.57	p=.812
	Day x Session	F(10,15)= 2.77	p=.037
Simple Addition (ADATT)	Gender	F(1,24)= 1.70	p=.205
	Gender x Day	F(2,23)= 0.52	p=.601
	Day	F(2,23)=13.80	p<.001
	Gender x Session	F(5,20)= 1.77	p=.165
	Session	F(5,20)=21.72	p<.001
	Gender x Day x Session	F(10,15)= 1.85	p=.136
	Day x Session	F(10,15)=17.18	p<.001
Simple Addition (ADPC)	Gender	F(1,24)= 0.09	p=.761
	Gender x Day	F(2,23)= 0.54	p=.592
	Day	F(2,23)= 0.38	p=.689
	Gender x Session	F(5,20)= 0.51	p=.766
	Session	F(5,20)= 1.82	p=.155
	Gender x Day x Session	F(10,15)= 2.04	p=.104
	Day x Session	F(10,15)= 1.13	p=.400

ANALYSES OF VARIANCE RESULTS FOR PERFORMANCE MEASURES (CONT.)

Variable	Effect	F-ratio	p-value
Addition with Constant (CAATT)	Gender	F(1,22)= 1.85	p=.187
	Gender x Day	F(2,21)= 1.09	p=.354
	Day	F(2,21)= 3.42	p=.052
	Gender x Session	F(5,18)= 1.08	p=.403
	Session	F(5,18)=10.30	p<.001
	Gender x Day x Session	F(10,13)= 1.98	p=.124
	Day x Session	F(10,13)= 7.04	p=.001
Addition with Constant (S1PC)	Gender	F(1,22)= 1.88	p=.185
	Gender x Day	F(2,21)= 0.30	p=.740
	Day	F(2,21)= 2.84	p=.081
	Gender x Session	F(5,18)= 0.80	p=.562
	Session	F(5,18)= 0.89	p=.508
	Gender x Day x Session	F(10,13)= 1.19	p=.377
	Day x Session	F(10,13)= 2.63	p=.053
Addition with Constant (S2PC)	Gender	F(1,22)= 0.41	p=.531
	Gender x Day	F(2,21)= 1.62	p=.222
	Day	F(2,21)= 2.87	p=.079
	Gender x Session	F(5,18)= 1.50	p=.240
	Session	F(5,18)= 2.26	p=.092
	Gender x Day x Session	F(10,13)= 0.31	p=.966
	Day x Session	F(10,13)= 2.90	p=.038
Spatial Rotation (SRATT)	Gender	F(1,24)= 2.92	p=.100
	Gender x Day	F(2,23)= 0.64	p=.538
	Day	F(2,23)= 7.14	p=.004
	Gender x Session	F(5,20)= 0.64	p=.670
	Session	F(5,20)= 4.39	p=.007
	Gender x Day x Session	F(10,15)= 0.46	p=.893
	Day x Session	F(10,15)= 2.89	p=.031
Spatial Rotation (SRPC)	Gender	F(1,24)= 2.14	p=.156
	Gender x Day	F(2,23)= 1.00	p=.382
	Day	F(2,23)= 17.19	p<.001
	Gender x Session	F(5,20)= 2.41	p=.073
	Session	F(5,20)= 1.55	p=.221
	Gender x Day x Session	F(10,15)= 0.71	p=.707
	Day x Session	F(10,15)= 3.83	p=.010