THE "FOG OF WAR": DOCUMENTING COGNITIVE DECREMENTS ASSOCIATED WITH THE STRESS OF COMBAT

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ABSTRACT

Anecdotal reports from military conflicts suggest cognitive performance is severely degraded by the stress of combat. However, there is little objective information available to confirm these observations. Recently, our laboratory has had several unique opportunities to study cognitive function in warfighters engaged in exercises designed to simulate the stress of combat. These studies were conducted with two very different types of military volunteers. In one study, subjects were officers, with an average of 9 years of military service, who were members of an elite, operational U.S. Army unit, the 75th Ranger Regiment. In the other study, the participants were younger, mostly enlisted, trainees with only 3 years of military experience on average, and who were in training to determine whether they would qualify to join an elite U.S. Navy unit, the SEALS. We administered a variety of identical computer-based cognitive tests to both groups. We consistently observed that during stressful combat-like training, every aspect of cognitive function assessed was severely degraded, compared to the subjects' own baseline, pre-stress performance. Relatively simple cognitive functions such as reaction time and vigilance were significantly impaired, as were more complex functions, including memory and logical reasoning. The magnitudes of the deficits were greater than those typically produced by alcohol intoxication or treatment with sedating drugs. Undoubtedly, such decrements would severely degrade operational effectiveness. Furthermore, it is likely such cognitive decrements would be even greater during the stress of actual combat. War planners, doctrine developers and warfighters, especially leaders, need to be aware that combat stress will result in extensive and severe deficits in cognitive performance. Operational planning for the Objective Force must carefully consider the consequences of errors and degraded cognitive performance in stressful operations and develop appropriate countermeasures.

1. INTRODUCTION

"*War is uncertain, mentally complex, physically demanding, and an intensely emotional experience. Objective Force soldiers must be physically and mentally tough enough to dominate their opponents despite these challenges.*" (United States Army, 2002)

The Objective Force Warrior must be physically and mentally tough to continue functioning in an extremely stressful environment, the future battlefield. The demands on cognitive functions, such as vigilance, reaction time, situational awareness, memory and decision making will be extraordinary, given the complexity and pace of future combat operations. In addition to these demands, traditional stressors associated with combat will still be present. Continuous operations, and consequently sleep loss, are to be expected, as will be environmental stress from exposure to heat, cold and high altitude. Hydration and nutritional state may often be compromised. Injury and death, and the fear associated with these factors will be experienced by many warfighters. Operational stress will increase as opposing forces utilize tactics and strategies designed to overcome our technological and organizational advantages, employing technology themselves in unconventional and unanticipated ways (United States Army, 2002).

There is considerable anecdotal documentation of the severity and the devastating impact of combat on the ability of warfighters to process cognitive information and act quickly, effectively and decisively on the battlefield. In the popular literature the phrase, the "fog of war" has been used to describe this mental state, as well as the many external factors contributing to uncertainty and indecision. This term suggests that confusion, chaos and resulting errors occur because of the multiple stressors of the battlefield.

Although the existence and operational impact of the "fog of war" is acknowledged by military personnel and historians, scientific documentation of the nature and severity of the deficits in cognitive function on the battlefield is virtually non-existent. One way to overcome the adverse cognitive effects of combat is believed to be realistic military training. Although many of the stressors associated with combat can be simulated in training exercises, the full range and intensity of combat cannot be adequately duplicated due, in part, to the high risk of injury or death and the presence of actual casualties on the battlefield. In spite of this limitation, information collected during high intensity training exercises intended to simulate combat is more likely to reveal cognitive decrements that would be present during actual combat compared to data collected in non-stressful laboratory settings. Objective documentation of the nature and severity of cognitive performance decrements in simulated combat may provide insight into causes, management and treatment strategies to mitigate such deficits.

Recently, our laboratory has had the opportunity to evaluate the cognitive function, and in some instances selected physiological factors, of warfighters engaged in relatively brief, high-intensity training operations, such as a U.S. Army Ranger training exercise designed to evaluate junior leaders, and Hell Week of U.S. Navy SEAL training during which candidates are selected for further training as SEALS (Smoak et al., 1988; Waller, 1994; Lieberman et al., in press). Both of these training scenarios were intended to simulate combat-like conditions by combining multiple stressors. Common elements of the exercises included sleep deprivation, high levels of continuous physical activity, substantial physiological, environmental and psychological stress and inclusion of simulated, combat-like activities.

2. METHODS AND RESULTS

All volunteers participating in the two studies presented here were active duty military personnel. The behavioral evaluations used in each study were identical tests of cognitive function administered on IBM-compatible laptop computers. When practical, non-invasive measures of physical status were also employed. An Institutional Review Board approved each study and all subjects gave written informed consent.

2.1 Behavioral Tests Administered

A battery of behavioral tests was selected to assess a wide range of cognitive functions associated with key military tasks. Basic functions, such as vigilance, perception and reaction time, which are required for the detection, identification and response to critical battlefield stimuli, were quantified. More complex functions such as learning, memory and logical reasoning were also assessed, as these are necessary for complex, multimodal information processing and decision making on the battlefield.

Four-Choice Visual Reaction Time Test

This is a test of ability to respond rapidly and accurately to simple visual stimuli. Volunteers were presented a series of visual stimuli at one of four different spatial locations on the computer screen (Dollins et al., 1993). They indicated the correct spatial location of each stimulus by pressing one of four adjacent keys on the keyboard. Parameters recorded included correct and incorrect responses, response latency, premature errors (responding before presentation of the stimulus) and time-out errors (response latency greater than one second). The test took about five minutes to complete.

USARIEM Visual Vigilance Test

This test assessed vigilance, the ability to sustain attention during a relatively boring, continuous task, which generates minimal cognitive load (Fine et al., 1994; Lieberman et al., 1998). The subject was required to continuously scan the computer screen to detect the occurrence of an infrequent, difficult to detect stimulus, which appeared at random intervals and locations on the screen for two seconds. Each test session lasted 20 minutes.

Matching-to-Sample Test

Short-term spatial memory (working memory) and pattern recognition are evaluated by this task (Shurtleff et al., 1994). An 8 x 8 matrix of a red and green checkerboard pattern was presented for 6 seconds, was removed and was followed by a variable delay interval. After the delay, two matrices were presented: the original and a second matrix, which differed slightly. The volunteer then attempted to select the matrix that matched the original sample. The test took about 5 minutes to complete.

Repeated Acquisition Test

This test assessed motor learning, attention and short-term memory (Ahlers et al., 1994). Volunteers learned several sequences of 12 keystrokes using the four arrow keys of the computers based on visual feedback presented on the computer screen. The time to complete this task was approximately 10 minutes.

Grammatical Reasoning Test

Adapted from the Baddeley Grammatical Reasoning Test, this task assessed language-based logical reasoning (Baddeley, 1968). On each trial, a logical statement, such as "A is preceded by B," was followed by the letters AB or BA. The volunteer decided whether each statement correctly described the order of the two letters. A session lasted for 32 trials and takes five minutes to complete. It could not be administered to the SEAL trainees due to limitation in the time available to conduct testing during Hell Week.

Profile of Mood States (POMS) Questionnaire

Mood state is a sensitive indicator of the ability of an individual to function adequately. The POMS, which has been used in a wide variety of civilian and military studies, is a standardized inventory of mood states (McNair et al., 1971). The volunteers rated a series a 65 mood-related adjectives on a five-point scale, in response to the question, "How are you feeling right now?" The individual adjectives factor into six mood sub-scales: Tension, Depression, Anger, Vigor, Fatigue and Confusion. It took less than 5 minutes to complete.

2.2 Study I: A Brief but Intense Training Exercise Conducted by an Operational Ranger Unit

This study was conducted with U.S. Army Rangers (N=31) participating in a combat training exercise designed to simulate a high-intensity, light infantry operation in a hostile environment. The mean age of the volunteers was 32 years and their average height and weight were 178 ± 1.4 cm and 82 ± 1.3 kg, respectively. All were officers with the rank of Captain, and had served an average of 9 years on active duty. The exercise was conducted in a hot, humid environment, with maximum ambient temperatures as high as 31^{o} C and daily lows reaching 19^{o} C. Humidity averaged 86% in the morning and 56% in the afternoon.

The exercise consisted of three phases: a garrison preparation phase, a field exercise and a concluding garrison phase. Subjects' cognitive performance, mood and body composition were assessed once during each phase. The first test session was conducted at approximately 1600 h on day 1, in a classroom-like setting at the beginning of the preparation phase of the exercise. The unit deployed to the field at 0100 h on day 3, and testing was conducted on day 4 at 1300 h in a tent. The final testing session was conducted at approximately 0500 h on day 5, immediately upon return to garrison in the same location as the first test session and before the volunteers had an opportunity to sleep, eat or rehydrate.

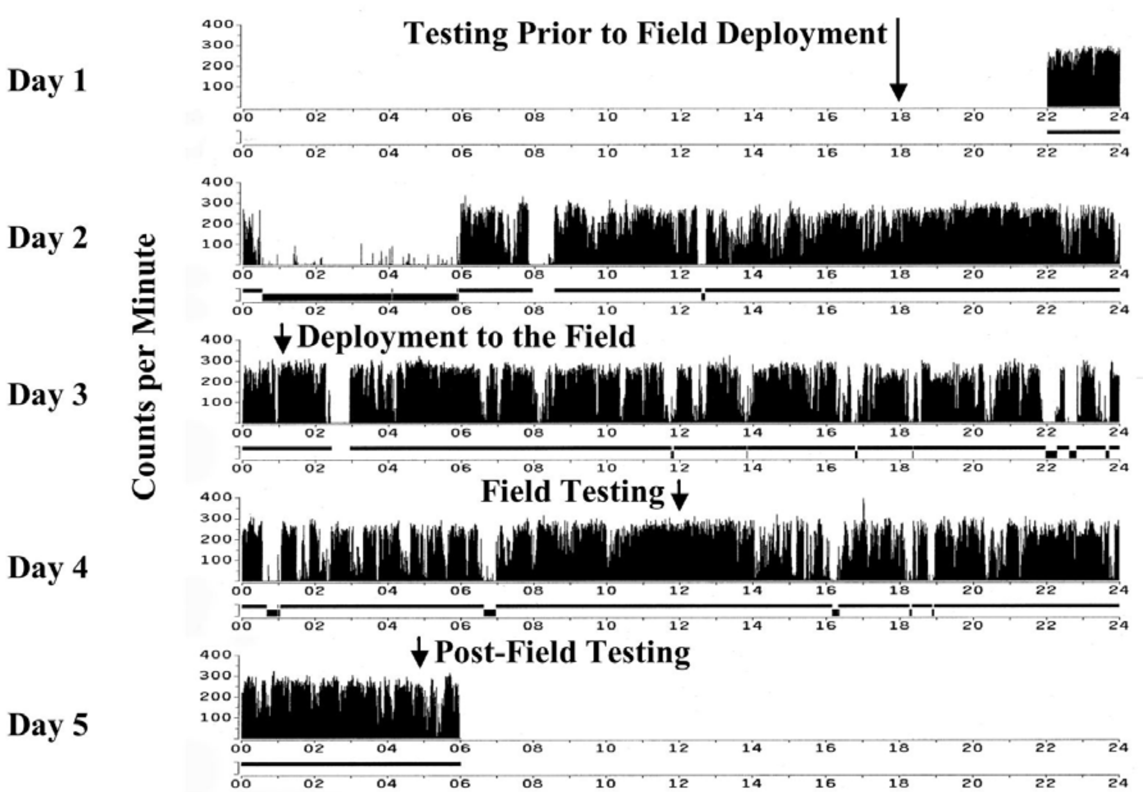

Figure 1. Representative activity monitor (actigraph) data from one Ranger officer continuously collected over the 73 hours of the study. The vertical height of each line plotted on the x-axis represents the number of movements detected in one minute of time. Appropriately placed arrows indicate testing and deployment times. Each day of the study is plotted as a 24-hour period starting at 0000 hours. Below the x-axis of each day's plot is a second axis which displays estimated sleep versus waking time (Cole and Kripke, 1988). The thicker, lower bar on the second axis indicates that the subject is sleeping. Once the officers deployed to the field they got very little sleep (3.0$\pm$0.2 hours).

Based on data continuously collected during the exercise using wrist-worn activity monitors (for a detailed review of this technology see Tryon, 1991), the Rangers had few opportunities to sleep during the field portion of the exercise, which lasted 53 hours (Fig. 1). Including the pre-exercise preparation time, the officers were almost continuously awake for 72 hours, during which their average mean sleep time totaled only 3.0±0.2 hours in short naps. Changes in body composition were assessed using calibrated scales, a whole body dual-energy x-ray absortiometer system (DEXA) (Mazess et al., 1990) and whole body bioimpedance, which provided an estimate of hydration state (Kushner and Schoeller, 1986). On average, each volunteer lost 4.1±0.2 kg (9 lbs) of body weight during the exercise, which predominately consisted of water, although loss of fat and lean body mass was also observed. Weight loss of this magnitude over this brief period indicates that the physiological status of the officers was substantially degraded.

At least one dependent variable of every behavioral test administered; choice reaction time, vigilance, matching-to-sample, repeated acquisition, and grammatical reasoning, was significantly impaired ($p<0.001$) by the end of the field exercise (Fig. 2-5). Furthermore, mood state, an indicator of overall mental status that is related to operational effectiveness, was severely degraded. Self-reported Vigor significantly decreased ($p<0.001$), while Fatigue ($p<0.001$), Depression ($p<0.002$), Anger ($p<0.009$) and Confusion ($p<0.001$) increased dramatically.

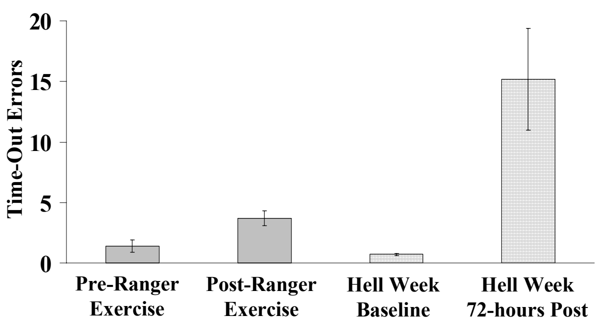

Figure 2. Four-Choice Visual Reaction time task mean time out errors (±SEM) - taking longer than 1 second to respond - for the Ranger and SEAL studies. This test assessed the ability to respond quickly and accurately to a simple visual stimulus.

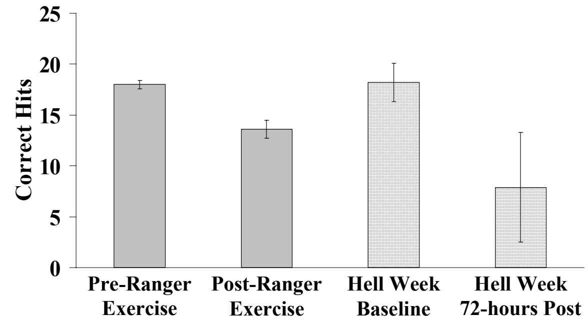

Figure 3. Mean number of correct detections on the Visual Vigilance test (±SEM) for the Ranger and SEAL studies. This test assessed ability to maintain alertness for a sustained period of time.

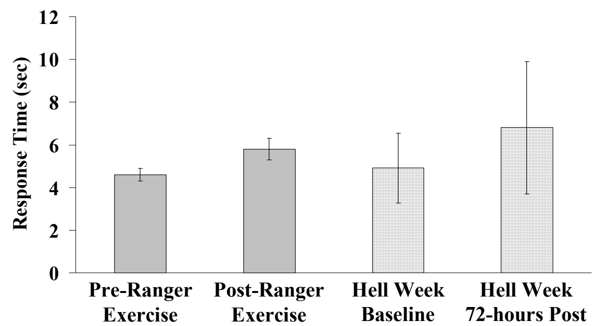

Figure 4. Mean Response time in seconds (±SEM) on the Matching-to-Sample task for the Ranger and SEAL studies. This test assessed short-term visual memory and recognition ability.

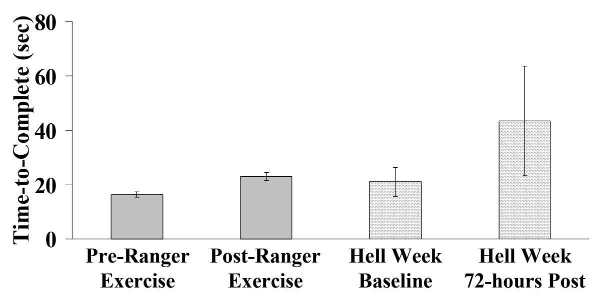

Figure 5. Mean time-to-completion in seconds (±SEM) on the Repeated Acquisition task for the Ranger and SEAL studies. This test assessed learning and short-term memory.

2.3 Study II: Hell Week of U.S. Navy SEAL Training

This study was conducted during Hell Week of U.S. Navy SEAL Training at the Naval Special Warfare Training Center (NSWTC), Naval Amphibious Base, Coronado, CA. The primary purpose of the study was to determine the optimal dose of caffeine to employ in combat-like conditions (Lieberman et al., in press), but data from 16 volunteers assigned to the control group who did not receive caffeine, but did receive a placebo, are reported here. Their mean age was 24 years, and they had served on average 3 years in the military. Cognitive testing was conducted prior to the start of Hell Week and after 73 hours of Hell Week had elapsed, during which the volunteers had only 1 hour of sleep. Navy SEAL training is intense and designed to identify individuals who can withstand a variety of operational stressors, especially exposure to cold water and sustained high levels of intense physical activity, while maintaining high levels of physical and mental function. Only about one in four individuals who attempt the 8-month long course complete it (Waller, 1994). One of the most acutely stressful periods of SEAL training is Hell Week, during which trainees undergo sustained sleep deprivation in combination with extensive environmental, physical and psychological stress (Fig. 6). Trainees are under the constant supervision of trained instructors and are required to engage in continuous 24-hour activities. Hell Week provides an opportunity to determine whether trainees have the physical and mental attributes to reliably perform under combat-like conditions. Most Hell Week activities are conducted on the beach, surf or in small boats. During Hell Week, trainees are almost totally deprived of sleep, subjected to frequent and severe cold stress and engage in near constant, extremely demanding, physical activities. Psychological stressors include verbal confrontations with instructors and activities with no-win outcomes (Smoak et al., 1988). Generally, more than half of the trainees who start Hell Week do not complete it, and therefore cannot continue SEAL training. Most withdrawals from training are voluntarily initiated by the trainee, except for medical withdrawals. The training repeatedly pushes trainees to their physical and mental limits so they will be prepared for the extraordinary challenge of serving in operational SEAL units.

Cognitive performance in the SEAL trainees was, in most instances, more severely impaired than among the Rangers. Choice reaction time, vigilance, attention and memory were all significantly impaired on at least one dependent measure ($p<0.007$) on the same cognitive tests administered to the Rangers (Fig. 2-5). Not surprisingly, all aspects of mood state assessed were adversely affected by the stressors of Hell Week to an even greater extent than observed during the Ranger training exercise ($p<0.003$).

Figure 6. Navy SEAL trainees in their boats attempt to cross the surf line during Hell Week. The boats frequently capsized, soaking the whole crew.

3. DISCUSSION

The nature and severity of the cognitive decrements measured in these two very different types of simulated combat, conducted with different military populations, were severe. The magnitude of the deficits observed was greater than those produced by alcohol intoxication (Williamson and Feyer, 2000) or treatment with sedating drugs (Millar, 1992). Although warfighters and military planners anticipate deficits in complex cognitive tasks in combat, it is not clear whether the loss in very basic cognitive functions we observed, such as reaction time and visual perception, is expected. The Ranger combat training exercise, which appeared to us to be a more realistic simulation of combat than Hell Week, was intended to resemble the activities experienced in light infantry operations conducted by elite units. Hell Week is designed to simulate combat operations conducted by SEAL units, so it included stressors such as sustained exposure to cold water and other military activities conducted in a costal environment. The SEAL trainees were much less experienced than the Ranger officers and probably subjected to greater levels of stress. The environmental and psychological stress they were experiencing appeared more severe and sustained than the stressors the Rangers experienced. Therefore, it is not surprising that the cognitive performance of the SEAL trainees was more severely compromised.

On the battlefield, the severe decrements we measured during either of these training exercises would significantly impair the ability of warfighters to perform their duties. Virtually every task conducted on the battlefield, from the simplest to the most complex, requires the individual to employ multiple cognitive functions. For example, firing a weapon at the right time at the correct target requires the following cognitive elements: vigilance and pattern recognition to detect the target; choice reaction time to fire at the correct target at the right instant; logical reasoning to determine whether firing a weapon at a selected target is tactically appropriate and permitted within the rules of engagement; and short-term memory to insure that the warfighter is aware of the location of friendly forces. The tests we employed measured all of these functions and all were substantially impaired.

It is likely that some of the well-documented, often tragic, errors that have occurred in combat can be attributed to impaired cognitive function. For example, friendly fire incidents that occurred in Operations Desert Storm and Enduring Freedom have been attributed to cognitive errors (Belenky et al., 1994; Loeb, 2002). It can be hypothesized that some of the serious accidents that have occurred during training exercises may be the consequence of severe, unanticipated decrements in cognitive function. Furthermore, we have even observed significant decrements in cognitive function during a brief training exercise lasting less than a day. In that study, conducted with soldiers who were neither sleep deprived nor exposed to significant operational stress other than physical training, significant loss of vigilance was observed (Lieberman et al., 2002). The decrement appeared to be associated with inadequate feeding, and was mitigated by providing supplemental calories in the form of a carbohydrate beverage.

The term the “fog of war” has been used in various historical documents and firsthand reports to describe the overall combat environment. However, the phrase fails to capture the scientific aspects of the deficits objectively documented in our two populations, and by other investigators in training exercises and simulations (Opstad et al., 1978; Banderet et al., 1981; Haslam, 1984; Morgan et al., 2000). A less colorful but more scientific term for this devastating loss of both simple and complex cognitive abilities might be “acute combat-stress induced cognitive decline”. It should clearly be distinguished from Combat Stress Reaction (Solomon and Benbenishty, 1986) since it appears to be present in all individuals exposed to these stressors, not just susceptible individuals. In addition, it should be distinguished from cognitive degradation induced by sleep deprivation alone, since multiple stressors are present in combat and the adverse effects can occur suddenly and unexpectedly.

Training can certainly mitigate some of the decrements in function we observed. However, it is clear from the performance of the Rangers that even their 9 years of military training was insufficient to prevent substantial loss of cognitive function. Pharmacologic and nutritional interventions can also partially restore performance that is degraded by sleep deprivation and/or operational stress (Newhouse et al., 1989; Comperatore et al., 1996; Caldwell et al., 2000; Lieberman et al., 2002; Lieberman et al., in press). However, little research is available on the effects of interventions like drugs and nutritional supplements during periods of severe combat-like stress. Such research should be conducted so that recommendations for the use of these interventions will be appropriate for the conditions in which they will be employed. As the complexity of equipment, weapons and communications increases and forces are dispersed, as envisioned in Objective Force planning scenarios (United States Army, 2002), these cognitive decrements will have a greater impact on the effectiveness of the warfighter. Furthermore, the increasing lethality of conventional weapons likely to be employed by adversaries, as well as real or hypothetical chemical, biological and radiological threats, will increase the level of stress on the future battlefield, and the cognitive demands on the warfighter.

CONCLUSION

Although the adverse impact of combat on cognitive performance is widely recognized, the interaction of severe cognitive impairments and the increasing complexity and stress of modern warfare may not be fully anticipated in planning or training for the Objective Force. The studies reported here demonstrate that opportunities to assess cognitive decrements induced by intense training scenarios are available and should be exploited by military scientists. Such studies would provide detailed information on the nature and extent of cognitive decrements that are associated with combat-like stress, as well as the underlying nutritional, physiological and hormonal factors associated with the deficits. In addition, they could provide opportunities to evaluate interventions to prevent cognitive deficits and advance our understanding of how humans cope with severe, acute stress.

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