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The Warfighter’s Stress Response: Telemetric and Noninvasive Assessment

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Our investigations into the effects of stressful military training have shown that individuals exhibiting superior performance differ significantly from individuals exhibiting poor performance in their psychological and biological responses to stress. Specifically, stress-hardy individuals retain mental focus and clarity of memory under stress, commit fewer errors during stress, experience less burnout, demonstrate better navigational skills, and are able to stay physiologically calmer during potentially life threatening events and during uncontrollable stress. To ascertain individual differences in stress responses, we will investigate the effects of stressful military training on physiological, and cognitive functioning of armed forces members. Noninvasive saliva sampling will be used to assess hormonal stress levels. Additionally we developed novel telemetric technology for untethered measurements of heart rate activity. We will compare these physiological measures with training performance, cognitive performance and measures of psychological stress. Due to Institutional Review Board delays no human subjects data are available for this annual report. A 6-month no cost extension has been requested.
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Introduction

Our investigations into the effects of stressful military training have shown that individuals exhibiting superior performance differ significantly from individuals exhibiting poor performance in their psychological and biological responses to stress. Specifically, stress-hardy individuals retain mental focus and clarity of memory under stress, commit fewer errors during stress, experience less burnout, demonstrate better navigational skills, and are able to stay physiologically calmer during potentially life threatening events and during uncontrollable stress. To ascertain individual differences in stress responses, we will investigate the effects of stressful military training on physiological, and cognitive functioning of armed forces members. Noninvasive saliva sampling will be used to assess hormonal stress levels. Additionally we developed novel telemetric technology for untethered measurements of heart rate activity. We will compare these physiological measures with training performance, cognitive performance and measures of psychological stress. A 6-month no cost extension has been filed. Due to Institutional Review Board delays no human subjects data are available for this annual report.
This research was designed to meet several objectives as listed in the statement of work: Develop and further refine baseline psychological and biological profiles that predicts superior performance under highly stressful training situations; Develop and further refine models that characterize stress induced psychological and biological responses that are associated with superior performance under highly stressful training situations; Develop and further refine a telemetric device for the measurement of Heart Rate Variability; and Provide evidence for a noninvasive, objective assessment of operational performance under highly stressful training situations.

Previous investigations into the effects of stressful military training (such as Army and Navy survival schools, Combat Diver Qualification Course, and Special Forces Selection and Assessment) have shown that elite war fighters differ significantly from general war fighters in their psychological and biological responses to stress. Specifically, stress-hardy individuals retain mental focus and clarity of memory under stress, commit fewer errors during stress, experience less burnout, demonstrate better navigational skills, and are able to stay physiologically calmer during potentially life threatening events (such as lack of oxygen) as well as during uncontrollable stress (such as interrogation stress). [2,3,8]

To ascertain individual differences in stress responses, we proposed to investigate the effects of stressful military training on the metabolic and hormonal functioning of armed forces members. We developed novel telemetric technology for untethered measurements of heart rate activity, and will use noninvasive saliva sampling to assess hormonal stress levels. Metabolic responses to stress will be studied in Aviation Preflight Indoctrination (API) students reporting to the Naval Operational Medicine Institute (NOMI) located at Naval Air Station (NAS) Pensacola for water survival training, Special Forces members and aircrew reporting to Brunswick NAS. and Ft. Bragg for Survival Resistance Evasion and Escape (SERE) training, and military members across the services reporting to the Combat Diver Qualification Course (CDQC) at Trumbo NAS, Key West, FL. All of these training sites have been part of ongoing or previous investigations conducted by our research team.

We have found that those individuals who have better stress tolerance exhibit significantly different patterns of heart rate variability, both at baseline (one week prior to stress exposure) and during stress exposure (to be reviewed later). These baseline differences in heart rate variability are predictive of actual military and cognitive neuropsychological test performance scores assessed during and after stress exposure. Heart rate variability (HRV) indexes both peripheral and central activity of the
parasympathetic and sympathetic nervous systems. Recent brain imaging studies have confirmed that at least one component of heart rate variability (high frequency power) reflects activity in areas of the brain critical to the allocation of resources during stress, such as the medial pre-frontal cortex. Thus, assessment of HRV provides a noninvasive means of evaluating the neural systems intimately involved in the capacity to attend to and respond to a threat. These findings linking HRV to actual cognitive performance robustly support the utility of HRV in the assessment of human performance.

**Specific Aims/Synopsis & Hypotheses**

This study was designed to extend the findings from our previous neuro-biological studies and characterize: 1) Baseline psychological and biological profiles that predict superior performance under stress; 2) Stress-induced psychological and biological responses that are associated with superior performance under stress. This research will provide a systematic characterization of psychobiological responses to highly stressful operations and will provide information that may be extended to the selection and training needs of the DOD. Specifically, this protocol was primarily designed to make use of noninvasive telemetric devices designed to assess human physiology and to evaluate the degree to which such devices both predict and enhance our understanding of human performance. In addition, this research will provide a detailed characterization of the relationship between telemetric physiologic assessment measures and the more traditional measures that have been used in our previous studies (neuro-hormone responses; paper and pencil tests). It is hoped that the data obtained in this project will extend our previous findings, provide additional clues to the factors contributing to excellence in military performance, and finally, provide evidence for a noninvasive, objective assessment of operational performance. It is expected that this type of information will not only lay the groundwork for the development of countermeasures designed to buffer against the negative effects of stress on soldiers, but also provide additional information for selection and assessment programs.

Over the past 4 years our research team has investigated and published a series of papers describing the impact of highly intense stress on the psychological and neuro-biological responses of healthy soldiers who are enrolled in U.S. Army & Navy Survival School training (see appendix). We have also studied soldiers participating in U.S. Special Forces Assessment and Selection, the Canadian Joint Task Force Selection and in Special Forces Underwater Warfare Operations (Scuba) training. Taken together, the results of these studies have provided evidence that individuals identified by the military as “stress hardy” (or “elite”) exhibit a psychological and biological profile that is significantly different from those individuals who are not identified as “stress hardy” and who do not tolerate stress well. For example,
we have found that "stress hardy" personnel exhibit significantly
greater abilities to remain "cool under pressure" (both biologically
and psychologically), retain mental focus, and clarity of memory for
events experienced during stress. In addition, they appear to perform
fewer operational performance errors during the exposure to stress (i.e., they demonstrate superior performance during interrogation,
exit better navigational skills (both land navigation and
underwater navigation), are able to stay physiologically calm during
potentially life threatening events (such as lack of oxygen).

Based on our previous findings, we expect that as they have
exhibited significant differences in neuro-hormone responses to
stress, individuals exhibiting superior performance during training
will also exhibit significant differences in HRV. In brief, certain
biological systems in the body and brain that are involved in the
response of an animal to threat can be indirectly and noninvasively
assessed through specific types of analyses of the timing between
beat-to-beat (RR) intervals of the heartbeat. Because there is a
relationship between the neuro-hormones and neurobiological systems
involved in both threat responding and in the regulation of heart
rate, analyses of HRV will provide a non-invasive method for assessing
and predicting an individual's ability to perform under stress. Since
HRV analyses may be assessed telemetrically the present technology may
provide a means of assessing human performance in military training
environments and in the theatre of operations.

As discussed, previous studies provide evidence that innate
differences in threat response systems may explain why some
individuals may be more stress tolerant than others. Exposure to
stress affects both parasympathetic and sympathetic nervous systems,
both of which regulate the heart. It is hypothesized that a person's
ability to tolerate high stress and to continue performing effectively
will be related to variability of their heart beat. More precisely,
it is hypothesized that Individuals who have high variability when at
rest and low variability when confronted with challenge will be
significantly more stress tolerant and exhibit superior objective
performance since this capacity for variability is indexing both the
modulation of parasympathetic and sympathetic activity.

The overarching hypothesis is that differences in operational
performance, differences in mental clarity during stress (e.g.,
memory) and differences in negative psychological reactions to stress
(e.g., dissociation) will be predicted by HRV when assessed prior to,
during, and after military training.
Specifically, we hypothesize that stress hardy individuals will exhibit:

1. **HIGH HRV** (both High Frequency [HF, 0.15 - 0.40hz] and Low Frequency [LF, 0.04 - -0.15hz] domains) under baseline, resting conditions.
2. **LOW HRV** (High Frequency [HF] and Low Frequency [LF] domains) prior to participating in training stress.
3. **LOW LF HRV and HIGH HF HRV** during exposure to stress.
4. **HIGH HRV** at recovery (24 hours after stress cessation)

**Secondary Hypotheses regarding HRV:**

1. HRV assessed just prior to training will be significantly, negatively associated with both visual and verbal memory for events experienced during stress.
2. HRV assessed prior to training stress will be significantly negatively associated with actual military performance during interrogation stress.
3. Individuals with low variability prior to training stress will have fewer symptoms of dissociation at baseline and in response to stress. These individuals will also have a higher Neuropeptide-Y (NPY) release during stress and return to baseline levels of NPY within 24 hours after stress exposure.

**Secondary Hypotheses Regarding Hormonal Responses to Training Stress:**

The current work includes the assessment of plasma and salivary hormone responses prior to, during and after stress exposure. As with our previous studies, this will allow us to examine the degree to which the telemetric assessment measures of HRV are related to circulating levels of hormones that are involved in the human response to threat - and which have been shown to predict military performance. [2,3,8]

Due to our previous reports and our preliminary findings (noted below), our primary hypothesis is that individuals with greater capacity for NPY release and recovery during stress will be those with a stress hardy HRV profile. We anticipate that at baseline and 24 hours after stress there will be a significant, negative relationship between HRV and NPY. During stress there will be a positive relationship between NPY and specific measures of HRV such as the LF/HF ratio (a measure of sympathetic tone) and the HF component of HRV (the vagal component) and NPY. We also hypothesize those individuals who exhibit a rapid return to pre-stress levels of NPY will be the most successful in training performance, and on the cognitive tasks.

Salivary hormones will be examined as well. We expect that exposure to training stress will significantly increase cortisol and...
dehydroepiandrosterone (DHEA) and will significantly decrease the sex steroids testosterone and estradiol. In addition, acute stress exposure will significantly increase salivary indices of catecholamines. These hormone measures are predicted to return to baseline at the conclusion of the training. In this project, the measures of cortisol, catecholamines and of testosterone will serve as biological indicators of the impact of the training stress. Cortisol will also be assessed to evaluate the hypothesis that neurosteroids such as DHEA and estradiol will buffer against the stress induced effects of glucocorticoids (cortisol). Specifically we will test whether individuals who exhibit greater levels of estradiol and DHEA at baseline or during stress tolerate stress better and perform better compared to individuals who do not have comparable levels.

We will also test whether individuals with low estradiol and low DHEA are predicted to exhibit a greater propensity to dissociate when exposed to training stress. Specifically, individuals with greater overall stress-induced levels of cortisol are predicted to exhibit poorer training performance and poorer performance on the cognitive tasks. Also individuals with significantly greater levels of DHEA and with significantly higher DHEA/cortisol ratios will perform better in training and on the cognitive tasks. Finally, individuals with greater DHEA/cortisol ratios will exhibit better performance in training and on the cognitive tasks.

In order to enhance our current understanding of why and how human beings differ when confronted with highly stressful operations (such as military operations) it is essential to examine the relationship between military performance and HRV, neurohormones and psychological responses to stress are. This study will provide detailed information about normal patterns of human HRV prior to and in response to realistic operational stress. This type of information may also improve our current understanding of human tactical decision making under stress.

Data from our investigations at U.S. Army and Navy Survival School Training, Special Forces Underwater Warfare Operations and from Allied Special Operations Selection and Assessment, show that intense psychological and physical stress affect neuro-hormones in a manner comparable to psycho-biological responses to real world threat to life situations. Further, these studies demonstrate a significant relationship between psychological and biological responses to stress and objectively assessed operational performance. The current proposal is designed to extend our previous data by focusing directly on whether HRV reflects and predicts superior tolerance to stress. In addition, and because a great deal is known about the neuroanatomy involved in HRV and in threat response systems, the data will enhance our understanding of the neurobiology that is linked to performance.
It is hoped that the information from this study will assist in the development of: 1) objective methods for the assessment of human performance during stress and thereby provide aids for military commanders and medical personnel concerning the psychological and physiological status of soldiers during ongoing operations; 2) measures and procedures applicable to selection and assessment, prevention, early diagnosis and 3) counter measures to maladaptive stress reactions.

As will be discussed below, our preliminary data of HRV one week prior to stress exposure is predictive of cognitive performance, military instructor ratings, sustained focus, and mental flexibility during and following exposure to stress at SERE school. This evidence suggests that models can be developed that will predict who will respond most favorably during stressful situations which could ultimately affect tactical decision making.

The technology and modeling that will be utilized in this project will provide a systematic characterization of psycho-biological responses to highly stressful operations and will provide information that may be extended to the selection and training needs of the DoD. This protocol is primarily designed to make use of noninvasive telemetric devices designed to assess human physiology and to evaluate the degree to which such devices both predict and enhance our understanding of human performance. In addition, this research will provide a detailed characterization of the relationship between telemetric physiologic assessment measures and the more traditional measures that have been used in our previous studies (neuro-hormone responses; paper and pencil tests). It is hoped that the data obtained in this project will extend our previous findings, provide additional clues to the factors contributing to excellence in military performance and, finally, provide evidence for a noninvasive, objective assessment of operational performance. Because HRV analyses may be assessed telemetrically, the present technology may provide a means of assessing human performance in both military training environments and in the theatre of operations.

Background

The psychological and biological hypotheses in this proposal are based upon data from our previous research at Army and Navy survival school training, at Special Operations Selection, and at Special Forces Underwater Warfare Operations training. As described in more detail below, each of these sites has contributed to our understanding of the way healthy subjects are affected by highly intense stress, and how (and why) some individuals may tolerate stress better than others. The rationale for examining HRV and human performance is based upon both the literature and, more directly on the specific findings of our previous studies. To facilitate an understanding of the results of
our previous investigations, we will discuss the data in four categories: 1). Psychobiological Responses to Acute Stress; 2). Differences in the Psychobiological Responses to Acute Stress Between “Stress Hardy” and General Troop Soldiers; 3) The Relationship between NPY and Heart Rate and Heart Rate Variability; 4) The Relationship between Heart Rate Variability and Objectively Assessed Cognitive and Military Performance. All results reported are at the p<0.05 level unless otherwise stated.

1). **Psychobiological Responses to Acute Stress** In order to examine human psychobiological responses to acute, uncontrollable stress, we studied over 125 soldiers participating in U.S. Army & U.S. Navy survival school training. [1,2,3,4] Survival school training is realistic, extraordinarily intense, and designed to prepare soldiers to deal with extreme situations such as evading capture by the enemy and surviving as prisoners of war. Several factors make survival school an ideal environment for the study of acute stress in humans. First, the course design permits a baseline, stress and recovery assessment. Second, the realistic and intense nature of the stress applied during the course enhances the likelihood that data are relevant to real world scenarios.

In assessing the impact of acute stress on humans, we elected to use hormone measures guided by the pre-clinical literature. Consistent with the large body of data regarding mammalian neurophysiological responses to threat, we assessed components of the Hypothalamic-Pituitary-Adrenal (HPA) axis (i.e., cortisol), components of the Hypothalamic-Pituitary-Gonadal (HPG) axis (i.e., testosterone), adrenal steroids (i.e., DHEA) as well as catecholamines (i.e., norepinephrine, epinephrine). We also assessed NPY due to the growing body of pre-clinical and clinical evidence suggesting that it functions as an endogenous anxiolytic agent that may buffer against the effects of stress on the mammalian brain. [5] NPY is a 36-amino acid peptide that belongs to the pancreatic polypeptide family. It is co-localized (and released) with neurons containing norepinephrine, and is intimately involved in the regulation of both central and peripheral noradrenergic system functioning. [5,6,7,8]

In our studies to date, the acute stress of survival school has significantly increased cortisol (Figure 1), norepinephrine (Figure 2), epinephrine (not shown), and neuropeptide-Y (Figure 3), and significantly reduced testosterone, and thyroid hormones (T4 and T3) (not shown). [1,2,3] The magnitude of the stress-induced hormone changes is comparable to those documented in soldiers and civilians confronted with real-life threat to life experiences [9,10,11,12].
Figure 1
Serum Cortisol Before, During and After Acute Stress

Figure 2
Plasma NE Before, During and After Stress

Figure 3
Plasma NPY Before, During and After Stress
As shown in Figure 4 our studies indicate that acute stress exposure in healthy human subjects results in increased psychological symptoms of dissociation [4].

Dissociation refers to a variety of symptoms that reflect an individual’s tendency to disconnect from the environment during a highly stressful situation. Typical dissociative symptoms include feeling like one is outside one’s own body; feeling as if one is observing the environment through a tunnel or lens; experiencing colors and sounds as enhanced or diminished, etc.[13] Dissociation is a common psychological response to life threatening events. Because it has been associated with subsequent stress vulnerability and trauma-related psychopathology, the significant increases in dissociate symptoms during training provide evidence that survival school offers a realistic model for the study of uncontrollable stress in humans. [14,15]

2). Differences in the Psychobiological Responses to Acute Stress Between “Stress Hardy” and General Troop Soldiers: The survival school setting also has provided an opportunity to compare psychobiological responses of soldiers identified by the military as “stress hardy” to the responses of soldiers who have been identified as not “stress hardy.” The “stress hardy” group consists of Special Forces soldiers (SF) who have already successfully completed rigorous selection programs. The group not identified by the military as “stress hardy” consists of general troop soldiers, Rangers and Marines (non-SF). Consistent with pre-clinical literature of animals that have been toughened by repeated exposure to stress, SF soldiers have shown
less overall HPA activation (as measured by cortisol) in response to stress and greater release of norepinephrine (NE) (Figure 5 and 7).

As shown in Figure 7 SF soldiers released significantly more NPY during stress exposure compared to Non-SF soldiers (N= 26).

Further, mean plasma NPY in Non-SF soldiers was significantly depleted at recovery, while mean recovery NPY levels in SF soldiers did not differ significantly from baseline (Figure 8).
Pre-clinical and clinical studies suggest that capacity for central NPY release may provide an index of an organism's ability to manage high levels of stress. Lower NPY release during stress and low post-stress levels of NPY have been viewed as indicative of stress vulnerability, whereas increased production of NPY and the ability to maintain normal levels after stress exposure have been interpreted as signs of stress resilience. [2,3,16] Thus, the NPY data in SF soldiers is consistent with the notion of stress hardiness.

Although we measured NPY peripherally, we believe that the data are relevant to central NPY activity because a constellation of psychological and performance data characterized as "stress hardiness" was related to peripheral NPY. First, like NPY, psychological symptoms of dissociation were significantly different between SF and Non-SF soldiers (N=49). Symptoms of dissociation were significantly lower (Figure 9) in SF subjects.
Second, there was a significant, negative relationship between dissociation and actual subject performance during stress (as rated by the instructors of the course) (Figure 10) \(r = -0.68; p<0.001\).

![Figure 10](image1)

Third, there was a significant, positive relationship between NPY during stress and performance during stress (Figure 11) \(r = 0.45; p<0.04\).

![Figure 11](image2)

Taken together, these data suggest that individuals who exhibit low stress-induced levels of dissociation and high levels of NPY perform better during high intensity military training. In a study conducted
at the U.S. Navy survival school, we have now replicated these findings. [17](See Appendix).

Coupled with the data from the Army survival school, these findings support the hypothesis that individuals who are identified as "special" (or stress hardy) differ in certain psychological and biological indices from those who are less stress hardy.

3). The Relationship Between NPY and Heart Rate & Heart Rate Variability:

Based on the findings of our previous investigations which showed significant differences in NPY responses to stress between elite and general troop soldiers, we hypothesized that significant differences might also be measured in heart rate and of heart rate variability in elite, versus general troop members. This hypothesis derives from the pre-clinical and clinical studies that have provided evidence that the neuro-biological systems and transmitters that are modulated by NPY [6,7,18,19,20,21] may also significantly influence heart rate and heart rate variability [22,23,24,25,26,27,28].

As shown in Figure 12, in our pilot investigation of HRV in military subjects at survival school, we found that elite, compared to non-elite soldiers exhibited significantly different HRV (as measured by several indices of HRV: High Frequency (HF) [0.15hz - 0.40hz] and Low Frequency (LF) [0.04hz - -0.15hz] band domains when assessed at rest - 24 hours after stress exposure. (Note: HRV units are in ms^2 and are Log 10 Transformed). As shown in Figure 13, there was a significant, positive relationship between plasma NPY and HRV at that assessment time point. These data support the hypothesis that those individuals who have a larger capacity to return to pre-stress levels of NPY are those who also exhibit increased variability of HRV when not under stress. Consistent with the idea that HRV is an index of resilience to stress, the elite military personnel when not presented with a challenge, exhibit robust parasympathetic control of the heart and significantly greater HRV.
Figures 12 & 13

Heart Rate Variability 24 post stress

Elite & General Troop Soldiers

![Graph showing HRV indices](image)

GROUP

HF differences: t = 7.1; p < 0.0001
LF differences: t = 9.4; p < 0.0001

4). The Relationship Between HRV and Objectively Assessed Cognitive & Military Performance:

According to the vagal tone theory put forward by Porges et al., individuals who are stress hardy are those who, when not under stress, experience robust parasympathetic (vagal) control of the heart. [29, 30] However, when presented with environmental challenge or demand, vagal rates of firing are markedly reduced leaving said individuals in a sympathetic mode and better prepared for threat responding. Thus, resilient individuals will be those who exhibit high HRV variability when not under stress, and low variability when confronted with stress. The difference between these two states of variability in heart rate is considered "vagal tone" and thought to index the capacity for the modulation of vagal (parasympathetic) activity. Further, and because of the relationships between CNS threat response and attentional systems, vagal tone is thought to index the ability of an organism to allocate attentional resources during an emotional or threatening situation. [31] Our knowledge about the neuronal circuitry between CNS threat response systems and regulation of heart beat variability is limited at this time. However, we consider the "vagal tone" theory a useful model that may assist in the interpretation of our preliminary HRV data.

In a pilot investigation, we measured HRV in soldiers enrolled in survival school training while they were waiting to be deployed to the field for the experiential phase (the high stress phase) of the course. Thus, this was not a resting baseline, but rather a pre-stress assessment collected during a relative state of anticipatory anxiety. HRV was assessed in subjects between 1600 and 1630. Each subject was supine and wore the Polar Vantage NV™ watch and a
recording chest strap for a period of 10 minutes. [32,33,34] The files were downloaded and analyzed using Polar Precision Performance Software. The raw frequency band analyses were examined. Due to kurtosis and skewedness, these data were transformed using a log 10 transformation. These transformations resulted in normally distributed data.

As noted in Figures 14, 15, 16; there were significant, negative relationships between HRV recorded prior to deployment and the objectively assessed cognitive and military performance of the subjects 5 days later while they were undergoing acute stress. Soldiers with low variability prior to stress exhibited superior mental clarity and problem solving abilities when tested after exposure to interrogation stress. The performance scores were calculated by the Survival School instructors who were blind to the research data. In addition, the individuals with low pre-stress HRV demonstrated significantly better visual memory as demonstrated by their performance on a standardized test of visual memory (the Rey Complex Figure memory task).[35]

Based upon the nature of the tasks and the above noted data regarding neuro-hormonal responses to interrogation stress, these data strongly support the hypothesis that individuals who are more resilient to the negative effects of stress on mental functioning are those who are capable of withdrawing vagal control of the heart prior to stress exposure. Because of our previous data showing that such individuals exhibit higher HRV when not under stress, the findings from these two studies support the idea that stress resilient individuals may have more "vagal tone" compared to those who are less stress resilient.
Figure 14: HF HRV at Baseline and Stress

Figure 15: LF HRV at Baseline and Stress

Figure 16: HRV and Memory Scores: After exposure to interrogation stress, subjects were given the Rey-Osterrieth Complex Figure test. Although subjects did not differ on the copy aspect of the test, the individuals who exhibited low HRV at baseline (one week earlier) demonstrated significantly higher scores for the recall component of the memory task (p<0.05).
In a second pilot study of HRV and military performance, we evaluated HRV in soldiers participating in Combat Dive training. This training site was selected for two main reasons:

1.) In contrast to the acute, uncontrollable stress of Survival School, the stress of Dive School is controllable and is of longer duration than survival school. Analysis of HRV at Dive School offered the opportunity to evaluate whether the relationship between HRV and performance noted at survival school would also be observed reliably at a different site of military training.

2) The measures of performance at dive school are explicitly objective and less subjective than those of survival school. One of the primary objective performance measures at Dive School is how well a student is able to perform the task of underwater navigation. This is both physically and psychologically challenging in that it entails sustained physical exertion while using a re-breathing device simultaneous with tracking motion and direction in the dark underwater. There is significant risk involved in that swimming too slowly or surfacing will result in expulsion from the course. Swimming too rapidly will result in running out of the limited oxygen supply. Descending below 25 feet will result in neurologic damage due to the partial pressure of oxygen, and vomiting into the re-breather will result in possible drowning. Students are dropped off in the ocean more than 2 miles from shore and instructed to aim for an identified target. The navigation score is measured as a function of the timing of the swim and of how many meters away from the target the student is when arriving on shore. In order to stay on target, the task requires sustained concentration and an ability to inhibit a sense of alarm or panic.

As noted in Figure 17, the individuals who exhibited significantly lower HRV prior to the execution of the navigation task demonstrated superior (higher) underwater navigation skills. Consistent with our previous data (reviewed above) the individuals with the highest navigation scores where also those who exhibited greater levels of NPY and significantly fewer symptoms of dissociation during the training.
Overall, the data from our preliminary studies support the idea that: 1) HRV can be reliably assessed during military training programs; 2) Individuals demonstrating superior performance on objectively assessed tasks exhibit significant differences in HRV both prior to stress exposure as well as 24 hours after stress exposure. These data are robust and consistent with what is know about the relationship between specific CNS structures involved in selective attention, emotional responding and HRV. [36,37,38]

Based upon the above, the purpose of this work is to evaluate HRV more extensively in soldiers enrolled in several types of stressful military training in order to determine whether these findings can be replicated and determine the degree to which they correlate to other types of assessment techniques (paper and pencil tests, hormone analyses). Clearly, if HRV represents a valid and reliable method of assessing and predicting performance in military personnel, it will offer an objective assessment that can enhance current paper and pencil assessment techniques.

This work builds on the preliminary data in several ways:

1.) It provides a more complete assessment of HRV in soldiers by assessing soldiers at a true “baseline” state. In addition, the present proposal will assess HRV at multiple time points during the training (pre-stress, during stress exposure) and post stress assessment - after completion of the training. Further, a telemetric HRV recording device for each subject in a collection cycle and will allow for a more complete data analysis. Continuous monitoring will allow estimation of true baseline rate, such as heart beat rate just before waking at the beginning of training.
2.) This proposal includes a new technology that also telemetrically measures HRV data. However, unlike the Polar Vantage NV\textsuperscript{TM} system, which is limited to approximately 60 minutes of RR data per assessment time, this new technology will permit continuous monitoring with at least 24-hour data buffering assessment in 30 subjects per sited study in this project. A 24-hour collection methodology will permit more precise analyses of baseline, stress and recovery data. Coupled with the Polar Vantage NV\textsuperscript{TM} system, we will be able to determine whether more extensive recordings offer enhanced precision in predicting performance.

3.) This proposal includes Army and Navy survival school sites and pilot training sites. In addition, it includes the Combat Dive Training site since this training site has both Army and Navy personnel in attendance. A more precise application of methodology across sites will permit an analysis about the degree to which psychobiological profiles of individuals are able to predict military performance of different types: interrogation stress; navigational stress; flight training stress.

4.) We believe that, based on the results of this proposal, we will be able to design a portable real-time system for evaluation of psychophysiological state of each soldier during training or in the theater of operations.

5.) Finally, the present proposal will permit a more detailed examination of the relationship between HRV and stress hormones known to affect human cognition and performance under stress. A better understanding of these relationships will enhance current awareness as to what may be inferred about peripheral and central nervous systems activity by HRV analyses.
Basic Study Design (regardless of site)

Subjects

As in our previous samples, subjects will be included in the study if they are eligible for enrollment in the training programs. Subjects will be excluded from participation if they are taking medications or if they have a medical history of head trauma or injury that would significantly affect the sympathetic and parasympathetic responses to stress and thus affect the HRV.

Sample Size Justification

To calculate power, we used the independent variable of LF HRV because it was highly predictive of interrogation performance in our earlier studies. We are proposing a sample size of about 130 subjects at each of the four experimental sites totaling 520 experimental participants. With a sample size this large, 90% of the time a true R as small as .30 for a regression equation with two independent variables can be distinguished from an R = 0.

Data Collection

At each of the training sites, HRV data will be collected in all subjects at 4 time points: Baseline; Pre-Stress; Stress; and Recovery. Although the testing sites differ from one another in certain respects, the data will be collected according to the same principles at each site:

Baseline Assessment will occur at a time point after enrollment and prior to when training is initiated. (Due to the fact that our pilot data raise the possibility that a true "baseline" may be difficult to assess - since the personnel enrolled in the training often ruminate about the training well before it begins - HRV will be assessed in a comparison group of military personnel who are eligible, but not yet assigned to Survival School, Dive School or Aviation Preflight Indoctrination [API]).

Pre-Stress Assessment will be conducted when subjects are in a state of anticipatory anxiety. (for Survival School, this will be just prior to deployment on evasion; for API, while lined up for the 9D5 Helo Dunker, for Dive School, prior to gearing up for the underwater navigation tasks).
Stress Assessment will occur when subjects are directly experiencing stress (interrogation stress, water stress, navigation stress).

Recovery Assessment will occur 24 hours after stress exposure. Due to the limitations of the naturalistic setting, it is not possible to assess all subjects one week post training. However, a randomly selected sub-group of survival school subjects, and dive school from Fort Bragg and API students from Pensacola, will have HRV assessment conducted one week after completing training. This assessment will provide data about the degree to which 24 post stress assessments are indicative of more extended recovery from stress.

Heart Rate Variability Data Collection

The present proposal will use two telemetric assessment techniques in order to assess HRV in subjects: The Polar Vantage NVTM system; and the WISE System.

Polar Vantage NVTM: We have previously used the Polar Vantage NVTM system in our pilot studies of HRV. This system consists of a watch and elastic chest strap that, through coded transmission, record RR intervals. This system is resilient and can be used in natural training environments (dry or wet) and does not interfere with an individual’s gear or military performance. The watches are capable of recording approximately 60 minutes worth of RR interval data. These data may be downloaded through a contact pad to a laptop computer and stored for off line analysis. The Polar Precision Performance software permits editing and storage of the data for analysis using the Polar software (another software statistical program may also be used such as SPSS). Time domain, frequency domain and geometric analyses are possible with the Polar software. Recordings of HRV that are less than 10 minutes in duration will be analyzed using frequency band analyses (spectral analysis); recordings of HRV that are between 30 minutes and 60 minutes in length will be analyzed and reported in time, frequency and geometric domains.

WISE HRV System [39]: Our second system, developed by one of the co-investigators on this project (Emil Jovanov), is designed to record up to 24 hours of HRV data. The system is compact, and will record HRV through the telemetric chest strap of the Polar device. The enhanced capability for recording time will permit us to assess HRV during a night of sleep (at baseline and at recovery) or during the execution of a military performance that is greater than 60 minutes in duration. In addition to the amount of data that can be recorded, this technology can be downloaded without disturbing the subject. This permits on line HRV
measures during student performance at the bottom of the pool, or while asleep. Both the watch system and the WISE HRV system minimize interference with training procedures.

Hormonal Data Collection:

In addition to HRV data, all subjects will participate in paper and pencil as well as salivary hormone assessment at Baseline and at Recovery. Salivary hormone measures will also be collected at the Pre-Stress and Stress time points. As in our previous papers, we will assess salivary hormones (cortisol, testosterone, DHEAS, and estradiol) in order to assess the impact of training stress. To determine the levels of cortisol, dehydroepiandrosterone (DHEA), testosterone, estradiol and catecholamines (MHPG), salivary samples will be collected in Salivette tubes (vials), frozen, and shipped to the National Center for PTSD, Veterans Administration, in West Haven, CT where they will be analyzed by radioimmunoassay procedures as described. [2,3,8]. At two of the sites in this project (Navy Survival School; Dive School) we will also collect plasma NPY data at baseline, stress and at recovery.

Psychological Measures

Brief Trauma Questionnaire (BTQ): A valid and reliable self-report instrument designed to provide information about history of trauma exposure and exposure to traumatic stress that will be administered at baseline. [40]

Clinician Assisted Dissociative States Scale (CADSS): A valid and reliable self report measure of psychological symptoms of dissociation that will be administered at baseline assessment and following the administration of the declarative memory task following the stressful training event at all sites. [14]

Rey-Osterrieth Complex Figure (ROCF): A valid and reliable measure of visuospatial and organizational skills that will be administered 5 minutes following the stressful training event at all sites. [35]

Declarative Memory Task: A declarative task similar to the task used by O’Donnell will be administered following the ROCF at all sites. [41] Participants will be presented with a list of nouns containing 5 inherent categories to learn in 5-minutes. Participants will then be distracted for 5 minutes and then instructed to write all of the words in one of the categories. This type of memory task is described by Eichenbaum and Otto as a typical declarative memory task. [42]
Military Performance measures

In this project, the primary outcome measures for each of the sites will be the outcome scores of the training programs in which the subjects are participating. For those students at API, the outcome measure will be performance on the Multi-place Underwater Egress Trainer, the 9D5 Helo-Dunker. The 9D5 is a reasonably realistic representation of a helicopter conducting an emergency landing, turning upside down and sinking. Exposure to the 9D5 is a mandatory training evolution during the Naval Aviation Survival Training Program and has been reported to be the most stressful training event at API. The performance measure at the Survival Schools will be measures of interrogation performance and problem solving strategy scores demonstrated during interrogation stress. The outcome measure for students at Dive School will be the final class academic score (written test scores) and objective operational task score for underwater navigation performance during Free Ascent Training.

Specific Study Design

Aviation Preflight Indoctrination

Figure 18: Aviation Preflight Indoctrination
SERE

Figure 19: SERE

Didactic training: Confinement after day 2 phase training

- HRV
- AM hormone baseline sample (saliva and plasma)
- CADSS
- BTQ
- PM hormone sample (saliva and plasma)

Confinement phase

- HRV throughout
- Post-confinement hormone sample (saliva and plasma)
- ROCF
- Declarative memory test
- CADSS

24 hours later

- HRV
- AM recovery hormone sample
- PM recovery hormone sample

Week after training

- HRV
- AM hormone sample (saliva and plasma)
- PM hormone sample (saliva and plasma)

CDQC

Figure 20: CDQC

Indoc Week

- HRV
- AM hormone baseline sample (saliva and plasma)
- CADSS
- BTQ
- PM hormone sample (saliva and plasma)

Week 3 of training

- HRV
- Pre-Free Ascent hormone sample (saliva and plasma)
- Free Ascent testing
- Post-Free Ascent hormone sample (saliva and plasma)
- ROCF
- Declarative memory test
- CADSS

Free Ascent Day

- HRV
- AM recovery hormone sample
- PM recovery hormone sample

24 hours later

- HRV
- AM hormone sample (saliva and plasma)
- PM hormone sample (saliva and plasma)

Final Week

- HRV
- AM hormone sample (saliva and plasma)
- PM hormone sample (saliva and plasma)
Data Analysis

Prior to analysis the HRV data will be evaluated for kurtosis and skewedness. Log 10 transformations will be performed prior to the use of statistical tests assuming a normal distribution of data. Since the primary goal is to test whether or not HRV predicts military performance, Baseline and Pre-Stress HRV will be examined first. Using the independent variables BTQ, Baseline Dissociation, and Branch of Service, we will examine whether significant differences in HRV exist. Military performance measures will be analyzed as continuous and non-continuous variables. Ntile splits will be created in order to perform both linear and logistic regression analyses.

The hormonal data will be analyzed with one-way, repeated measure ANOVAs with Tukey’s post-hoc analyses to assess changes in neuroendocrine measures in response to the training events. A one-way, repeated measure ANOVA will also be used to compare baseline and later dissociation Pearson product moment correlation analyses will be conducted to examine relations among: (1) BTQ ratings and baseline stress and recovery neuroendocrine values, (2) dissociation and baseline stress and recovery neuroendocrine values. Regression analyses will be performed between the neuroendocrine measures and (1) training performance, (2) the ROCF and (3) declarative memory performance. All alpha values will be set at 0.05.

Key Research Accomplishments

The development and refinement of the WISE HRV system has been a major accomplishment of this work. Psychophysiological evaluation of military members undergoing intense training requires reliable, high precision instrumentation. For the acquisition of heart rate variability, standard holter type HRV amplifiers have been used. However, reliable transmission and real-time processing requires an intelligent sensor equipped with a standard microprocessor/microcontroller. We developed and evaluated an intelligent microcontroller based sensor with custom a HRV amplifier as represented in Figure 21.
Figure 21. Initial Wireless Intelligent Sensor with HRV sensor WISE HRV

The core of WISE sensor is Texas Instruments' microcontroller MPS430F149 with an integrated 8-channel 12-bit analog to digital (A/D) converter and the LINX wireless transceiver module TC-916-SC that operates at 916 MHz. The microcontroller features 16-bit RISC architecture, ultra-low power consumption (less than 1 mA in active mode, less than 1 µA in standby mode), 60KB flash memory, 2KB RAM, and a small 64-pin Quad Flat Pack (QFP) package. HRV signals are amplified, conditioned, and converted using internal 8-channel, 12-bit A/D converter on the microcontroller. Additional analog channels are used to monitor battery voltage, wireless link quality, and other external analog inputs. Therefore, WISE is capable of reporting the battery status and generating low-battery warnings to the higher system levels.

In our initial experiments we used standard wet electrodes for HRV holter. The result was excellent signal quality and relative immunity to noise and movement artifacts. Unfortunately, this approach is not applicable for intensive training, and prolonged monitoring lasting longer than 24 hours.

In the second generation, we attempted to create a sensor with dry electrodes, using conductive rubber electrodes. This approach was very convenient from the user’s perspective. Unfortunately, this approach was not immune to errors. Physical exercise and electrode movement artifacts affected signals excessively. Ultimately the research team proved this method unreliable. It was necessary to develop a special signal conditioning circuit. Fortunately, a new generation of recreational heart monitoring devices, like Polar, offers a wireless link between the chest strap with electrodes and a watch-type data acquisition unit. This type of device is very convenient for heart
monitoring during normal activity, exercise and training. Our experiments proved its reliability and usefulness and we decided to base our future HRV sensors on HRV monitoring device. The main problems of Polar based monitors were:

- Lack of real-time signal processing

- Limited memory, most commercially available HRV monitors allow data acquisition of approximately one-hour activity (depending on heart rate). Prolonged studies require uninterrupted data acquisition for at least 24 hours

- Inconvenient data uploading using infrared link to PC. Due to limited memory storage, acquired data should be uploaded to the server for off-line analysis. It is necessary to interrupt regular activity (or even wake-up the soldier), connect wearable unit to the computer and upload already stored information.

We found an intelligent Polar-band based sensor developed by RP Technologies, Huntsville, AL using standard RS232 link to PC for data upload. Therefore, we decided to base our development on that device by adding wireless communication capabilities (RF 900MHz), larger non-volatile memory for 24-hour monitoring and a mobile wireless gateway to iPAQ PDA. Main features of the approach include:

- Reliability Local memory storage and bi-directional link to the server allows reliable data acquisition and uploading

- High resolution time measurement - 1ms

- 24 hour data storage that allows uninterrupted training and activity for longer periods

- Automatic upload whenever reliable wireless communication link is available. WISE HRV checks for the reliable data link periodically and uploads already stored data. Data is uploaded simply by walking by the soldier exercising (or even sleeping) with PDA based wireless data acquisition device. Therefore, we don’t need to interrupt training activity to upload data (Figure 22)
The prototype system is implemented with the standard two-channel bio-amplifier from Teledyne Brown, and gateway link to iPAQ PDA. Our report about this system has been presented at the IEEE Engineering in Medicine and Biology Conference, in Houston, Texas, in October 2002 (see appendix).

The WISE HRV system was developed as an intelligent microcontroller based monitor with analog signal input or wireless input from POLAR type chest belt and bi-directional wireless link to data collection device – wireless gateway (PDA or laptop PC). A block diagram of the WISE HRV system is represented in Figure 23, and a working WISE HRV prototype is represented in Figure 23.

The WISE HRV system is smaller than a pack of cigarettes, and therefore, users can wear the device in their pocket close to the HRV transmission belt without a physical connection to either the belt or the mobile gateway. The mobile gateway will establish a wireless link with individual WISE HRV devices on distances up to 100 feet automatically and upload existing data to the archive. We have
integrated the latest battery technology (LiIon batteries) to decrease the device size and extend battery life.

In the next phase we plan detailed measurements of reliability of transmission as a function of distance in experimental settings, and experimental measurement of the power consumption. Our current measurements indicate battery life of at least 24-48 hours.

The choice of a data acquisition platform is critical for device acceptance and ease of use. Although a laptop PC represents the best platform for software development and application environment, it's size could interfere with the smooth noninvasive collection of data in the field. Therefore, we decided to focus on a new generation of personal digital assistants (PDA). The Compaq iPAQ platform is particularly appealing for this project.

Main features of the iPAQ PDA computing platform include:

- significant processing power (at least 200 MHz RISC processors)
- excellent screen resolution and brightness
- decent program development environment
- system support for file sharing
- availability of serial and USB interfaces for custom developed modules.

We experimented with development environments on the iPAQ PDA. The iPAC supports system development in Embedded C++ and Visual Basic for Windows CE. Developed applications are conveniently downloaded to the PDA and tested. Our current software system is developed as a

Figure 24. WISE HRV Sensor prototype
combination of Embedded Visual Basic and Visual C++. Visual Basic was used for development of graphical user interfaces, while Visual C++ was used for development of processing modules for faster execution. Therefore, main processing functions are executed from DLL modules developed using Embedded Visual C++. This combination allows fast development of a graphical user interface with excellent execution performance that is necessary for real-time processing of communication events.

The convenience of file sharing between traditional computers/ or laptops and the PDA is another advantage of this system. Generated files can be automatically transferred to a PC as soon as the PDA is returned its cradle for recharging and file transfer. We concluded that the iPAQ represents an excellent platform for a data collection workstation, and the transfer of collected records to the PC.

Serial and USB connectors allow interface with custom developed interface modules. Unfortunately, serial/USB connector does not provide enough power for additional devices. Therefore, we had to provide an additional battery for the wireless interface device that is necessary to download the data from WISE HRV sensors.

To address this issue, we developed a dedicated low-power wireless gateway for iPAQ PDA to decrease the size and power consumption of the PDA used to collect data from soldiers. A working prototype of the wireless gateway with iPAQ PDA is represented in Figure 25.

Figure 25. Mobile gateway interface

The software for the WISE HRV system was written to maximize the capabilities of our system while meeting strict power consumption requirements. For that reason the LINX transceiver is shut down most
of the time. Only periodically it is enabled to check whether the iPAQ gateway is present or not. Each WISE HRV periodically listens for the header sent by an iPAQ during a communication session. The WISE HRV system can be programmed to listen for variable amounts of time, depending on the protocol. Although the power consumption of a microcontroller is relatively small compared to the power consumption of LINX transceiver, the microcontroller is also kept in low power mode until it needs to perform certain tasks.

We developed a special communication protocol to allow reliable communication, data acquisition and facilitate future encryption for protection of transmitted data, see the appendix for a detailed description of the basic software and data system organization.

We have successfully implemented a working prototype of the monitoring system, that includes:

- Working portable HRV monitor WISE HRV with:
  - wireless heart rate sensing from Polar chest belt with 1 ms resolution
  - wireless communication with mobile gateway
  - 24 hour flash memory data acquisition
  - LiIon rechargeable battery
- Working wireless gateway for iPAQ PDA
- Basic protocols for reliable communication with mobile PDA data acquisition station
- Automatic merging of communication sessions into single user session
- MATLAB environment for custom HRV signal processing

The research team has experienced a series of setbacks concerning the collection of the psychobiological data at the training sites. Local Institutional review Board approval has been received, however, we are currently gathering additional information required for the Human Subjects Research Review Board (HSRRB). We have filed for a 6-month no cost extension. The results of this study may extend the findings from our previous neuro-biological studies and further define the psychological and biological profiles that predict superior performance under stress and stress-induced psychological and biological responses that are associated with superior performance under stress.

A second line of investigation will build on the evidence that HRV may represent an inexpensive methodology for the objective assessment of human military performance. We expect to apply for and develop more compact and efficient systems which could be used in a theatre of operations in order to determine whether, in addition to
predicting performance in the training environment, HRV predicts performance during theatre of operations activity.

**Reportable Outcomes**

The Development and testing of the WISE HRV system has been presented (see appendix). If the present project replicates the findings from our previous studies and from our pilot investigations, then we anticipate several lines of investigation in the future. First, we expect that the link between NPY, HRV and performance will warrant further investigation into the biology of a specific “stress resilient” profile. It is possible that this profile is the product of selection programs or, alternatively, the product of specific training environments. Clarifying the etiology of this profile may offer the possibility of increasing its percentage in the active duty population. We have applied for an additional year for funding for this project to further develop the telemetric technology and add additional metabolic measures including oxygen consumption, minute ventilation, respiratory frequency, and carbon dioxide production that will allow for several derived measures which have been shown to correlate with psychological states such as anxiety.

**Conclusions**

Although the research team has experienced setbacks concerning the collection of the psychobiological data at the training sites, the 6-month no cost extension will allow adequate time to meet the requirements of the HSRB, analyze data, and prepare reports. This protocol is primarily designed to make use of noninvasive telemetric devices designed to assess human physiology and to evaluate the degree to which such devices both predict and enhance our understanding of human performance. In addition, this research will provide a detailed characterization of the relationship between telemetric physiologic assessment measures and the more traditional measures that have been used in our previous studies. The data obtained in this project may extend our previous findings, provide additional clues to the factors contributing to excellence in military performance and, finally, provide evidence for a noninvasive, objective assessment of operational performance.
References


39. WISE heart rate monitoring system. See: appendix.


submitted to the Department of Psychology, College of Arts and Social Sciences, The University of West Florida.

# Appendices

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WISE HRV Presentations and Publications

Prolonged Telemetric Monitoring of Heart Rate Variability Using Wireless Intelligent Sensors and a Mobile Gateway. Presented at the IEEE Joint EMBS-BMES 2002 Meeting, Houston, TX.

Prolonged Telemetric Monitoring of Heart Rate Variability Using Wireless Intelligent Sensors and a Mobile Gateway. Presented at the IEEE Joint EMBS-BMES 2002 Meeting, Houston, TX.
PROLONGED TELEMETRIC MONITORING OF HEART RATE VARIABILITY USING WIRELESS INTELLIGENT SENSORS AND A MOBILE GATEWAY

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Abstract - Mobile health monitors allow patients to leave the hospital and engage in normal activity, uploading physiological data only periodically. Most existing systems use fixed gateways to upload data to the server. The Wireless Distributed Data Acquisition System presented in this paper is developed for prolonged, synchronized, health/stress monitoring of a selected group of subjects/patients. The system is based on mobile client devices, and mobile gateways. We use personal digital assistant (PDA) as a mobile gateway to collect data from individual monitors, and synchronize collected records with existing records on the telemedical server. Each client device uses flash memory as a temporary storage until the reliable connection with a mobile gateway is established. Individual intelligent sensors are based on very low-power microcontroller TI MSP430F149, and use standard 900 MHz wireless link, and flash memory. This system is used to evaluate the effects of stressful military training. We have found that patterns of heart rate variability correlate with stress tolerance.

Keywords - Wireless monitoring, Intelligent sensors, Heart rate variability, Stress detection, Telemedicine.

I. INTRODUCTION

Existing wireless health monitoring systems mostly assume mobile patients with fixed gateways for data collection [1]. As a result, mobility of monitoring subjects is constrained within the range of wireless transceiver. Extending range, on the other side, significantly decreases battery life of monitoring device. In this paper we present development of original environment for prolonged monitoring of heart rate variability (HRV) within the group of subjects under stressful military training.

HRV indexes both peripheral and central activity of the parasympathetic and sympathetic nervous systems. Recent brain imaging studies have confirmed that at least one component of heart rate variability (high frequency power) reflects activity in areas of the brain critical to the allocation of resources during stress, such as the medial prefrontal cortex. Thus, assessment of HRV provides a non-invasive means of evaluating the neural systems intimately involved in the capacity to attend to and respond to a threat. These findings linking HRV to actual cognitive performance robustly support the utility of HRV in the assessment of human performance.

Traditionally, a holter-type heart activity-monitoring device requires multiple, unwieldy, wires connecting electrodes with data acquisition/processing unit. We are developing a family of intelligent wireless sensors integrated into personal area network of intelligent sensors [2]. A new generation of recreational heart-monitoring devices is based on the same principle [3]. They provide a wireless link between the chest strap with electrodes and a watch-type data acquisition/processing unit. This type of device is very convenient for heart monitoring during normal activity, exercise and training. However, commercially available devices have severe limitations for versatile signal processing. The most important limitations include limited data memory and inconvenient data upload to the server. Most commercially available HRV monitors allow data acquisition of at most few hours. Prolonged studies require uninterrupted data acquisition for at least 24 hours. It is necessary to interrupt regular activity (or even wake-up the subject), connect wearable unit to the computer and upload already stored information.

II. DISTRIBUTED TELEMEDICAL SYSTEM

The Wireless Distributed Data Acquisition System uses Wireless Intelligent Sensors (WISE) [2] as individual HRV monitors, and a Mobile Wireless Gateway (MOGUL) [4], as presented in Fig. 1. The system is organized in Master-Slave configuration with MOGUL acting as a master. The WISE devices are small battery powered data acquisition and processing devices with physiological sensors, a wireless transceiver, and a large flash memory. The MOGUL is responsible for collecting data from the WISE devices and processing the retrieved data.

Periodic visits to the training facility with the handheld MOGUL device allows uploading of collected data from individual WISE sensors. The MOGUL moves in a path that allows it to come into wireless contact with the WISE devices in this system. During the time that the MOGUL is able to talk to the WISE devices it downloads and catalogues

Figure 1. Block diagram of the telemedical monitoring system
all of the data measurements stored on the WISE devices. The WISE devices that are not in range of the MOGUL's wireless transceiver store all of their measurements, waiting to upload them to the MOGUL. It is possible to connect the MOGUL wirelessly to the Internet, and create true real-time telemedical system. It was not necessary for the given application.

A. Wireless Intelligent Sensor – WISE

The core of our Wireless Intelligent Sensor (WISE) consists of Texas Instruments' microcontroller MPS430F149 that is responsible for A/D data acquisition and processing. The controller features 16-bit RISC architecture, ultra-low power consumption (less than 1 mA in active mode and less than 1 μA in standby mode), 60KB flash memory, 2KB RAM, AD converter (8 12-bit channels), integrated UARTs and a 64-pin QFP package. Additional analog channels are used to monitor battery voltage, wireless link quality, and other external analog inputs. Therefore, WISE is capable of reporting the battery status and reporting low-battery warnings to higher systems in the system hierarchy.

We use a standard 900 MHz RF link for wireless communication.

We currently use two WISE sensors for HRV monitoring:

- WISE ECG uses an off-the-shelf two-channel bio-amplifier TETMD A110-1/2 from Teledyne for signal conditioning. The output signals from the bio-amplifier are converted to digital signals using internal 8-channel, 12-bit AD converter integrated in microcontroller.

- WISE HRV uses receiver for Polar heart rate monitor belt, providing only processing, storage and wireless communication.

B. Mobile Gateway - MOGUL

A MOGUL device polls all of the WISE devices that is configured to poll using specialized wireless interface. The connection between the MOGUL and the central server could be a standard 802.11b or Bluetooth wireless link. We are currently using Compaq's iPAQ pocket PC as a MOGUL, as shown in Fig. 3.

V. CONCLUSION

Our preliminary results indicate that those individuals who have better stress tolerance also exhibit significantly different patterns of heart rate variability, both before and during stress exposure. These baseline differences in heart rate variability are predictive of actual military and cognitive neuropsychological test performance scores assessed during and after stress exposure.

Proposed system allow synchronous data collection from a group of monitored subjects, where data upload does not interfere with their regular activity. As a result, significantly larger database of continuous records could be collected that allows better resolution and statistical significance of individual measurements within the group.

ACKNOWLEDGMENT

This project is partly supported by USAMRMC grant 01145005 for Research Program in Metabolic Monitoring.

REFERENCES


Figure 2. WISE_ECG sensor.

Figure 3. MOGUL device using iPAQ PDA.
A Distributed Non-invasive Wireless Heart Rate Variability Monitoring System

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Heart rate variability can be used to monitor the psycho-physiological state of groups of soldiers in the battlefield or during intensive training. We present a non-invasive wireless system developed for synchronized distributed monitoring of heart rate variability. Each microcontroller sensor is equipped with the low power/low range (up to 100 ft) wireless transceiver, and communicates with the mobile gateway whenever gateway comes to a range and identifies itself. The system is being developed for aviation selection at the Naval Aerospace Medical Research Laboratory at Pensacola, Florida. We present the status of our current development and discuss possible applications for stress and psycho-physiological state estimation in the battlefield.
WISE HRV Protocol
WISE HRV System Protocol

We developed a special communication protocol to allow reliable communication, data acquisition and facilitate future encryption for protection of transmitted data. In this section we describe basic software and data system organization.

Collected data is organized as follows. Monitoring of each group of soldiers is considered as one data session. Each visit of operators creates individual communication session. Multiple communication sessions are processed to create a single data file per user and per session. Details of organization of the software system are given below.

4.1. User View

List of actions performed by operators (iPAQ and PC operators) during and after each training session:
1. Each device is initialized – mapped to a user (see iPAQ Applications)
2. Mapping information is stored to database (see Data Formats)
3. iPAQ operator periodically visits users/devices and collects data (see PC<:>iPAQ)
4. Collected data is moved from iPAQ to PC (see iPAQ<:>PC)
5. PC operator runs program for data merging and archiving (see iPAQ<:>PC)
6. PC operator periodically (preferably after each training session) creates a backup of archived data

4.2. File Names and Data Formats

Automatic processing of communication session files must combine multiple individual files. In order to facilitate automatic processing we adopted the following convention about data file names.

FILE NAMES

<Letter><Three-digit number><Two-digit number - Monitor Logical ID><Two-digit number - Communication Session ID>.DAT

In order to conform to 8.3 file name convention, maximum number of WISE HRVs (or users) in a single training session is limited to 100, as well as the number of communication sessions. This is represented by two digit Monitor Logical ID (WW). If this number has to be increased, letters can be used as well, increasing those numbers to almost 1300. Total number of different training sessions is 26,000.
4.3. Data Formats

Minimum set of data or data structures needed to support the monitoring is:

- Assignment database – maps users to devices, and lists all the devices used in the training session. For each training session contains at least following set of records:
  - WISE HRV_ID
  - POLAR_ID
  - USER_ID
  Each field in this record is a pointer to a structure that describes particular component or user.
- Communication Session Counter (kept in WISE HRV’s flash memory) – used for file name creation and to keep data in correct order.

4.4. Communication Protocol

WISE HRV monitoring system consists of two protocols, operating between the monitor and PDA and between the PDA and a PC.

4.4.1. WISE HRV ↔ iPAQ

WISE HRV is designed for independent operation with occasional availability of wireless connection to the mobile data acquisition unit (PDA). Therefore, it is organized to perform the following operations:
1. WISE HRV stores data in a circular buffer located in flash memory, keeps pointers to the portion of data not yet sent.
2. When polled (see later) it transfers data to the iPAQ (for protocol, see later), until all data is transferred, updating pointers. This is called a communication session.
3. iPAQ stores data in a data file, using naming convention given above.

All the commands exchanged between the iPAQ and the monitor have the following syntax:

<COMMAND>[:<SOURCE_ADDRESS><DEST_ADDRESS><ARGUMENTS>]

iPAQ performs polling of WISE HRVs active in the current training session, using WISE HRV’s physical IDs.

4.4.2. iPAQ ↔ PC

Data upload from the mobile data acquisition unit to the PC as performed as follows:
1. File synchronization:
   - Collected files are copied to a specified PC folder
2. Start PC program that will:
- Merge (or append) all the files from a specific training session and specific user, creating a single data file for one (training session / user) combination. Programs takes care that data files are merged in proper order. Name format of a merged data file is 
  \(<L><TTT><WW>\).DAT
- Archive processed files either by creating a zip file for each training session or by creating a separate folder for each session and storing all the raw data session files.

4.5. iPAQ Application

Application running on iPAQ PDA must be able to map a monitoring device to user (assignment), start and stop acquisition on individual monitors.

4.5.3. Assignment

The operator must assign a device per each user(soldier) during every session. This is performed as follows:

- User creates text file containing a list of user IDs and corresponding WISE HRV IDs for the current training session.
- For each device that will be used in this particular training session, following set of actions is executed:
  i. SEND (iPAQ Actions):
     - SESSION_ID
     - LOG_WISE HRV_ID (Logical WISE HRV ID, assigned for this session)
     - USER DATA (First/Last Name)
  ii. INITIALIZE (WISE HRV Actions):
      - Communication Session Counter
      - Flash Memory Pointers
  iii. TEST input signal (iPAQ Action):
      - Polar belt identification (POLAR_ID)
  iv. SEND average (or last) RRint (WISE HRV Action):
      - iPAQ waits at most 2 seconds for response
4.5.4. START ACQUISITION

WISE HRV monitor collects individual block of HRV data, storing them in flash memory. The following list of commands represents a typical data acquisition communication session between the iPAQ and the participating WISE HRV:

a. `<POLL> <iPAQ_ID> <WISE HRV_PHYS_ID>`

b. `<STATUS> <WISE HRV_LOG_ID> <iPAQ_ID> <ARG>
   <ARG> = {COMM_SESS_CTR | ERR_CODE}
   <STATUS>={OK_NO_DATA | OK_DATA | ERROR}

c. `<ACK> <iPAQ> <WISE HRV_PHYS_ID>` [Can be combined into one message]

d. `<REQ> <iPAQ> <WISE HRV_PHYS_ID>`

e. `<DATA> <WISE HRV_LOG_ID> <iPAQ_ID> <DATA_BYTES>`

f. `<ACK> <iPAQ> <WISE HRV_PHYS_ID>`

g. `<STATUS> <WISE HRV_LOG_ID> <iPAQ_ID>
   <STATUS>={OK_NO_DATA}`

Steps d, e, f are repeated until all available blocks of data are transferred without errors. Retransmissions will occur if CRCs don’t match. iPAQ will initiate retransmission by sending `<NACK>` message instead of `<ACK>` message. WISE HRV will respond to next `<REQ>` message by sending the same block again. Alternatively, instead of having separate ACK and REQ messages, REQ message can have an argument `<COMM_SESS_CTR>`. Therefore, if there were errors, iPAQ will request the same block again.

Format of `<DATA_BYTES>`:
- `<BUFFER_ID><Data><CHECKSUM>`

4.5.5. Stop Acquisition

HRV data acquisition could be stopped at all WISE HRVs in the current training session, or for individual WISE HRVs. After successful START ACQUISITION, the following set of messages will be sent:

h. `<STOP> <iPAQ_ID> <WISE HRV_PHYS_ID>`

i. `<ACK> <WISE HRV_LOG_ID><iPAQ_ID>`

5. Software Organization

System software for wireless HRV monitoring is executed on two platforms: portable wireless heart rate monitor (WISE HRV) and mobile PDA gateway.

5.1. WISE HRV Software Organization

Software for Wireless Heart Rate Monitor is completely written in C, using IAR Embedded Workbench environment.
Main program has two major sections. The first section initializes the resources of MSP430 microcontroller — Asynchronous Serial Interface (UART0), Synchronous Serial Interface (SPI1), TimerB, and ComparatorA. Also, the board contains various off-processor components — LINX transceiver, external flash memory, etc. These components also have to be initialized. At the beginning, both serial interfaces are initialized, and then the synchronous interface is used to initialize flash memory. Asynchronous serial interface works at 19200 bps, while the synchronous is initialized to work with one fifteenth of a system clock. System clock is currently set to maximum speed of 8 MHz. TimerB is set to generate an interrupt every millisecond, while ComparatorB is set to generate an interrupt whenever the input signal exceeds one quarter a predefined threshold of Polar signal conditioning circuit. ComparatorB works with a 250 ns resolution.

The second section is a simple loop in which a microcontroller sits in a low power mode, waiting for the flag from the UART0 RX interrupt routine. This flag will be raised once a special message is received from the appropriate iPAQ gateway, which indicates its presence. WISE HRV will respond to the messages received from iPAQ according to the protocol explained before. If the data is requested, WISE HRV will read a block of data from the flash memory, starting from the address that is pointed to by a special pointer, and send it through the asynchronous serial interface to the LINX wireless transceiver.

The TimerB interrupt routine is scheduled to run every millisecond and performs two tasks — increments global time and keeps track of different time-out events. Finally, ComparatorA interrupt routine fires every time a signal captured from a Polar belt exceeds a predefined threshold, indicating that a heartbeat is detected. When this happens, ComparatorA interrupt routine has a couple of tasks to perform:
- Calculate the time interval between last two heart beats (RRint);
- Store RRint into a buffer if this interval is within its normal limits, or
- store a relative time if the RRint is exceptionally long (probably missed heart beats). In this case, this relative time has to be calculated and properly formatted;
- Check if the buffer is full, in which case the full buffer is transferred to the flash memory and the pointer to the next free location in the flash memory is updated.

As a support to all the tasks performed by main program and interrupt routines, several drivers are written. As stated earlier, WISE HRV uses both asynchronous and synchronous serial interfaces. Asynchronous interface is used for wireless communication with gateway, while the synchronous interface is used for communication with flash memory. Therefore, a serial driver had to be written, which provides functions such as UART and SPI initialization, reading and writing from the ports, etc. Flash memory driver provides functions for erasing memory, storing blocks or pages of data, checking the status of memory, reading data from the memory, etc.

Software for WISE HRV was written having in mind the strict power consumption requirements. For that reason, LINX transceiver is shut down most of the time. Only periodically it is enabled to check whether the iPAQ gateway is present or not. Each WISE HRV listens for the amount of time that is long enough to catch at least one header sent either by iPAQ or by some other WISE HRV device that has already started its communication session with a
corresponding iPAQ. In that case, WISE HRV will start listening all the time until it receives a message sent to it, or until time out occurs. Although the power consumption of a microcontroller is relatively small compared to the power consumption of LINX transceiver, microcontroller is also kept in low power mode until it needs to perform certain tasks.

5.2. iPAQ Gateway Software Organization

iPAQ Gateway software is written in both Microsoft Embedded Visual C++ and Embedded Visual Basic. Graphic interface part is written in Visual Basic for simplicity, while the processing part is written in Visual C++ for speed. C++ part is organized as a Dynamically Linked Library (dll) which implements functions that can be called from Visual Basic, and mostly deals with a communication port and data packets received wirelessly.

Main program in Visual Basic creates user interface form, which contains buttons that give commands for setting up the monitors, sending commands to them, and displays information received from monitors.

Pressing the button calls a C++ function that is a part of a dll library, which then usually creates a thread that will take care of specific action. One example would be a ReadPort thread, which is created upon opening a port, when iPAQ operator initiates data collection. When iPAQ gateway is instructed to start collecting data from the monitors it initiates the polling procedure. For each monitor, a special message is sent that contains a header (a characteristic array of bytes that designates a beginning of each message and also synchronizes the LINX transceiver), iPAQ identification, WISE HRV identification, and a command. After sending each of the messages iPAQ goes into receiving mode, waiting for a response. If the appropriate WISE HRV responds within a predefined time, iPAQ will initiate a data transfer session with that particular Monitor until its completion; otherwise, it will send a calling message to the next WISE HRV. This process will continue until all the monitors send all the data (i.e. until each one of them sends NO_DATA message), until time out occurs, or until iPAQ operator closes the session. iPAQ displays to its operator a progress report for the whole group of Monitors, as well as the individual progress in data transferring. At the same time, each Monitor keeps track of data being sent by updating pointers in the flash memory. That ensures reliability, i.e. allows data to be collected in several sessions if the session gets interrupted.

The dedicated gateway hardware (Figure 5) is built in such way that changes in RTS line switch LINX from transmit to receive mode and vice versa. For that reason, software is organized as follows:

- To send a message, iPAQ first has to reset RTS line (to set Transmit Enable pin on LINX transceiver)
- Wait 4-6 ms for LINX to switch from receive to transmit mode
- Send a message
- Set RTS line (set Receive Enable pin on LINX transceiver)
- Wait 4-6 ms for LINX to switch from transmit to receive mode
- Wait for the message or data from WISE HRV or for the time out to occur.
The hardest part of system implementation is an ongoing process of system testing and debugging. Since our project requires use of iPAQ serial port, it has to be removed from cradle to be connected to a gateway. Therefore, debugging capabilities of Visual Basic and Visual C++ could not be used. For the monitor part, debugging was easier since we included JTAG connector to the board, and were able to use a debugger from IAR Embedded Workbench environment. The real challenge was to set up proper timing for switching both LINX transceivers form transmit to receive mode and vice versa at the same time, and for this purpose a mixed analog/digital oscilloscope with a logic analyzer was used.

Another serious problem was a large interference in unlicensed 900 MHz RF band. It was surprising that so many devices use the same frequency band with unpredictable activation and interference. However, we established a reliable communication using low level transceiver synchronization and transmission repeats. We suggest exploration of alternative wireless communication methods in the future generation of wireless heart rate monitors.

6. WISE HRV Performance Measures

Wireless heart monitor WISE HRV features two wireless links: the first one is local to the chest belt, while the second one is communication to data acquisition unit.

In order to evaluate communication between the monitor and the chest belt, we measured device sensitivity and influence of the position on the body. According to our experiments, we concluded the following:
- Prototype receiver works reliably on front and back side of the upper side of user's body independent of device position.
- Device sensitivity is dramatically reduced below belt line. Therefore, It will not be possible to carry the device in pants' pocket.
- Wireless signal reception is bad on the side of body close to hip in certain device orientation.

As conclusion, heart rate monitor should be carried in vest pocket on the front or back side of the body.

7. HRV signal processing

We developed a custom test environment for HRV processing in MATLAB for easier development of signal processing procedures that will be used later in the selection process after justifying their value. We have been evaluating interpolation methods and subsampling since original heart rate intervals (RRint) are sampled at 1 KHz. It is very important to maintain a good time resolution (1 ms in our case), but spectral signal processing is performed with smaller time resolution. In addition to standard static processing using 5 min segments or 24 hour variability, we found promising some alternative processing methods, such as dynamic evaluation of individual heart rate variability in collective stressful situations.
We accepted experiences from the open literature, and we currently process short time heart rate variability starting from 1 min RRint data, interpolated using linear interpolation in 256-1024 points. This approach is convenient for spectral analysis and provides spectral resolution of the processed HRV signal with frequency $\Delta f = 0.0167$ Hz.
Questionnaires

Brief Trauma Questionnaire
Clinician Assisted Dissociative States Scale
Rey-Osterreith Complex Figure Task
Declarative Memory Task
The following questions ask about events that may be extraordinarily stressful or disturbing for almost everyone. Please circle Yes or No to report if any of these events have happened to you.

If you answer Yes for an event, please answer the two additional questions that are listed on the right to report: (1) whether you thought your life was in danger or you might be seriously injured; and (2) whether you were seriously injured. If you answer No for an event, go on to the next event.

<table>
<thead>
<tr>
<th>Has this ever happened to you?</th>
<th>Answer these questions for each event that has happened to you.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Did you think your life was in danger or you might be seriously injured?</td>
</tr>
<tr>
<td>1. Have you ever served in a war zone, or have you ever served in a noncombatant job that exposed you to war-related causalities (for example, as a medic or on graves registration duty?)</td>
<td>Yes No</td>
</tr>
<tr>
<td>2. Have you ever been in a serious car accident, or a serious accident at work or somewhere else?</td>
<td>Yes No</td>
</tr>
<tr>
<td>3. Have you ever been in a major natural or technological disaster, such as a fire, tornado, hurricane, flood, earthquake, or chemical spill?</td>
<td>Yes No</td>
</tr>
<tr>
<td>4. Have you ever had a life-threatening illness such as cancer, heart attack, leukemia, AIDS, stroke, etc.?</td>
<td>Yes No</td>
</tr>
<tr>
<td>5. Before age 18, were you physically punished or beaten by a parent, caretaker, or teacher so that: you were very frightened; or you thought you would be injured; or you received bruises, cuts, welts, lumps or other injuries?</td>
<td>Yes No</td>
</tr>
</tbody>
</table>
6. Not including any punishments or beatings you already reported in question 5, have you ever been attacked, beaten, or mugged at any age by anyone, including friends, family members, or strangers?  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

7. Has anyone ever made or pressured you into having some type of unwanted sexual contact?  

Note: By sexual contact we mean any contact between someone else and your private parts or between you and someone else's private parts  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

8. Have you even been in any other situation in which you were seriously injured, or have you ever been in any other situation in which you feared you might be seriously injured or killed?  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

9. Has a close family member or friend died violently, for example, in a serious car crash, mugging, or attack?  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

10. Have you ever witnessed a situation in which someone was seriously injured or killed, or have you ever witnessed a situation in which you feared someone would be seriously injured or killed?  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Note. Do not answer Yes for this question for any event you have already reported in questions 1-9.
Clinician Assisted Dissociative States Scale
ID#: ____________________

EXPERIENCE SCALE
Please indicate if you have ever had the following experiences during an event or incident by placing an "X" in the second column. If you have had any of these experiences, indicate the intensity of the experience in the third column using the following scale:
1=Slightly  2=Moderately  3=Considerably  4=Extremely

<table>
<thead>
<tr>
<th>Have you ever had the following experience?</th>
<th>If yes, mark &quot;X&quot;</th>
<th>Intensity of the experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did things seem to be moving in slow motion?</td>
<td></td>
<td></td>
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<tr>
<td>2. Did things seem to be unreal to you, as if you were in a dream?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Did you have some experience that separated you from what was happening, for instance, did you feel as if you were watching a movie or a play, or as if you were an automaton?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Did you feel as if you were looking at things from outside of your body?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Did you feel as if you were watching the situation as an observer or a spectator?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Did you feel disconnected from your own body?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Did your sense of your own body feel changed: for instance, did your own body feel unusually large or unusually small?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Did people seem motionless, dead or mechanical?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Did objects look different than you would have expected?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Did colors seem to be diminished in intensity?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Did you see things as if you were in a tunnel, or looking through a wide-angle photographic lens?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Did the experience seem to take much longer than you would have expected?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Did the experience happen very quickly, as if there were a lifetime in a moment?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Were there things that happened during the experience that you later couldn't account for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Did you space out, or in some other way lose track of what was going on during the experience?</td>
<td></td>
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<tr>
<td>16. Did sounds almost disappear or become much stronger than you would have expected?</td>
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<td></td>
</tr>
<tr>
<td>17. Did things seem too very real, as if there were a special sense of clarity?</td>
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<td></td>
</tr>
<tr>
<td>18. Did it seem as though you were looking at the world through a fog, so that people and objects appeared far away or unclear?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Did colors seem much brighter than you would have expected?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Rey-Osterreith Complex Figure Task

Using the space below, copy the picture as precisely as you can.

Following 5-10 minutes the participant is asked to draw this figure from memory
Memorize all the words in the list highlighted below.

<table>
<thead>
<tr>
<th>List A</th>
<th>List B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soldier</td>
<td>Principal</td>
</tr>
<tr>
<td>Beaver</td>
<td>Pig</td>
</tr>
<tr>
<td>Nurse</td>
<td>Lawyer</td>
</tr>
<tr>
<td>Peas</td>
<td>Corn</td>
</tr>
<tr>
<td>Rat</td>
<td>Fox</td>
</tr>
<tr>
<td>Professor</td>
<td>Clerk</td>
</tr>
<tr>
<td>Brain</td>
<td>Nose</td>
</tr>
<tr>
<td>Carrot</td>
<td>Mushroom</td>
</tr>
<tr>
<td>Throat</td>
<td>Heels</td>
</tr>
<tr>
<td>Wolf</td>
<td>Seal</td>
</tr>
<tr>
<td>Tooth</td>
<td>Mouth</td>
</tr>
<tr>
<td>Rice</td>
<td>Apple</td>
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<tr>
<td>Coach</td>
<td>Cook</td>
</tr>
<tr>
<td>Lion</td>
<td>Monkey</td>
</tr>
<tr>
<td>Chest</td>
<td>Hand</td>
</tr>
<tr>
<td>Onion</td>
<td>Spinach</td>
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<tr>
<td>Finger</td>
<td>Eye</td>
</tr>
<tr>
<td>Mouse</td>
<td>Bear</td>
</tr>
<tr>
<td>Grape</td>
<td>Plum</td>
</tr>
<tr>
<td>Judge</td>
<td>Farmer</td>
</tr>
</tbody>
</table>

Please write all the words you recall from the list.
Biographical Sketch
Amanda O’Donnell
Charles A. Morgan
Emil Jovanov
Frank Andrasik
Michael C. Prevost
BIOGRAPHICAL SKETCH

Provide the following information for the key personnel. Photocopy this page or follow this format for each person.

<table>
<thead>
<tr>
<th>NAME</th>
<th>POSITION TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amanda O'Donnell, M.A.</td>
<td>Research Psychologist, NAMRL</td>
</tr>
</tbody>
</table>

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training).

<table>
<thead>
<tr>
<th>INSTITUTION(S) AND LOCATION</th>
<th>DEGREE(S) (if applicable)</th>
<th>YEAR(S)</th>
<th>FIELD(S) OF STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of West Florida</td>
<td>B.A.</td>
<td>1995</td>
<td>Psychology</td>
</tr>
<tr>
<td>University of West Florida</td>
<td>M.A.</td>
<td>1997</td>
<td>Psychology</td>
</tr>
<tr>
<td>University of West Florida</td>
<td>Ed.D.(ABD)</td>
<td>2002</td>
<td>Curriculum &amp; Instruction</td>
</tr>
</tbody>
</table>

RESEARCH AND PROFESSIONAL EXPERIENCE:

Positions
1998 to Present: Research Psychologist, Naval Aerospace Medical Research Laboratory
Responsibilities include serving as an Investigator on a team conducting personnel selection research primarily within the aviation community.

Principal Investigator:

The War Fighter’s Stress Response: Telemetric and Noninvasive Assessment
Selection of Aviation Personnel with Regard to their Potential Risk of Capture: Psychobiological Assessment of Student Aviator Exposure to a Stressful Training Event
Biopsychological Assessment of Spatial Abilities

Co-Investigator:

Medical, Aptitude, and Personality Determinants of Isoperformance Curves and their Impact on Naval Aviation Selection
Pilot Prediction System
Automated Spatial Abilities Test
Landing Craft Air Cushion Navigator Selection System
LCAC Craftmaster and Engineer Crew Selection: Validation of the Cogscreen and Two Subtests of the ASTB

1995 – 1998: Research Associate, The Behavioral Medicine Laboratory, University of West Florida
Responsibilities included: Day to day management of ongoing research projects which included the following investigations: prophylactic medication for the control of migraine headaches; sleep improvement in the geriatric population; memory improvement in the geriatric population; non-invasive treatments for migraine headache; the utility of biofeedback for a variety of disorders.

1993-1995: Research Assistant: Laboratory for Studies in Cognitive Psychophysiology
All studies involved either 19 channel or 128 channel EEG/ERP. Primary responsibility was an investigation that attempted to determine the role of the P200 in early encoding. Lab involvement also included providing assistance with all phases of ongoing research projects involving cognitive psychophysiology.

Professional Activities

Reviewer, Journal for Applied Psychophysiology and Biofeedback
Reviewer, Journal for Behavior Therapy
Member, Institutional Review Board, Naval Aerospace Medical Research Laboratory
Member, Association for Applied Psychophysiology and Biofeedback
Member, South Eastern Psychology Association

Awards

Civilian of the Year, Naval Aerospace Medical Research, 2002
Civilian of the Year, Naval Aerospace Medical Research, 2001
Student Research Award, Association for Applied Psychophysiology and Biofeedback, 1997
Outstanding Graduate Student of the Year 1996-97 Department of Psychology, University of West Florida

Publications and Presentations (note, former name was Albert)


Blower, D.J., Williams, H.P., and Albert, A.O., Predicting Primary Flight Grades by Averaging Over Linear Regression Models: Part 1, NAMRL-1410, Naval Aerospace Medical Research Laboratory, Pensacola, Florida, January 2000. (AD A 375 398)


BIOGRAPHICAL SKETCH
Provide the following information for the key personnel. Photocopy this page or follow this format for each person.

<table>
<thead>
<tr>
<th>NAME</th>
<th>POSITION TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles A. Morgan III, M.D., M.A. (GS-15)</td>
<td>Associate Professor of Psychiatry &amp; Research Affiliate, History of Medicine, Yale University</td>
</tr>
</tbody>
</table>

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training).

<table>
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<tr>
<th>INSTITUTION(S) AND LOCATION</th>
<th>DEGREE(S) (if applicable)</th>
<th>YEAR(S)</th>
<th>FIELD(S) OF STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Union College, Angwin, CA</td>
<td>B.A.</td>
<td>1982</td>
<td>French</td>
</tr>
<tr>
<td>Loma Linda University School of Medicine, CA</td>
<td>M.D.</td>
<td>1986</td>
<td>Medicine</td>
</tr>
<tr>
<td>Yale University</td>
<td>M.A.</td>
<td>1996</td>
<td>History of Medicine</td>
</tr>
</tbody>
</table>

RESEARCH AND PROFESSIONAL EXPERIENCE:

Positions
Internship (1986 to 1987), Jerry L. Pettis Memorial VA Hospital, Loma Linda, CA. Psychiatry Resident (1987 to 1989), Dept. of Psychiatry, Loma Linda, University Medical Center, Loma Linda, CA. Staff Psychiatrist, (1988 to 1989) David & Margaret Home for Girls, La Verne, CA. Chief Resident, (1989 to 1990), Neurobiological Studies Unit, National Center for Post Traumatic Stress Disorder, West Haven VA Medical Center, West Haven, CT. Yale University Dept. of Psychiatry. Assistant Professor of Psychiatry (1990 to 1993), Yale School of Medicine. Medical Director (1990 to 1991), Dual Diagnosis Unit & Medical Director, Neurobiological Studies Unit, National Center for PTSD. V.A. Medical Center, West Haven, CT. Director of Substance Abuse/PTSD Clinic, Medical Director (1991 to 1992), Desert Storm Outreach Clinic, VA Medical Center, West Haven, CT. Director of Outpatient Psychotherapies (1991 to 1992), PTSD/Anxiety Clinic, National Center for PTSD, VAMC, West Haven, CT.
Assistant Director (1992 to 1993) Outpatient Mental Health Department of Psychiatry, WHVAMC.
Court Clinic Psychiatrist (1993 to ), Yale Dept. of Law and Psychiatry.
Assistant Professor of Psychiatry (1993 to 1996), Yale University School of Medicine.
Associate Professor of Psychiatry & Research Affiliate (1996 to ), History of Medicine, Yale University Associate Director PTSD Program, National Center for PTSD, VA Connecticut.

Research Grants
Principal Investigator: Psychobiological Assessment of High Intensity Military Training, (DoD).
Funding ongoing: $225,000.00 total for fiscal years 1998, 1999, and 2000

Awards
The Stephen Fleck Faculty Award as Exemplary Physician and Clinical Teacher, Yale Department of Psychiatry, 1996-97
Lucia P. Fulton Fellowship Award (History of Medicine, the Nathan Smith Club, Yale University School of Medicine) 1999.

Forensics

SELECTED PEER REVIEWED PUBLICATIONS
Krystal J.H., Webb E., Grillon C., Cooney N., Casa L., Morgan C.A, III, Southwick S.M.,
Davis M., & Charney D.S. Evidence of acoustic startle hyper-reflexia in recently
detoxified alcoholics: Modulation by yohimbine and m-chlorophenylpiperazine

Southwick SM, *Morgan III CA*, Nicolaou AL, Charney DS: Consistency of Memory for

*Morgan CA*, Grillon C, Southwick SM: Startle Abnormalities in Women with Sexual

Grillon C, *Morgan CA*, Davis M, & Southwick SM. Effects of experimental context and
explicit threat cues on acoustic startle in Vietnam veterans with posttraumatic stress

*Morgan CA*, Kingham P, Nicolaou A, Southwick SM: Anniversary Reactions in Desert
Storm Veterans: A Naturalistic Inquiry 2 years after the Gulf War. *J of Traumatic

Grillon C, *Morgan CA*, Davis M, & Southwick SM. Effects of darkness on acoustic startle

Grillon C & *Morgan CA*: Fear Contextual Startle Conditioning to Explicit and Contextual
Cues in Gulf War Veterans with Posttraumatic Stress Disorder. *J Abn Psychology*,

*Morgan CA III & Grillon C*. Abnormal mismatch negativity in women with sexual assault

p1075-9.

*Morgan III CA*, Wang S, Mason J, Hazlett G, Fox P, Southwick SM, Charney DS,

Neuropeptide-Y in Humans Exposed to Military Survival Training. *Biol Psychiatry*

Rassmusen A, *Morgan CA*, Hauger S, Bremner DJ, Southwick SM: Plasma NPY in
response to Yohimbine Challenge in combat veterans with, and without Post-traumatic

Relationships among Cortisol, Catecholamines, Neuropeptide Y and Human

Symptoms of Dissociation in Humans Experiencing Acute Uncontrollable Stress: A

and Subjective Distress in Humans Exposed to Acute Stress: Replication and

Non Peer Reviewed Publications


Chapters


Submitted/In Review

Morgan CA & Southwick: Trauma-Related Symptoms in Veterans of Operation Desert Storm: A Four-Year Follow-up.

Morgan CA, & Southwick SM: Inconsistency of Memory for Traumatic Events: Replication and Clarification Six-Years After the Gulf War.

Morgan CA & Southwick SM : Inconsistency of Memory for Traumatic Events: Replication and Clarification Six-Years After the Gulf War.


Morgan CA: "Don't Worry: It's not you, it's your brain:" The Rhetoric of Biology in Psychotherapy.

In preparation
Morgan CA, Grillon C, Southwick SM: Effect of Clonidine on Acoustic Startle in Combat Veterans with PTSD.


Other Professional Activities
VA Merit Review Subcommittee for Mental Health & Behavioral Science
Reviewer, Am J of Psychiatry
Reviewer, Arch Gen Psychiatry
Reviewer, Biological Psychiatry
Reviewer, Journal of Neuropsychosendocrinology
Book Reviewer, Journal of History of Medicine and the Allied Sciences

70
Book Reviewer, Nature Medicine
Member, International Society for Traumatic Stress Studies
Member, American Association for the History of Medicine
Member & Secretary/Treasurer, The Beaumont Club of Connecticut for the History of Medicine
Member, Pavlovian Society
BIOGRAPHICAL SKETCH

Provide the following information for the key personnel. Photocopy this page or follow this format for each person.

<table>
<thead>
<tr>
<th>NAME</th>
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<th>FIELD(S) OF STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emil Jovanov, Ph.D.</td>
<td>Associate Professor, UAH</td>
<td>School of Electrical Engineering, University of Belgrade</td>
<td>Dip.Ing.</td>
<td>1984</td>
<td>EE/Computer Engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>School of Electrical Engineering, University of Belgrade</td>
<td>M.Sc.</td>
<td>1989</td>
<td>EE/Computer Engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>School of Electrical Engineering, University of Belgrade</td>
<td>Ph.D.</td>
<td>1993</td>
<td>EE/Computer Engineering</td>
</tr>
</tbody>
</table>

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training).

RESEARCH AND PROFESSIONAL EXPERIENCE:

**Positions**
Research Assistant (08/84 to 12/96), Institute “Mihajlo Pupin.”
Program Director For Image Processing and Multimedia (12/96 to 08/98) Institute “Mihajlo Pupin.”
Visiting Assistant Professor (08/98 to 06/99), ECE Dept., The University of Alabama, Huntsville, AL.
Assistant Professor (07/99 to 06/01), ECE Dept., The University of Alabama, Huntsville, AL.
Associate Professor (07/01 to ), ECE Dept., The University of Alabama, Huntsville, AL.

**Research Grants**


Journals:


Submitted
Books, Chapters in Books
Yugoslav magazines:

Conference Proceedings:
BIOGRAPHICAL SKETCH

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<thead>
<tr>
<th>NAME</th>
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<tbody>
<tr>
<td>Frank Andrasik, Ph.D.</td>
<td>Senior Research Scientist/Professor, Psychology</td>
</tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Wright State University, Dayton, OH</td>
<td>B.A.</td>
<td>1971</td>
<td>Psychology</td>
</tr>
<tr>
<td>Ohio University, Athens, OH</td>
<td>M.S.</td>
<td>1973</td>
<td>Experimental Psychology</td>
</tr>
<tr>
<td>University of Pittsburgh School of Medicine, PA</td>
<td>------</td>
<td>1978-1979</td>
<td>Clinical Psychology Intern</td>
</tr>
<tr>
<td>Ohio University, Athens, OH</td>
<td>Ph.D.</td>
<td>1979</td>
<td>Clinical Psychology</td>
</tr>
</tbody>
</table>

RESEARCH AND PROFESSIONAL EXPERIENCE:

Positions

Associate Professor (9/83 to 4/86), Assistant Professor (9/79 to 8/83), Associate Director, Center for Stress and Anxiety Disorders (9/82 to 4/86), Department of Psychology, SUNYA, Albany, NY.

Research Associate Professor (1/84 to 4/86), Department of Neurology, Adjunct Associate Professor (5/83 to 5/88), Department of Family Practice, Albany Medical College, Albany, NY. Associate Director, Pain Therapy Centers, Greenville Hospital System, Greenville, SC, 4/86 to 6/87.

Senior Research Scientist, Institute for Human and Machine Cognition (10/99 to present), Associate Research Associate Professor, Pain Therapy Centers, Greenville Hospital System, Greenville, SC (10/99 to present), Department of Psychopharmacology, Psychiatry, University of Florida, Gainesville, FL, 5/99 to 10/99.

Vice Provost for Graduate Studies (6/99 to present), Professor, Psychology (7/87 to present), Director of Graduate Studies, Psychology (7/87 to 6/98), Chair, Psychology (8/89 to 5/90), Director, Behavioral Medicine Laboratory (5/89 to present), University of West Florida, Pensacola, FL.
Research Grants
Principal Investigator, "Assessment and Treatment of Childhood Headache," NINCDS, NS-16891, $220,852, 3 years, awarded 1/82.
Principal Investigator, Research Career Development Award, "Bio-Psychological Aspects of Headache in Children," NINCDS, NS-00818, $238,542, 5 years, awarded 9/83.
Principal Investigator, "Drug and Non-Drug Treatment for Adult & Pediatric Migraine," NINDS, NS-29855, $796,467, 4 years, awarded 9/92.
Co-Investigator, "Biobehavioral Approaches to the Treatment of Hypertension," NHLBI, NL-27622, $409,968, 3 years, awarded 8/81.
Co-Investigator, "Biofeedback for Pain: A Multipractitioner Outcome Study." Office of Alternative Medicine, RR-09365, $30,000, 1 year, awarded 2/94.
Co-Investigator, "Electro-Therapeutic Pain Blocking Splints & Bandages," NIDA, DA-11845, $750,000, 2 years, awarded 97.

Grant Reviewing
Ad Hoc Reviewer: Psychosocial and Biobehavioral Treatment Subcommittee (TDAA), NIMH, October, 1981; Psychopathology Subcommittee, NIMH, January, 1984; Epidemiology and Disease Control Study Section, NIH, May, 1984, May, 1985; Psychopharmacological, Biological, and Physical Treatments Subcommittee (TDAB), NIMH, June, 1985; Collaborative Research Grants Programme, NATO, April, 1986; Mental Health AIDS and Immunology Review Committee, NIMH, November, 1993; Neurology A Study Section, NIH, December, 1993.

Select Editorial and Professional Appointments and Honors
Editor, Applied Psychophysiology and Biofeedback (formerly Biofeedback and Self-Regulation), 1995-present.
Editor, Behavior Therapy, 1996-1998.
Associate Editor, Behavior Therapy, 1984-1986, 1995
Associate Editor, Biofeedback and Self-Regulation, 1991 to 1994.
Merit Award for Long-Term Research and/or Clinical Achievements, AAPB, 1992.
Distinguished Scientist Award, AAPB, 2002.

**Journal Articles, Chapters, and Texts (selected from 160 articles/chapters and 3 texts)**


BIOGRAPHICAL SKETCH
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<tr>
<th>NAME</th>
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<tbody>
<tr>
<td>Michael C. Prevost</td>
<td>Research Physiologist</td>
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<tr>
<td>University of Louisiana, Lafayette</td>
<td>B.A.</td>
<td>1989</td>
<td>General Studies</td>
</tr>
<tr>
<td>United States Sports Academy</td>
<td>M.A.</td>
<td>1991</td>
<td>Sports Science</td>
</tr>
<tr>
<td>Louisiana State University</td>
<td>Ph.D</td>
<td>1995</td>
<td>Exercise Physiology</td>
</tr>
<tr>
<td>Naval Operational Medicine Institute</td>
<td>-----</td>
<td>1996</td>
<td>Aerospace Physiologist</td>
</tr>
</tbody>
</table>

**RESEARCH AND PROFESSIONAL EXPERIENCE:**

**Positions**
Graduate Assistant/Research Assistant (1/92 to 11/95), Louisiana State University, Baton Rouge, LA.
Aerospace Physiologist (11/95 to 03/99), US Navy Operational Medicine Institute, Pensacola, FL.
Aeromedical Safety Officer (03/99 to 03/01), Marine Aircraft Group 39
Research Physiologist (03/01 to ), Naval Aerospace Medical Research Laboratory, Pensacola, FL.

**Certifications**
Night Imaging and Threat Evaluation Laboratory Instructor: Awarded by Air Force
Research Laboratory/Marine Air Weapons and Tactics Squadron One, May 1998.
Hyperbaric Medical Officer: Awarded by the Naval Diving and Salvage Training Center,
August 1996.
Aviation Safety Officer: Awarded by the Naval Postgraduate School, February 1999.
Master Training Specialist: Awarded by the Naval Operational Medicine Institute,
December 1998.
Contracting Officer Representative: Awarded by the Fleet Industrial Supply Center, San
Diego, CA, December 1996.

Publications
Cocaine Alters Myosin Isoform Expression In the Rat Soleus. (1995), Prevost MC,
Nelson AG, Kelly KP, Han DH, and Conlee RK, Journal of Applied Physiology, 79
(2): 514-517.
Creatine Supplementation Enhances Intermittent Work Performance. (1997), Prevost
MC, Nelson AG, Morris, GS, Research Quarterly for Exercise and Sport, 68 (3): 233-
240.
Myosin Isoenzyme Distribution in Striated Muscle of Cocaine-Conditioned Rats. (1995),
Morris GS, Prevost MC, Nelson AG, Kelly KP, Han DH, and Conlee RK, Research
Communications in Alcohol and substances of Abuse, 16(3): 133-143.
Moderate Diabetes Alters Myosin Isoenzyme Distribution in Cardiac But Not Skeletal
Muscle of Male Rats. (1996), Morris GS, Prevost MC, Nelson AG, Life Sciences, 58:
833-83.
Cohen BS, Nelson AG, Prevost MC, Thompson GD, Marx BD, Morris GD,
The Effect of Two Days of Velocity-Specific Isokinetic Training on Torque Production.

Presentations
The Effects of Caffeine Consumption Upon Performance While Running the Heat and
Humidity.
Cohen BS, Nelson AG, Prevost MC, Thompson GD, Southeast ACSM, Greensboro,
Effect of Continuous Caffeine Intake on Prolonged Exercise to Exahustion. Cohen BS,
Cocaine Affects Myosin Isoform Expression in the Rat Soleus (1993), Prevost MC,
Cocaine and Cardiac Isomyosin Distribution (1994), Nelson AG, Prevost MC, Morris
GS, Kelly KP,
Han DH, Conlee RK, Medicine and Science in Sports and Exercise 26:5, p. 69.
Three Days of Practice Improves Peak Torque at a Fast but Not at a Slow Velocity of
Contraction,


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<th>NAME</th>
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<tr>
<td>David J. Blower, Ph.D.</td>
<td>Senior Research Psychologist</td>
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<tbody>
<tr>
<td>Ohio State University</td>
<td>B.Sc.</td>
<td>1968</td>
<td>Psychology</td>
</tr>
<tr>
<td>Stanford University</td>
<td>Ph.D.</td>
<td>1979</td>
<td>Psychology</td>
</tr>
</tbody>
</table>

RESEARCH AND PROFESSIONAL EXPERIENCE:

Positions

- Research Scientist (1995 to 2002), Institute for Human and Machine Cognition, University of West Florida, Pensacola, FL. IPA assignment to Naval Aerospace Medical Research Laboratory.
- 1988-1994 Naval Aerospace Medical Research Laboratory, Pensacola, FL. Improved psychological tests for the selection of naval aviators and other operators of complex equipment. Promoted advanced techniques for data analysis and inference.
- 1977-1982 Naval Aerospace Medical Research Laboratory, Pensacola, FL. Investigated vision problems associated with head-up displays, assisted in the development of a battery of vision tests, wrote computer programs for the statistical
analysis of data, and used computer simulation to solve visual stimulus presentation problems.

1976-1977 College of Medicine, Ohio State University, Columbus, OH. Provided statistical consultation to faculty and students on medical research problems.
Teaching and Research assistant while a Ph. D. candidate (1971 to 1976). Stanford University, Palo Alto, CA.

PUBLICATIONS

Books

An Introduction to Scientific Inference: Vol. I The Bayesian Fundamentals, Third Millennium Inferencing, Pensacola, FL. 1998 (draft)

An Introduction to Scientific Inference: Vol. II The Maximum Entropy Principle, Third Millennium Inferencing, Pensacola, FL. 1999 (draft)

An Introduction to Scientific Inference: Vol. III Linear Regression, Third Millennium Inferencing, Pensacola, FL. 2000 (draft)

Technical Articles

A General Theory of Inference for Personnel Selection and Classification. Monograph for Office of Naval Research and Naval Health Research Center. Core funding project on optimal data analytic techniques to be used in the selection and training of Naval and Marine Corps aviators and other flight crew personnel. Draft version June 30, 2002.


An Update to the Landing Craft Air Cushion (LCAC) Selection System Prediction Algorithm, NAMRL Special Report 00-3, 2000.


Naval Aviation Selection Test Scores and Female Aviator Performance, Proceedings of the 69th AGARD Symposium, Tours, France, April 1990.


The Bias in the Presentation of Stimuli when the Up-and-Down method is used with Forced Choice Responding. NAMRL Technical Report 1269, July 1980.

Ph.D. DISSERTATION