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Award Number: MIPR2BCJYG2041

TITLE: The Warfighter's Stress Response: Telemetric and  
Noninvasive Assessment

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REPORT DATE: October 2002

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;  
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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE May 2002		3. REPORT TYPE AND DATES COVERED Final (15 Nov 01 - 30 Sep 02)
4. TITLE AND SUBTITLE The Warfighter's Stress Response: Telemetric and Noninvasive Assessment			5. FUNDING NUMBERS MIPR 2BCJYG2041	
6. AUTHOR(S) Amanda O'Donnell, Ed.D., Charles A. Morgan, M.D., Emil Jovanov, Ph.D., Frank Andrasik, Ph.D., Michael C. Prevost, Ph.D., David J. Blower, Ph.D.				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  Naval Aerospace Medical Research Laboratory Pensacola, Florida 32516  E-Mail: amanda@namri.navy.mil			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT  Approved for Public Release; Distribution Unlimited				12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 Words)  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.				
14. SUBJECT TERMS stress, heart rate variability, telemetric, cognitive performance, hormones				15. NUMBER OF PAGES 87
				16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT  Unlimited	

NSN 7540-01-280-5500

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

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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.

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## Body

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, exhibit 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 noninvasive 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

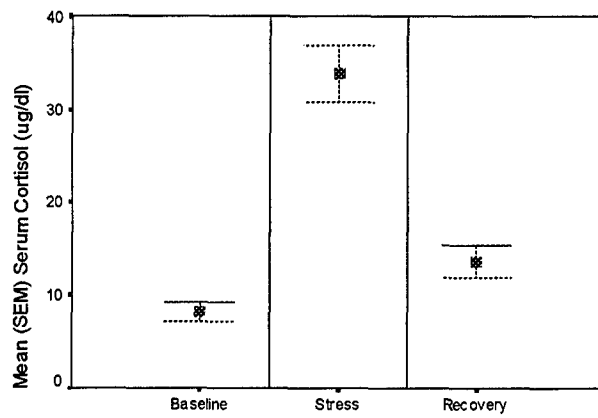


Figure 2

Plasma NE Before, During and After Stress

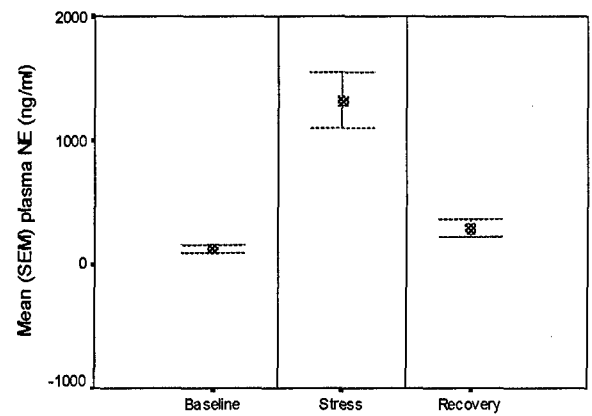
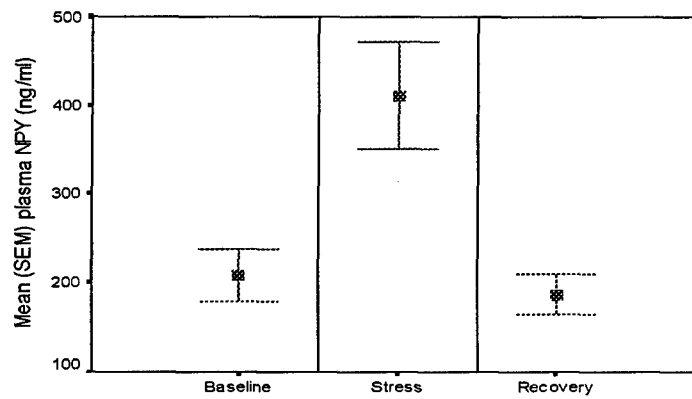


Figure 3

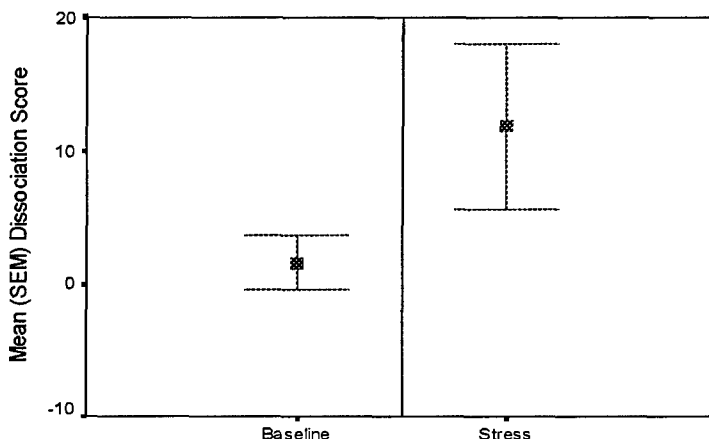
Plasma NPY Before, During and After Stress



As shown in **Figure 4** our studies indicate that acute stress exposure in healthy human subjects results in increased psychological symptoms of dissociation [4].

**Figure 4**

**Dissociation at Baseline and in Response to Stress**



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).

Figure 5

Cortisol at Baseline and Stress

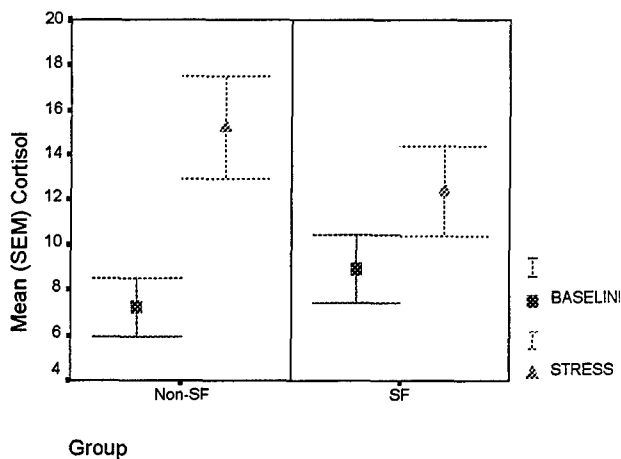
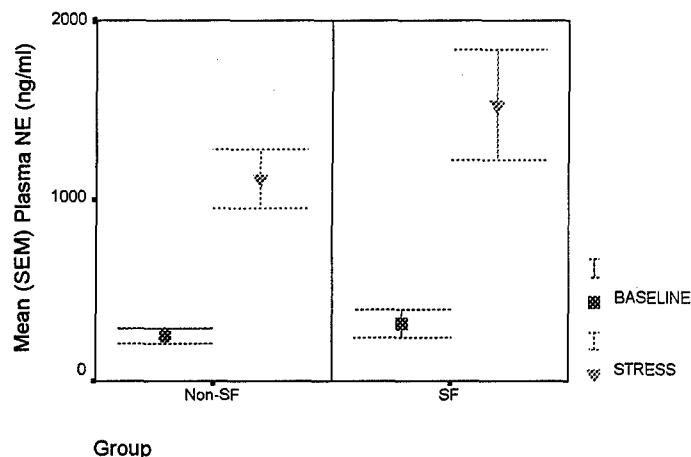


Figure 6

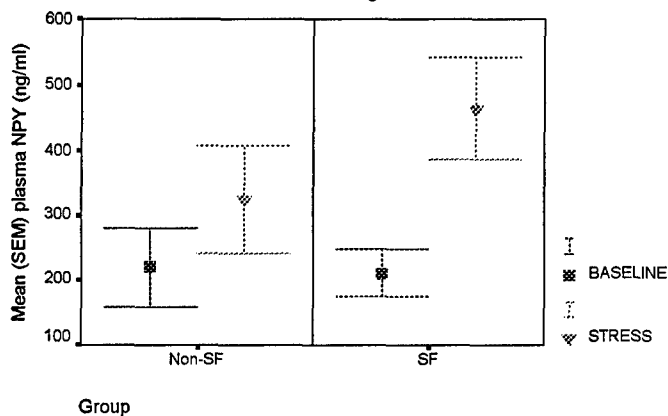
NE at Baseline and Stress



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

Figure 7

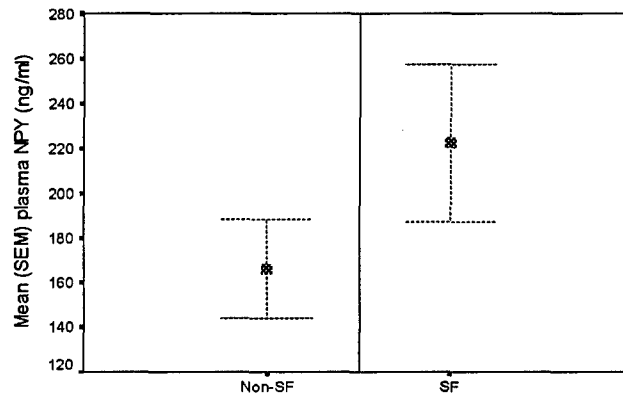
NPY at Baseline and During Stress



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).

Figure 8

Plasma NPY at Recovery

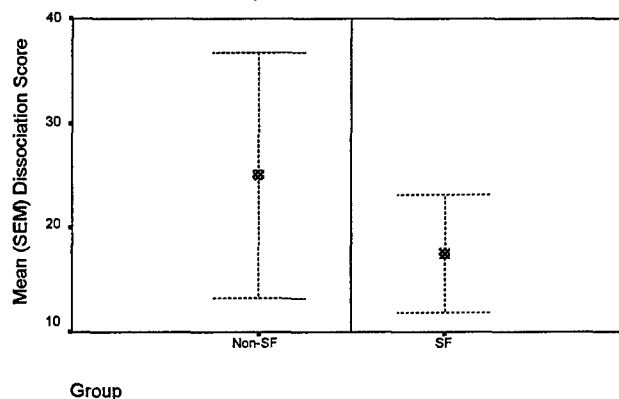


Pre-clinical and clinical studies suggest that capacity for central NPY release may provide an index of an organism's ability to manage high levels of stress. Lower NPY release during stress and low post-stress levels of NPY have been viewed as indicative of stress vulnerability, whereas increased production 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.

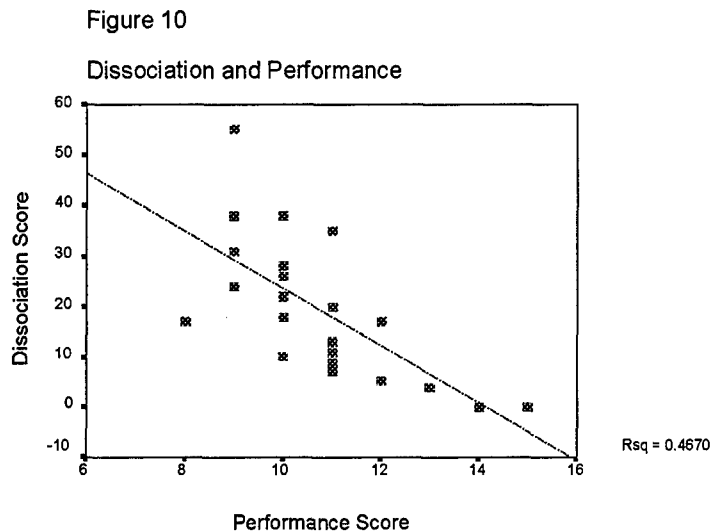
Although we measured NPY peripherally, we believe that the data are relevant to central NPY activity because a constellation of psychological and performance data characterized as "stress hardiness" was related to peripheral NPY. First, like NPY, psychological symptoms of dissociation were significantly different between SF and Non-SF soldiers (N= 49). Symptoms of dissociation were significantly lower (**Figure 9**) in SF subjects.

Figure 9

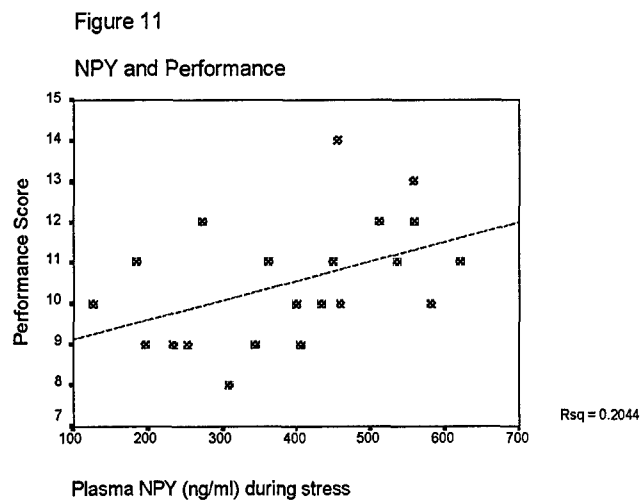
Dissociation in Response to Stress



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**) ( $r = -.68$ ;  $p < 0.001$ ).



Third, there was a significant, positive relationship between NPY during stress and performance during stress (**Figure 11**) ( $r = .45$ ;  $p < 0.04$ ).



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).

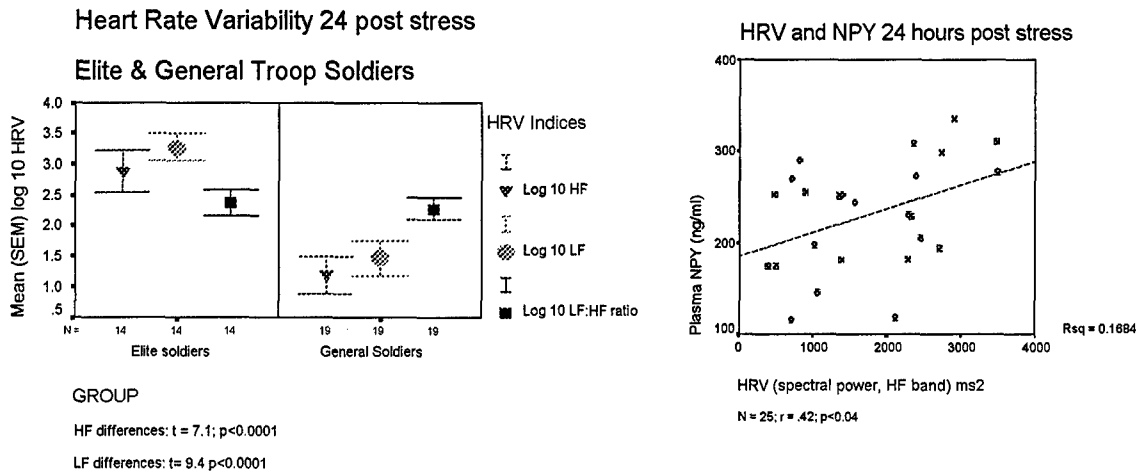
Coupled with the data from the Army survival school, these findings support the hypothesis that individuals who are identified as "special" (or stress hardy) differ in certain psychological and biological indices from those who are less stress hardy.

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  $\text{ms}^2$  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



#### 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.

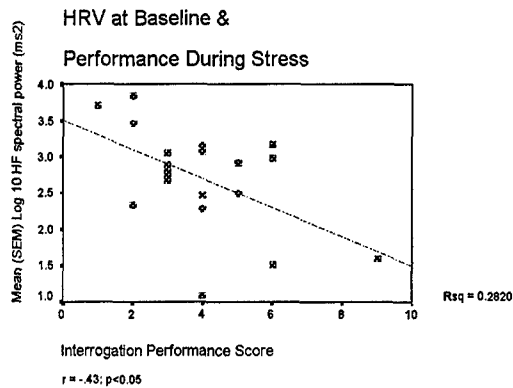
In a pilot investigation, we measured HRV in soldiers enrolled in survival school training while they were waiting to be deployed to the field for the experiential phase (the high stress phase) of the course. Thus, this was not a resting baseline, but rather a pre-stress assessment collected during a relative state of anticipatory anxiety. HRV was assessed in subjects between 1600 and 1630. Each subject was supine and wore the Polar Vantage NV<sup>TM</sup> 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.

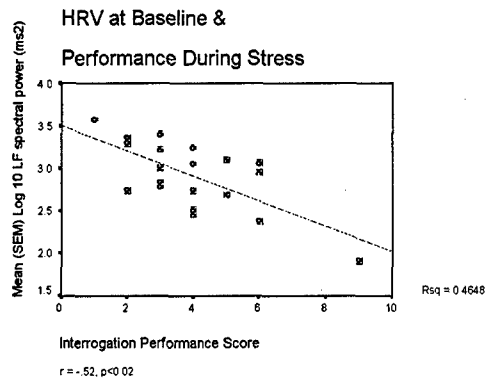
As noted in **Figures 14, 15, 16**; there were significant, negative relationships between HRV recorded prior to deployment and the objectively assessed cognitive and military performance of the subjects 5 days later while they were undergoing acute stress. Soldiers with low variability prior to stress 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.

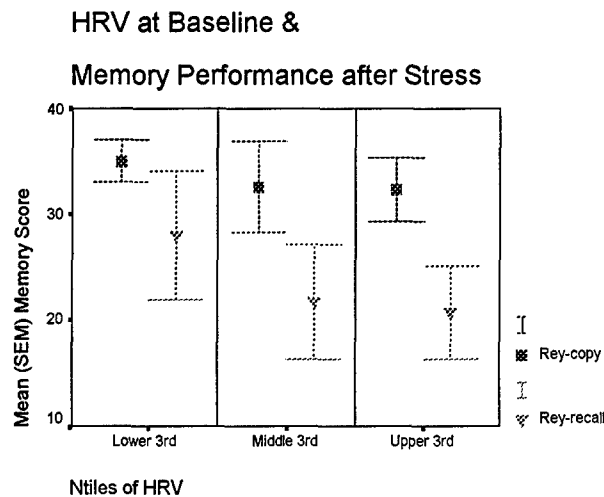
**Figure 14** HF HRV at Baseline and Stress



**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 ( $p < 0.05$ ).



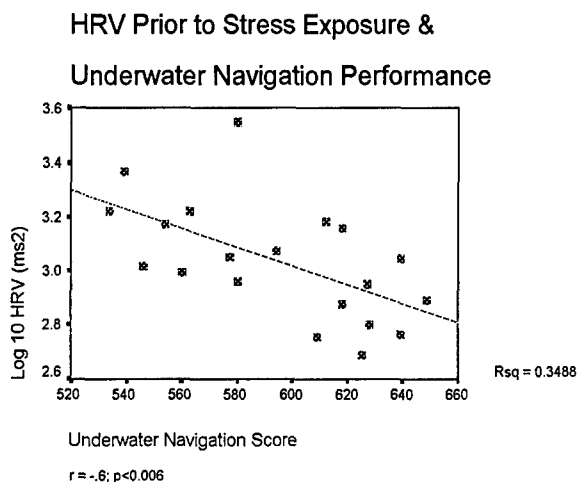
In a second pilot study of HRV and military performance, we evaluated HRV in soldiers participating in Combat Dive training. This training site was selected for two main reasons:

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 under water. 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 were also those who exhibited greater levels of NPY and significantly fewer symptoms of dissociation during the training.

FIGURE: 17



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 known 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<sup>TM</sup> 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<sup>TM</sup> 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 NV<sup>TM</sup> system; and the WISE System.

**Polar Vantage NV<sup>TM</sup>** : We have previously used the Polar Vantage NV<sup>TM</sup> 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 down loaded 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]

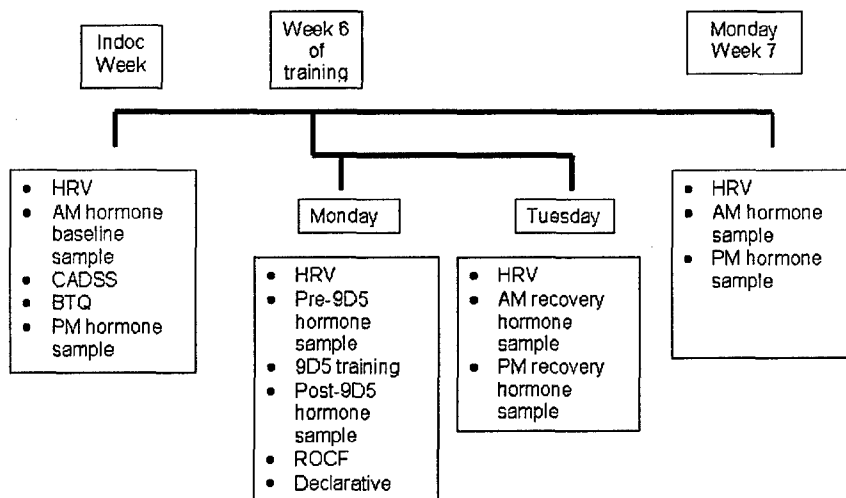
## Military Performance measures

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 at 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

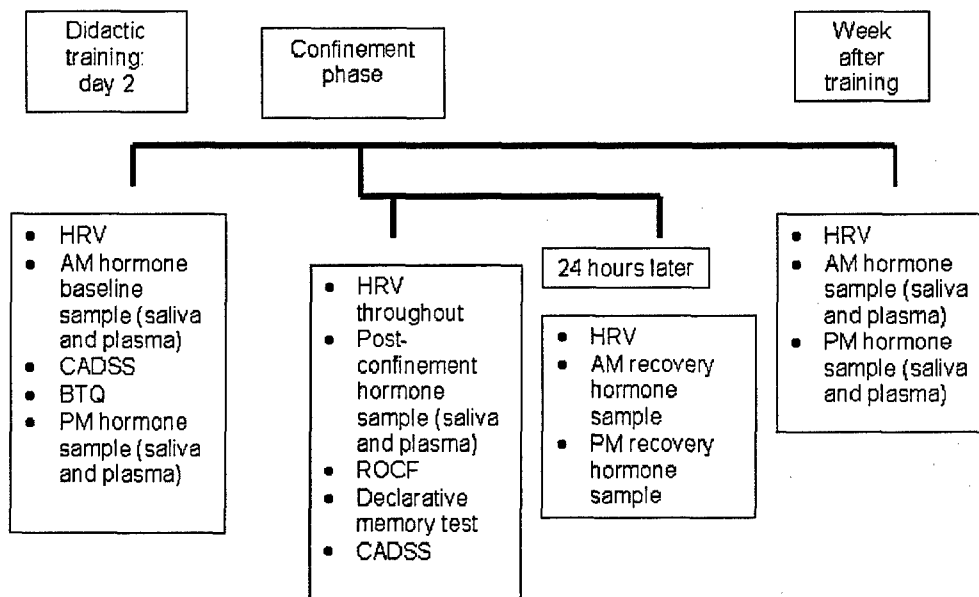
### Aviation Preflight Indoctrination

Figure 18: Aviation Preflight Indoctrination



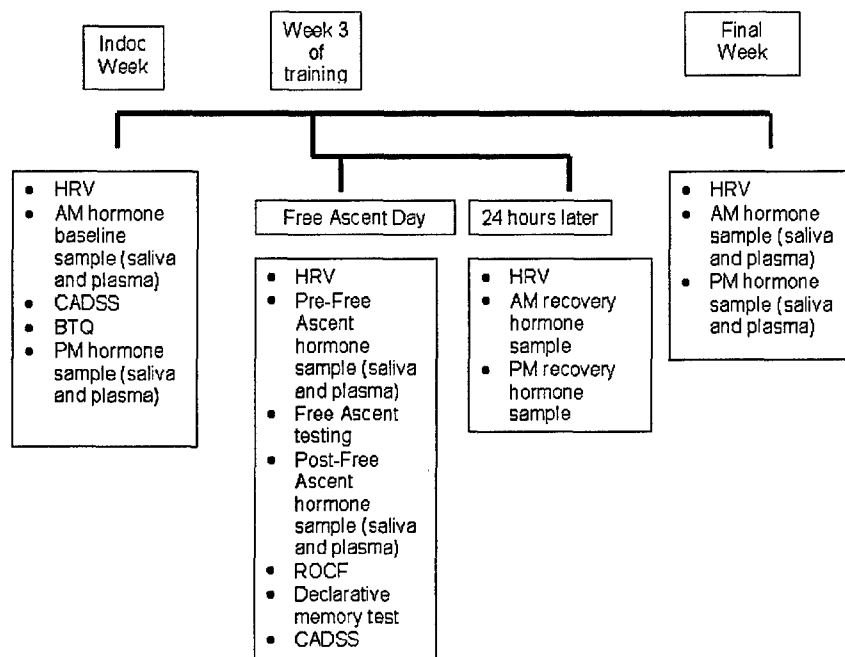
## SERE

Figure 19: SERE



## CDQC

Figure 20: DCQC



## 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 **W**ireless **I**ntelligent **S**ensor with HRV sensor **W**ISE  
**H**RV

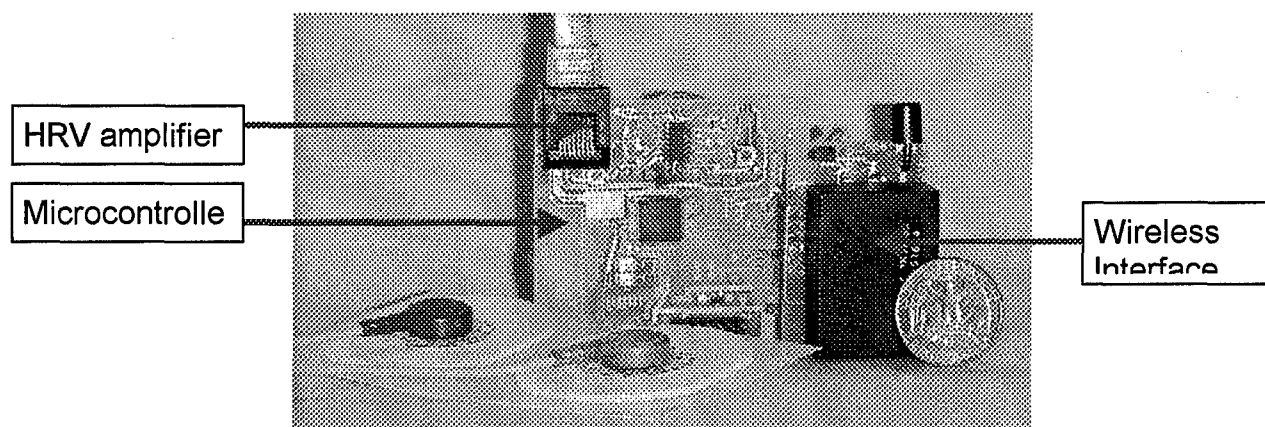


Figure 21. Initial **W**ireless **I**ntelligent **S**ensor with HRV sensor **W**ISE  
**H**RV

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  $\mu$ A 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)

Figure 22. Automatic Wireless HRV data collection in WISE HRV



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.

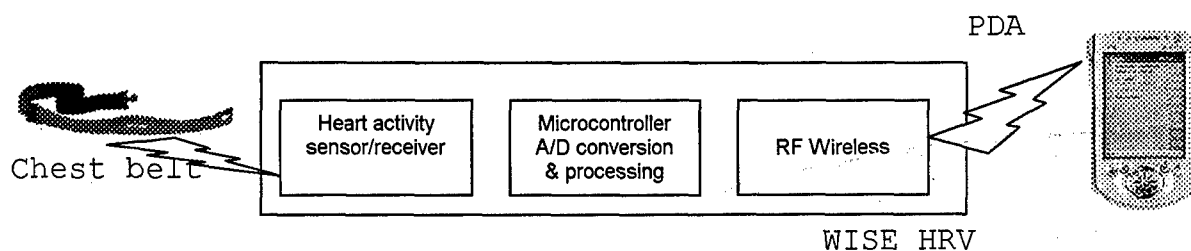


Figure 23. WISE HRV block diagram

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.

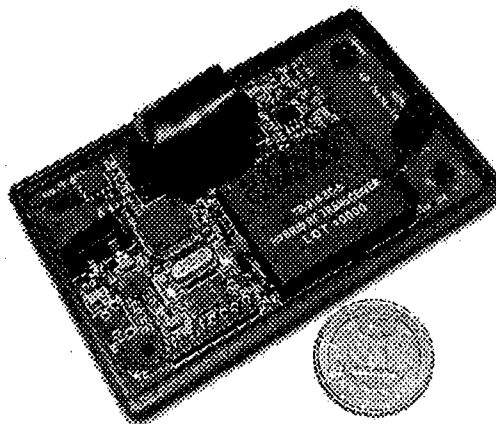


Figure 24. WISE HRV Sensor prototype

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 iPAQ 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

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.

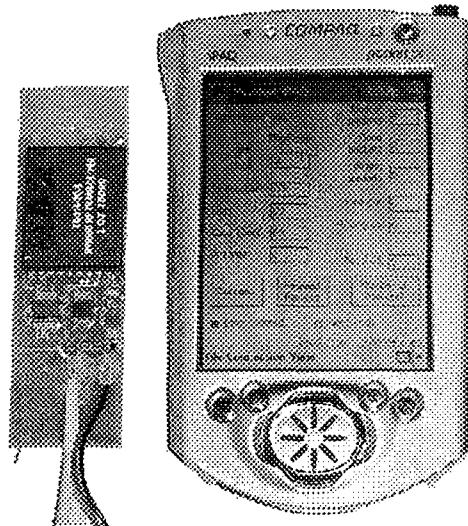


Figure 25. Mobile gateway interface

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.

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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.

A Distributed Non-invasive Wireless Heart Rate Variability Monitoring System. Abstract submitted to the International Society of Optical Engineering, 2003 Annual Meeting.

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 a 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 pre-frontal 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

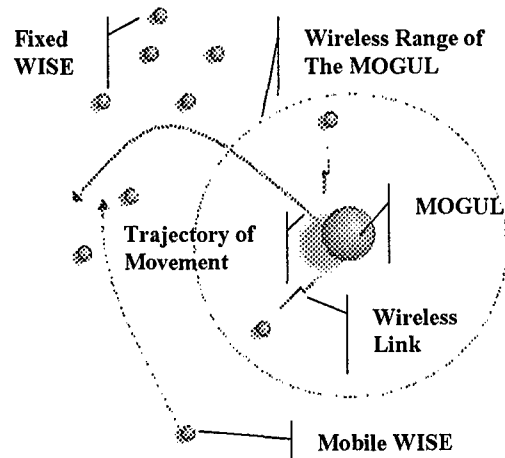


Figure 1. Block diagram of the telemedical monitoring system

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  $\mu$ A 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 it 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.

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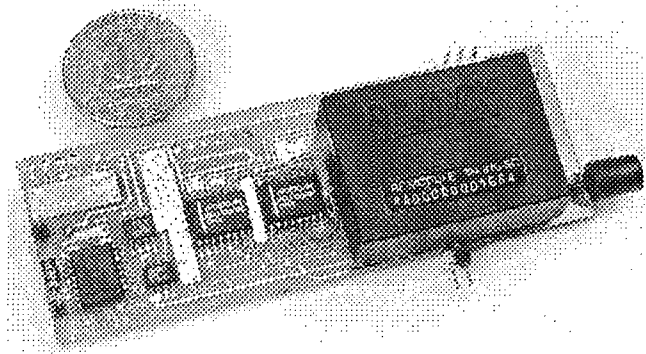


Figure 2. WISE\_ECG sensor.

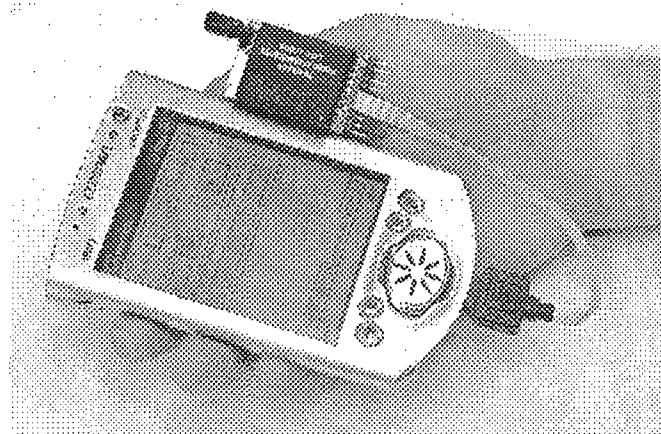


Figure 3. MOGUL device using iPAQ PDA.

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## **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 $\leftrightarrow$ iPAQ)
4. Collected data is moved from iPAQ to PC (see iPAQ $\leftrightarrow$ PC)
5. PC operator runs program for data merging and archiving (see iPAQ $\leftrightarrow$ 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

<L><TTT><WW><CC>.DAT

<L> - Letter

<TTT> - Three-digit number

<WW> - Two-digit number – Monitor Logical ID

<CC> - Two-digit number – Communication Session ID

} Training session ID

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



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 from 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

# BRIEF Trauma Questionnaire

ID #: \_\_\_\_\_

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.

Has this ever happened to you?	Answer these questions for each event that has happened to you.			
	Did you think your life was in danger or you might be seriously injured?		Were you seriously injured?	
1. Have you ever served in a war zone, or have you ever served in a noncombatant job that exposed you to war-related casualties (for example, as a medic or on graves registration duty?)	Yes	No	Yes	No
2. Have you ever been in a serious car accident, or a serious accident at work or somewhere else?	Yes	No	Yes	No
3. Have you ever been in a major natural or technological disaster, such as a fire, tornado, hurricane, flood, earthquake, or chemical spill?	Yes	No	Yes	No
4. Have you ever had a life-threatening illness such as cancer, heart attack, leukemia, AIDS, stroke, etc.?	Yes	No	Yes	No
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?	Yes	No	Yes	No

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?	Yes    No	Yes    No	Yes    No
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	Yes    No	Yes    No	Yes    No
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?	Yes    No		Yes    No
9. Has a close family member or friend died violently, for example, in a serious car crash, mugging, or attack?	Yes    No		
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?  Note. Do not answer Yes for this question for any event you have already reported in questions 1-9.	Yes    No		

# Clinician Assisted Dissociative States Scale

ID#: \_\_\_\_\_

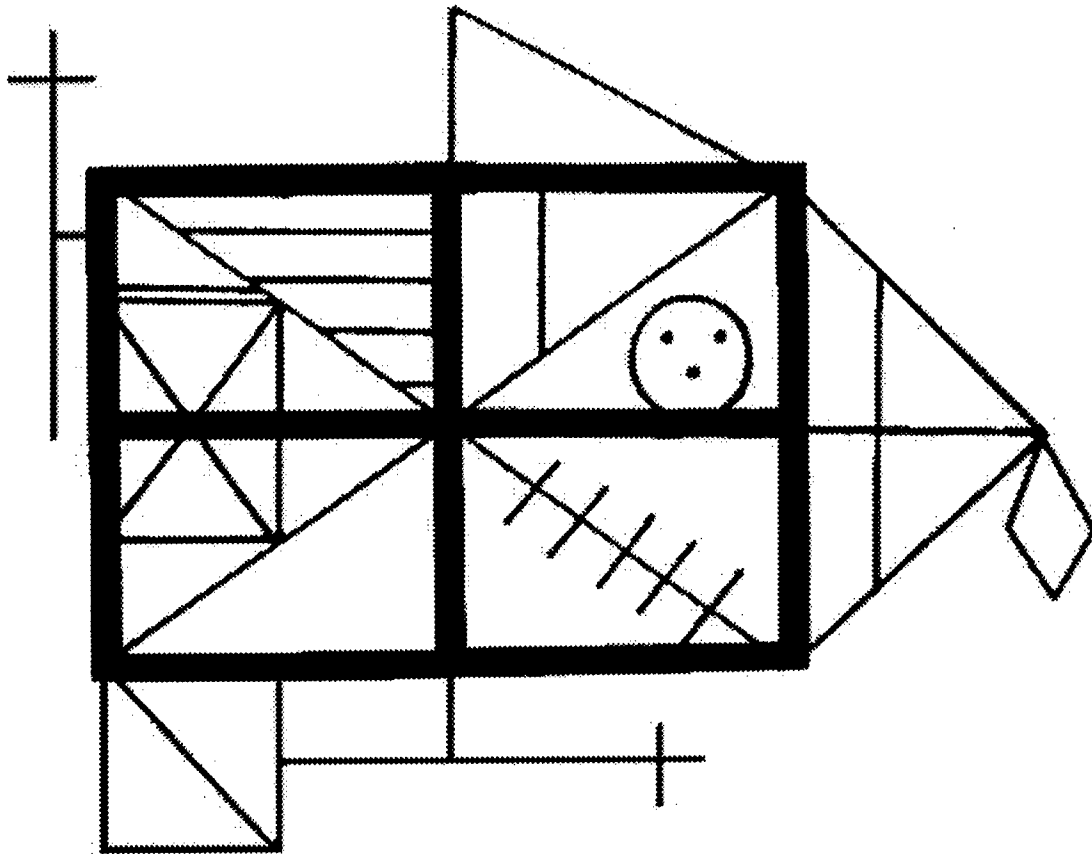
## EXPERIENCE SCALE

Please indicate if you have ever had the following experiences during an event or incident by placing in "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

Have you ever had the following experience?	If yes, mark "X"	Intensity of the experience
1. Did things seem to be moving in slow motion?		
2. Did things seem to be unreal to you, as if you were in a dream?		
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 automation?		
4. Did you feel as if you were looking at things from outside of your body?		
5. Did you feel as if you were watching the situation as an observer or a spectator?		
6. Did you feel disconnected from your own body?		
7. Did your sense of your own body feel changed; for instance, did your own body feel unusually large or unusually small?		
8. Did people seem motionless, dead or mechanical?		
9. Did objects look different than you would have expected?		
10. Did colors seem to be diminished in intensity?		
11. Did you see things as if you were in a tunnel, or looking through a wide-angle photographic lense?		
12. Did the experience seem to take much longer than you would have expected?		
13. Did the experience happen very quickly, as if there were a lifetime in a moment?		
14. Were there things that happened during the experience that you later couldn't account for?		
15. Did you space out, or in some other way lose track of what was going on during the experience?		
16. Did sounds almost disappear or become much stronger than you would have expected?		
17. Did things seem too very real, as if there were a special sense of clarity?		
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?		
19. Did colors seem much brighter than you would have expected?		

# 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.**

**List A**

Soldier  
Beaver  
Nurse  
Peas  
Rat  
Professor  
Brain  
Carrot  
Throat  
Wolf  
Tooth  
Rice  
Coach  
Lion  
Chest  
Onion  
Finger  
Mouse  
Grape  
Judge

**List B**

Principal  
Pig  
Lawyer  
Corn  
Fox  
Clerk  
Nose  
Mushroom  
Heels  
Seal  
Mouth  
Apple  
Cook  
Monkey  
Hand  
Spinach  
Eye  
Bear  
Plum  
Farmer

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

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### BIOGRAPHICAL SKETCH

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

NAME Amanda O'Donnell, M.A.	POSITION TITLE Research Psychologist, NAMRL
--------------------------------	--

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

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY
University of West Florida	B.A.	1995	Psychology
University of West Florida	M.A.	1997	Psychology
University of West Florida	Ed.D.(ABD)	2002	Curriculum & Instruction

#### 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)

**Albert, A.O., Andrasik, F., Grace, M.K., & Miller, C. (1999)** *The Effects of Feedback Modality on Thermal Biofeedback: Preliminary Investigation*. The South Eastern Psychology Association, Annual Meeting, Savannah, GA.

**Albert, A.O., Andrasik, A., Dunn, B.R., & Moore, J. (1998).** *Theta/Beta Training for Attention, Concentration and Memory Improvement in the Geriatric Population*. Student Award: The Association for Applied Psychophysiology and Biofeedback, Annual Meeting, Orlando, FL.

- Andrasik, F., Otis, J., **Albert**, A.O., Napier, D., Grace, M.K., Miller, C. (1998). *The effects of Three Different Resolution Settings on Peripheral Temperature Training*. The Association for Applied Psychophysiology and Biofeedback, Annual Meeting, Orlando, FL.
- Andrasik, F., & **O'Donnell** A.S. (1997). *The Effects of AV Stimulation on Self Reports of Relaxation, Anxiety, and Three Physiological Measures: The Results of an Investigation Conducted at the Behavioral Medicine Laboratory*. Technical report submitted to the Synetics Corporation.
- Blower, D, O'Donnell, A., & Casey, C. (2002). Predicting Probability of Success for Naval Aviation Candidates. Annual meeting of the Aerospace Medical Association, Montreal, Canada.
- 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)
- Casey, C., O'Donnell, A., & Blower, D. (2002) Automated spatial abilities test. Annual meeting of the Aerospace Medical Association, Montreal, Canada.
- Casey, C., O'Donnell, A., Blower, D. (2002). The Automated Pilot Examination System. Annual meeting of the Aerospace Medical Association, Montreal, Canada.
- Cahoon, M., **Albert**, A.O., & Dunn, B.R. (1999). *Predicting Retrieval from the Brain's Electrical Activity Generated at Encoding*. The South Eastern Psychology Association, Annual Meeting, Savannah, GA.
- Dunn, B.R., & **O'Donnell**, A.S. (1997). *The Relationship Between Two ERP Components and Memory*. Poster Presentation: The Florida Conference on Cognition, Annual Meeting, Pensacola, FL.
- O'Donnell**, A. S. (1997). *The Relationship Between the P200 Component of the Event Related Potential and Retrieval* Thesis submitted to the Department of Psychology, College of Arts and Social Sciences, The University of West Florida.
- O'Donnell**, A.S., & Dunn, B.R. (1997). *The Relationship of the P200 Generated at Encoding and Subsequent Retrieval* Society for Psychophysiological Research, Annual Meeting, Cape Cod, MA.
- Williams, H.P., **Albert**, A.O., and Blower, D.J. (1999). Selection of officers for U.S. naval aviation training. *Proceedings of the 41<sup>st</sup> Annual Conference of the International Military Testing Association*.

### BIOGRAPHICAL SKETCH

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

NAME	POSITION TITLE
Charles A. Morgan III, M.D., M.A. (GS-15)	Associate Professor of Psychiatry & Research Affiliate, History of Medicine, Yale University

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

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

#### 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: Assessment of Baseline and Fear Potentiated Acoustic Startle in PTSD, July, 1, 1992. V.A. R.A.G. (completed)

Co-Principal Investigator: Startle Modulation in Combat Veterans with PTSD, 1993-1998, NIMH. (completed).

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**

Expert Witness, International Tribunal for War Crimes committed in the former Yugoslavia, United Nations Court, The Hague, Netherlands. Case: The Prosecutor vs. Anto Furundzija. 1998

### **SELECTED PEER REVIEWED PUBLICATIONS**

**Morgan CA**, Grillon C, Southwick SM, Krystal JH, Davis M, Charney D. Yohimbine facilitated acoustic startle in combat veterans with post-traumatic stress disorder. *Psychopharmacol*, 110:342-346, (1993).

**Morgan CA**, Grillon C, Southwick S, Nagy LM, Davis M, Krystal, J.H., & Charney D. Yohimbine facilitated acoustic startle in combat veterans with post-traumatic stress disorder. *Psychopharmacol*, 1995, 117:466-471

**Morgan C.A.**, Grillon C., Southwick S.M., Davis M., & Charney D.S. Fear-potentiated startle in posttraumatic stress disorder. *Biol Psychiatry*. 1995, 38:378-385.

**Morgan C.A.**, Grillon C., Southwick S.M., Davis M., & Charney D.S. Fear-potentiated startle in posttraumatic stress disorder. *Biol Psychiatry*. 1995, 38:378-385.

Southwick SM, **Morgan CA**, Nicholau A, Darnell A, Charney DS: Trauma Related Symptomatology in Desert Storm Veterans: Two year follow-up, *Am J of Psychiatry*, 152;8, 1150-1155,(1995).

**Morgan CA**, Grillon C, Southwick S, Davis M, Krystal, J.H., & Charney D. Exaggerated acoustic startle in Gulf war veterans with PTSD. *Am J Psychiatry*, 1996, 153:64-68.

Grillon C., **Morgan CA**, Southwick S, Davis M, & Charney D. Baseline startle amplitude and PPI in Vietnam veterans with posttraumatic stress disorder. *Psychiatry Res.*, 64, 169-178:1996.

- 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 (mCPP). *Psychopharmacol*, 131, 207-215: 1997.
- Southwick SM, **Morgan III CA**, Nicolaou AL, Charney DS: Consistency of Memory for Combat-Related Traumatic Events in Veterans of Operation Desert Storm. *Am J Psychiatry* (1997) 154:173-177.
- Morgan CA**, Grillon C, Southwick SM: Startle Abnormalities in Women with Sexual Assault related PTSD. *Am J Psychiatry* (1997) 154:1076-1080.
- 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 disorder. *Biol Psychiatry*, Nov 15 1998, 44(10) p1027-36.
- 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 Stress* Vol. 11, No. 1, 1998.
- Grillon C, **Morgan CA**, Davis M, & Southwick SM. Effects of darkness on acoustic startle in Vietnam veterans with PTSD, *Am J Psychiatry*, 155, 812-817, 1998.
- Grillon C & **Morgan CA**: Fear Contextual Startle Conditioning to Explicit and Contextual Cues in Gulf War Veterans with Posttraumatic Stress Disorder. *J Abn Psychology*, (1999) 108: 134-142.
- Morgan CA, III** & Grillon C. Abnormal mismatch negativity in women with sexual assault related PTSD. *Biol Psychiatry*, (1999) 45: 827-832.
- Morgan CA**, Hill SR, Fox P, Kingham P, Southwick SM: Anniversary Reactions in Gulf War Veterans: A 6-Year Follow-up Report. *Am J Psychiatry*, (July, 1999), 156(7) p1075-9.
- Morgan III CA**, Wang S, Mason J, Hazlett G, Fox P, Southwick SM, Charney DS, Greenfield G: Hormone Profiles in Humans Experiencing Military Survival Training. *Biol Psychiatry*, 2000; 47: 891-901.
- Morgan III CA**, Wang S, Southwick SM, Rasmussen A, Hauger R, Charney DS: Plasma Neuropeptide-Y in Humans Exposed to Military Survival Training. *Biol Psychiatry* 2000; 47: 902-909.
- Rasmussen A, **Morgan CA**, Hauger S, Bremner DJ, Southwick SM: Plasma NPY in response to Yohimbine Challenge in combat veterans with, and without Post-traumatic Stress Disorder. *Biol Psychiatry*. In press.
- Morgan III CA**, Wang S, Hazlett G, Rasmussen A, Anderson G, Charney DS: Relationships among Cortisol, Catecholamines, Neuropeptide Y and Human Performance During Uncontrollable Stress. *Psychosomatic Med*. 63: 412-42; 2001
- Morgan III CA**, Hazlett G, Wang S, Richardson G, Schnurr P, Southwick SM: Symptoms of Dissociation in Humans Experiencing Acute Uncontrollable Stress: A Prospective Investigation. *Am J psychiatry*, 158:8; 1239-1247. 2001.
- Morgan III CA**, Rasmussen A, Wang S, Hauger R, Hazlett G: Neuropeptide-Y, Cortisol and Subjective Distress in Humans Exposed to Acute Stress: Replication and Extension of a Previous Report. *Biol Psychiatry*. In press.
- Non Peer Reviewed Publications
- Southwick, SM, Vojvoda D, **Morgan CA**, Lipschitz D: Persian Gulf War, Stress Effects of Encyclopedia of Stress, volume 3, pp 142-148, in press.

Southwick, SM, Paige S, **Morgan CA**, Bremner JD, Krystal JH, Charney DS: Neurotransmitter Alterations in PTSD: Catecholamines and Serotonin. *Seminars in Clinical Neuropsychiatry*; (1999) Vol. 4, (October), pp 242-248.

**Morgan CA**, and Grillon C: Acoustic Startle in Individuals with PTSD. *Psych Annals*, (1998) Vol. 28 (8); 430-434.

#### Chapters

Southwick SM, Yehuda R, **Morgan CA**: Clinical Studies of Neurotransmitter Alterations in Post Traumatic Stress Disorder. In: Neurobiological and Clinical Consequences of Stress: From normal adaptation to PTSD, Eds: Friedman MJ, Charney DS, and Deutch AY, Lippencott-Raven Publishers, Philadelphia, (1995) Chapter 18, pp 335-349.

Southwick SM, **Morgan CA**: West Haven VA Medical Center Operation Desert Storm findings. In: Returning Persian Gulf Troops, First Year Findings. Publisher DAV, March 31, 1992.

**Morgan CA** & Southwick SM: Biological alterations in Posttraumatic Stress Disorder: Implications for Research and the U.S. Military. In: Pennington Center Nutrition Series: Countermeasures for Battlefield Stressors. Eds. Friedl, Lieberman, Ryan & Bray. Publisher, Pennington Center, 2000. pp9-25.

#### Submitted/In Review

**Morgan CA**, Hazlett GA, Southwick SM, Zimolo Z, Hoyt G, Charney DS: : Plasma DHEA(S), Cortisol, and Symptoms of Dissociation in Humans Exposed to Acute Uncontrollable Stress.

**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**: From "Let There Be Light" to "Shades of Grey": The Appropriation of Combat Fatigue 1944-1945. *Bull. Of History of Medicine*. In revision.

**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.

**Morgan CA**, Wang S, Muncey K, Simpson P, Mason J: Heart Rate, Cortisol and Dissociation in Humans Participating in a Forced Swim Test: Toward a Biology of Selection.

#### 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 Neuropsychocrinology

Book Reviewer, Journal of History of Medicine and the Allied Sciences

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.

NAME	POSITION TITLE
Emil Jovanov, Ph.D.	Associate Professor, UAH

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

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY
School of Electrical Engineering, University of Belgrade	Dip.Ing.	1984	EE/Computer Engineering
School of Electrical Engineering, University of Belgrade	M.Sc.	1989	EE/Computer Engineering
School of Electrical Engineering, University of Belgrade	Ph.D.	1993	EE/Computer Engineering

#### 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

The US Army Medical Research and Material Command (USAMRMC) (2002), \$430,073. Principal Investigator: Amanda O'Donnell. *The War Fighters Stress Response: Telemetric and Noninvasive Assessment*.

University of Alabama, Huntsville, AL (2001). Principal Investigator: Emil Jovanov. *Distributed Processing in a Wireless Network of Intelligent Sensors*

University of Alabama, Huntsville, AL (2000). Principal Investigator: Emil Jovanov. *Development of Microcontroller-based Testbed Environment for Microcomputer Laboratory* (CPE429, EE 429/509)

Texas Instruments (1999) Principal Investigator: Emil Jovanov. *Real Time Monitoring of Heart Electrical Activity Using Low Power DSP*.

Ministry of Science and Technology of Serbia (MNT) (1996). Principal Investigator: Emil Jovanov. *Automatic quality control prototype*.

Republic Ministry of Science and Technology of Serbia (MNT) (1995). Principal Investigator: Emil Jovanov. *A Prototype Glass Viscosity Measurement System*.

#### Journals:

E. Jovanov, V. Milutinovic, A. Hurson, "Acceleration of Non-numeric Operations Using Hardware Support for the Ordered Table Hashing Algorithms," IEEE Transactions on Computers, Vol. 51, No. 11, 2002.

D.Rakovic, Z.Jovanovic-Ignjatic, D.Radenovic, M.Tomasevic, E.Jovanov, V.Radivojevic, Z.Martinovic, P.Sukovic, M.Car, and L.Skaric, "An overview of microwave resonance therapy and EEG correlates of microwave resonance relaxation and other consciousness altering techniques", Electro and Magnetobiology, Vol. 19 (2000), pp. 195-222.

A. Samardzic, E. Jovanov, D. Starcevic, "Real-time visualization of brain electrical activity", Real Time Imaging, Vol. 6, No. 1, February 2000, pp. 69-76.

D.Rakovic, M.Tomasevic, E.Jovanov, V.Radivojevic, P.Sukovic, Z.Martinovic, M.Car, D.Radenovic, Z.Jovanovic-Ignjatic, and L.Skaric, "Electroencephalographic (EEG) correlates of some activities which may alter consciousness: The transcendental meditation technique, musicogenic states, microwave resonance relaxation, healer/heelee interaction, and alertness/drowsiness", Informatica, Vol. 23 (1999), pp. 399-412.

E. Jovanov, K. Wagner, V. Radivojevic, D. Starcevic, M. Quinn, D. Karron, "Tactical Audio and Acoustic Rendering in Biomedical Applications", IEEE Transactions on Information Technology in Biomedicine, Vol. 3, No. 2, June 1999, pp. 109-118.

E. Jovanov, D. Starcevic, A. Samardzic, A. Marsh, Z. Obrenovic, "EEG analysis in a telemedical virtual world", Future Generation Computer Systems 15, pp. 255-263, 1999.

E. Jovanov, D. Starcevic, A. Marsh, Z. Obrenovic, V. Radivojevic, A. Samardzic, "Multi Modal Presentation in Virtual Telemedical Environments", High-Performance Computing and Networking, Proceedings Lecture Notes In Computer Science 1593, pp. 964-972, 1999.

G.C. Ray, A.Y. Kaplan, E. Jovanov, "Homeostatic Change in the Genesis of ECG During Yogic Breathing", Journal of the Institution of Engineers (India), Vol. 79, pp. 28-33, March 1999.

E. Jovanov, D. Starcevic, V. Radivojevic, A. Samardzic, V. Simeunovic, "Perceptualization of biomedical data", IEEE Engineering in Medicine and Biology Magazine, Vol 18, No. 1, pp. 50-55, 1999.

E. Jovanov, V. Vracar, A. Lazic, R. Dupalo, "A Prototype Glass Viscosity Measurement System", Glass Machinery Plants & Accessories, Issue 3, pp. 123-127, 1998.

D. Simic, D. Starcevic, E. Jovanov, "Guaranteed Single Disk Access for Very Large Database Files," Yugoslav Journal of Operations Research, Vol. 7, No. 1, pp. 65-78, 1997.

D. Starcevic, E. Jovanov, "Large File Operations Support Using Order Preserving Perfect Hashing Functions," Yugoslav Journal of Operations Research, Vol. 3, No. 2, pp. 1-18, 1993.

E. Jovanov, T. Aleksic, Z. Stojkov, D. Starcevic, "A Sorting Processor for Microcomputers", Microprocessing and Microprogramming, Vol. 23, No 1-5, pp. 273-278, 1988.

#### Submitted

Emil Jovanov, Dejan Raskovic, John Price, "*Patient Monitoring Using Personal Area Network of Wireless Intelligent Sensors*," submitted to IEEE Transactions on Information Technology in Biomedicine, 2001.

C.D. Bagwell, J.S. Jackson, E. Jovanov, "*A Survey of Power Aware Resource Management Support in Existing Operating Systems and Micro Kernels*," The 8<sup>th</sup> IEEE Real-Time and Embedded Technology and Applications Symposium, San Jose, California, September 2002.

J.S. Jackson, C.D. Bagwell, E. Jovanov, "*A Survey of System Level Dynamic Power Management Policies for Very Low-Power Mobile Computers*," The 8<sup>th</sup> The Eighth Annual International Conference on Mobile Computing and Networking MobiCom 2002, Atlanta, Georgia, September 2002.

P.S. Kerr, M. Oni, E. Jovanov, "*Approximating the Head-Related Transfer Function to Meet Portable Computing Requirements*," IASTED International Conference on Signal and Image Processing SIP 2002, Kauai, Hawaii, August 2002.

#### Books, Chapters in Books

E. Jovanov, D. Starcevic, V. Radivojevic, "*Perceptualization of Biomedical Data*", chapter in Akay, M., Marsh, A., Eds, "*Information Technologies in Medicine, Volume I: Medical Simulation and Education*", John Wiley and Sons, 2001.

D. Starcevic, E. Jovanov, V. Radivojevic, Z. Obrenovic, A. Samardzic, "Virtual medical devices for telemedical applications", in P. Spasic, I. Milosavljevic, M. Jancic-Zguricas, Eds., "*Telemedicine*", Academy of Medical Sciences of Serbian Medical Association, Belgrade, Yugoslavi, pp. 218-244, 2000.

E. Jovanov, "On methodology of EEG analysis during altered states of consciousness", in D. Rakovic, D. Koruga, Eds., "*Consciousness: Challenge of the 21st century science and technology*", ECPD, Belgrade, Yugoslavia, 1995., also on

<http://www.vxm.com/21R.94.html>

E. Jovanov, D. Starcevic, A. Marsh, Z. Obrenovic, V. Radivojevic, A. Samardzic, "*Multi modal presentation in virtual telemedical environments*", High-Performance Computing and Networking, Proceedings Lecture Notes In Computer Science, 1593: 964-972 1999.

Ph.D. Dissertation: E. Jovanov, "*The Architecture of Accelerator for Database Operations*", School of Electrical Engineering, University of Belgrade, Belgrade, Yugoslavia, 1993.

Yugoslav magazines:

- A. Samardzic, E. Jovanov, D. Starcevic, "A System for Visualization of Brain Electrical Activity", *Info Science*, 4/97, str. 32-36, 1997.
- E. Jovanov, "Medical Multimedia Systems", *Info Science*, 1/97, pp. 27-32, 1997.
- A. Samardzic, E. Jovanov, D. Starcevic, "An Example of Topographic Mapping of EEG Activity", *Info*, 5/96, pp. 22-25, 1996.
- A. Samardzic, D. Starcevic, E. Jovanov, V. Majstorovic, M. Rakic, B. Buric, "Realistic head-model development", *Info*, 3/96, pp. 19-24, 1996.
- A. Samardzic, D. Starcevic, E. Jovanov, "Digital Video Compression", *Info*, 1/96, pp. 29-34, 1996.
- Conference Proceedings:
- E. Jovanov, A. O'Donnel, A. Morgan, B. Priddy, R. Hormigo, "Prolonged Telemetric Monitoring Of Heart Rate Variability Using Wireless Intelligent Sensors And A Mobile Gateway," 2nd Joint EMBS-BMES, Houston, Texas, October 2002.
- D. Starcevic, Z. Obrenovic, E. Jovanov, V. Radivojevic, "Implementation of Virtual Medical Devices in Internet and Wireless Cellular Networks," 1<sup>st</sup> IFIP Workshop on Internet Technologies, Applications and Societal Impact, Wroclaw, Poland, October 2002.
- L. Collier, E. Jovanov, "A Prototype Emotion-Sensing Human-Computer Interface Device for PDA's," 11<sup>th</sup> World Congress of Psychophysiology, Montreal, Canada, July 2002.
- K.G. LeSueur, E. Jovanov, A. Milenkovic, "Lookup Table Based Real-Time Non-Uniformity Correction Of Infrared Scene Projectors," June 2002.
- D. Starcevic, Z. Obrenovic, E. Jovanov, V. Radivojevic, "Virtual Medical Devices in Internet and Wireless Cellular Networks," 6<sup>th</sup> Balkan Conference on Operational Research, Thesaloniki, Greece, May 2002.
- A.G. Volkov, E. Jovanov, "Electrical Signaling in Green Plants: Action Potentials," 16th Biennial International EURASIP Conference Biosignal, Brno, Czech Republic, June 2002.
- A.G. Volkov, J. Mwesigwa, E. Jovanov, A. Labady, D.J. Thomas, K. Lewis, T. Shvetsova, "Acid Rain Induces Action Potentials in Green Plants," The 4th International Workshop On Biosignal Interpretation, Como, Italy, June 2002.
- B. Priddy, E. Jovanov, "Wireless Distributed Data Acquisition System," The 34th Southeastern Symposium on System Theory (SSST2002), Huntsville, Alabama, pp. 463-466, 2002.
- M. Milenkovic, E. Jovanov, J. Chapman, D. Raskovic, J. Price, "An Accelerometer-Based Physical Rehabilitation System," The 34th Southeastern Symposium on System Theory (SSST2002), Huntsville, Alabama, pp. 57-60, 2002.
- C.D. Bagwell, E. Jovanov, J.H. Kulick, "A Dynamic Power Profiling of Embedded Computer Systems," The 34th Southeastern Symposium on System Theory (SSST2002), Huntsville, Alabama, pp. 15-19, 2002.
- D. Corley, E. Jovanov, "A low power intelligent video-processing sensor," The 34th Southeastern Symposium on System Theory (SSST2002), Huntsville, Alabama, pp. 176-178, 2002.
- E. Jovanov, "Distributed Signal Processing in a Wireless Network of Intelligent Sensors," 2001 Young Faculty Research Proceedings, The University of Alabama in Huntsville, pp. 59-65, 2001.
- J. Kim, E. Jovanov, "Biomedical Applications of Ultra Wide Band Personal Area Networks," ISPACS'2001 the 9th International Symposium on Intelligent Signal Processing and Communications Systems, Nashville, Tennessee, November 2001.
- D. Raskovic, E. Jovanov, K. Kavi, "Hierarchical Digital Signal Processing," ISPACS'2001 the 9th International Symposium on Intelligent Signal Processing and Communications Systems, Nashville, Tennessee, November 2001.
- E. Jovanov, D. Raskovic, J. Price, A. Moore, J. Chapman, A. Krishnamurthy, "Patient Monitoring Using Personal Area Networks of Wireless Intelligent Sensors," *Biomedical Sciences Instrumentation Vol. 37, Proc. 38th Annual Rocky Mountain Bioengineering Symposium*, April 2001, Copper Mountain, pp. 373-378, 2001.

### BIOGRAPHICAL SKETCH

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

NAME	POSITION TITLE
Frank Andrasik, Ph.D.	Senior Research Scientist/Professor, Psychology

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

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY
Wright State University, Dayton, OH	B.A.	1971	Psychology
Ohio University, Athens, OH	M.S.	1973	Experimental Psychology
University of Pittsburgh School of Medicine, PA	-----	1978-1979	Clinical Psychology Intern
Ohio University, Athens, OH	Ph.D.	1979	Clinical Psychology

#### 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

Vice Provost for Graduate Studies (6/98 to 9/99), 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, "Psychological Treatment of Headache," NINCDS, NS-15235, \$245,399, 3 years,

awarded 6/79, renewed 3 years, 6/82, \$275,585.

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**

Member: Risk, Prevention and Health Behavior-3 Study Section, NIH, 1999; Behavioral Medicine Study

Section, NIH, 1997-1999; Life & Biomedical Sciences Review Panel, NASA/AIBS, July, 1994, July,

1995; Special Emphasis Panels, NIH, July, 1993, June, 1994, October, 1994, December, 1995,

November, 1997, August, 1998.

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.

President, Association for Applied Psychophysiology and Biofeedback (AAPB), 1993-1994.

Merit Award for Long-Term Research and/or Clinical Achievements, AAPB, 1992.

Distinguished Scientist Award, AAPB, 2002.

Citation Paper Awards, AAPB, 1984, 1994, 1996, 2000.

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

Schwartz, M.J., & Andrasik, F. (in press). Biofeedback: A practitioner's guide (3rd ed.) NY: Guilford.

McLeod, M.S., Andrasik, F., Packard, R.C., & Miller, B.D. (in press). Cold room air inhalation to abort cluster headaches: An exploratory study. Journal of Headache and Pain.

Grazzi, L., Andrasik, F., D'Amico, D., Leone, M., Usai, S., Kass, S.J., & Bussone, G. (in press). Behavioral and pharmacological treatment of drug-induced daily headache: Outcome at three years. Headache.

Andrasik, F., & Walch, S.E. (in press). Biobehavioral assessment and treatment of recurrent headaches. In A.M. Nezu, C.M. Nezu, & P.A. Geller (Eds.), Comprehensive handbook of psychology, Volume 9: Health psychology. NY: Wiley.

Andrasik, F., & Flor, H. (in press). Biofeedback. In H. Breivik & C. Eccleston (Eds.), Clinical pain management: Treatment. London: Arnold Publishers.

Larsson, B., & Andrasik, F. (2002). Relaxation treatment of recurrent headaches in children and adolescents. In V. Guidetti, G. Russell, M. Sillanpää, & P. Winner (Eds.), Headaches and migraine in childhood and adolescence (pp. 307-316). London: Martin Dunitz.

Andrasik, F., Larsson, B., & Grazzi, L. (2002). Biofeedback treatment of recurrent headaches in children and adolescents. In V. Guidetti, G. Russell, M. Sillanpää, & P. Winner (Eds.), Headaches and migraine in childhood and adolescence (pp. 317-332). London: Martin Dunitz. [To be translated for a text in Russian, edited by M. Shtark & M.S. Schwartz.]

Andrasik, F. (2001). Assessment of patients with headaches. In D.C. Turk & R. Melzack (Eds.), Handbook of pain assessment (2nd ed.; pp. 454-474). NY: Guilford Press.

Grazzi, L., Andrasik, F., D'Amico, D., Leone, M., Moschiano, F., & Bussone, G. (2001). Electromyographic biofeedback-assisted relaxation training in juvenile episodic tension-type headache: Clinical outcome at three-year follow-up. Cephalalgia, 21, 793-803.

Andrasik, F. (2001). Migraine and quality of life: Psychological considerations. Journal of Headache and Pain, 2, S1-S9.

Folen, R.A., James, L.C., Earles, J.E., & Andrasik, F. (2001). Biofeedback via telehealth: A new frontier for applied psychophysiology. Applied Psychophysiology and Biofeedback, 26, 195-204.

Andrasik, F. (2000). Biofeedback. In D.I. Mostofsky & D.H. Barlow (Eds.), The management of stress and anxiety in medical disorders (pp. 66-83). Needham Heights, MA: Allyn & Bacon.

- Andrasik, F., & Passchier, J.** (2000). Psychological mechanisms of tension-type headache. In J. Olesen, P. Tfelt-Hansen, & K.M.A. Welch (Eds.). The headaches (2<sup>nd</sup> ed.; pp. 599-603). Philadelphia: Lippincott Williams & Wilkins.
- McGrady, A.V., **Andrasik, F.**, et al. (1999). Psychophysiologic therapy for chronic headache in primary care. Primary Care Companion for Journal of Clinical Psychiatry, 1, 96-102.
- Andrasik, F.**, Otis, J., Turner, B., & Simon, M.A. (1999). Research methods in health psychology. In M.A. Simon (Ed.), Manual de psicologia de la salud: Fundamentos, metodologia y aplicaciones (pp. 259-306). Madrid, Spain: Biblioteca Nueva.
- Bussone, G., Grazzi, L., D'Amico, D., Leone, M., & **Andrasik, F.** (1998). Biofeedback-assisted relaxation training for young adolescents with tension-type headache: A controlled study. Cephalalgia, 18, 463-467.
- Billiot, K.M., Budzynski, T.H., & **Andrasik, F.** (1997). EEG patterns and chronic fatigue syndrome. Journal of Neurotherapy, 2, 20-30.
- Haddock, C.K., Rowan, A.B., **Andrasik, F.**, Wilson, P.G., Talcott, G.W., & Stein, R.J. (1997). Home-based behavioral treatments for chronic benign headache: A meta-analysis of controlled trials. Cephalalgia, 17, 113-118.
- Napier, D., Miller, C., & **Andrasik, F.** (1997). Group treatment for recurrent headache. Advances in Medical Psychotherapy, 9, 21-31.
- Andrasik, F.** (1996). Behavioral management of migraine. Biomedicine & Pharmacotherapy, 50, 52-57.
- Rowan, A.B., & **Andrasik, F.** (1996). Efficacy and cost-effectiveness of minimal therapist contact treatments of chronic headaches: A review. Behavior Therapy, 27, 207-234.
- Otis, J.D., Rasey, H.W., Vrochopoulos, S., Wincze, J.P., & **Andrasik, F.** (1995). Temperature acquisition as a function of the computer-based biofeedback system utilized: An exploratory analysis. Biofeedback and Self-Regulation, 20, 183-188.
- Andrasik, F.** (1995). The role of behavioral techniques in the treatment of migraine. Japanese Journal of Biofeedback Research, 22, 14-18.
- Andrasik, F.**, & Wincze, J.P. (1994). Emotional and psychosocial aspects of mild head injury. Seminars in Neurology, 14, 60-66.
- Ham, L.P., **Andrasik, F.**, Packard, R.C., & Bundrick, C.M. (1994). Psychopathology in individuals with post-traumatic headaches and other pain types. Cephalalgia, 14, 118-126.
- Andrasik, F.** (1994). Twenty-five years of progress: Twenty-five more? (Presidential Address). Biofeedback and Self-Regulation, 19, 311-324.

- Andrasik, F., & Gerber, W.D.** (1993). Relaxation, biofeedback, and stress-coping therapies. In J. Olesen, P. Tfelt-Hansen, & K.M.A. Welch (Eds.), The headaches (pp. 833-841). NY: Raven.
- Passchier, J., & **Andrasik, F.** (1993). Psychological factors. In J. Olesen, P. Tfelt-Hansen, & K.M.A. Welch (Eds.), The headaches (pp. 233-240). NY: Raven.
- Andrasik, F., & Passchier, J.** (1993). Psychological aspects. In J. Olesen, P. Tfelt-Hansen, & K.M.A. Welch (Eds.), The headaches (pp. 489-492). NY: Raven.
- Oyama, O.N., & **Andrasik, F.** (1992). Behavioral strategies in the prevention of disease. In S.M. Turner, K.S. Calhoun, & H.E. Adams (Eds.), Handbook of clinical behavior therapy (2nd ed., pp. 397-413). NY: Wiley.
- Gagnon, D.J., Hudnall, L., & **Andrasik, F.** (1992). Biofeedback and related procedures in coping with stress. In A.M. La Greca, L.J. Siegel, J.L. Wallander, & C.E. Walker (Eds.), Stress and coping in child health (pp. 303-326). NY: Guilford.
- Andrasik, F.** (1992). Assessment of patients with headaches. In D.C. Turk & R. Melzack (Eds.), Handbook of pain assessment (2nd ed., pp. 344-361). NY: Guilford.
- Andrasik, F.** (1991). Aging and self-regulation: An introduction and overview. Biofeedback and Self-Regulation, 16, 333-336.
- Blanchard, E.B., Appelbaum, K.A., Radnitz, C.L., Michultka, D., Morrill, B., Kirsch, C., Hillhouse, J., Evans, D.D., Guarnieri, P., Attanasio, V., **Andrasik, F.**, Jaccard, J., & Dentinger, M.P. (1990). Placebo-controlled evaluation of abbreviated progressive muscle relaxation and of relaxation combined with cognitive therapy in the treatment of tension headache. Journal of Consulting and Clinical Psychology, 58, 210-215.
- Appelbaum, K.A., Blanchard, E.B., Nicholson, N.L., Radnitz, C., Kirsch, C., Michultka, D., Attanasio, V., **Andrasik, F.**, & Dentinger, M.P. (1990). Controlled evaluation of the addition of cognitive strategies to a home-based relaxation protocol for tension headache. Behavior Therapy, 21, 293-303.
- McCarran, M.S., & **Andrasik, F.** (1990). Behavioral weight-loss for multiply-handicapped adults: Assessing caretaker involvement and measures of behavior change. Addictive Behaviors, 15, 13-20.
- Andrasik, F., Oyama, O.N., & Packard, R.C.** (1990). Biofeedback therapy for migraine. In S. Diamond (Ed.), Migraine headache prevention and management (pp. 213-238). NY: Marcel Dekker.
- Waggoner, C.D., & **Andrasik, F.** (1990). Behavioral assessment and treatment of recurrent headache. In T.W. Miller (Ed.), Chronic pain (Vol. 1, pp. 319-361). Madison, CT: International Universities Press.
- Andrasik, F.** (1990). Psychological and behavioral aspects of chronic headache. In N.T. Mathew (Ed.), Advances in headache: Neurologic clinics (Vol 8, pp. 961-976). Philadelphia: W.B. Saunders.

### BIOGRAPHICAL SKETCH

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

NAME	POSITION TITLE
Michael C. Prevost	Research Physiologist

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

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY
University of Louisiana, Lafayette	B.A.	1989	General Studies
United States Sports Academy	M.A.	1991	Sports Science
Louisiana State University	Ph.D	1995	Exercise Physiology
Naval Operational Medicine Institute	-----	1996	Aerospace Physiologist

#### 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

Aerospace Physiologist: Board certification in Aerospace Physiology awarded by the Aerospace Medical Association, May 2001.

Category I Laser Systems Safety Officer: Awarded by Space and Naval Warfare Systems Command, September 1999.

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.  
Effects of Caffeine Ingestions on Endurance Racing in Heat and Humidity. (1996) Cohen BS, Nelson AG, **Prevost MC**, Thompson GD, Marx BD, Morris GD, *European Journal of Applied Physiology*, 73: 358-363.  
The Effect of Two Days of Velocity-Specific Isokinetic Training on Torque Production. (1999) **Prevost MC**, Nelson AG, and Maraj BK, *Journal of Strength and Conditioning Research*, 13(1), 35-39.

### **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, NC, January 1994.  
Effect of Continuous Caffeine Intake on Prolonged Exercise to Exhaustion. Cohen BS, Nelson AG, **Prevost MC**, Southwest ACSM, San Diego, CA, November 1995.  
Cocaine Affects Myosin Isoform Expression in the Rat Soleus (1993), **Prevost MC**, Nelson AG, Kelly KP, Han DH, Conlee RK, FASEB J. A:226.  
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,  
Nelson AG, **Prevost MC**, (1997), Southeast ACSM (Top 30 Abstract).

An Analysis of AV-8B "Harrier" Ejection Injuries (1998) **Prevost MC**, McCormack WP, Annual Meeting of

Aerospace Medical Association, Seattle, WA.

Evaluation of a 10-foot Oxygen Hose Extension for KC-130 Loadmasters (1998) McCormack WP,

**Prevost MC**, Annual Meeting of the Aerospace Medical Association, Seattle, WA.

Spatial Disorientation Phenomena in Naval Helicopter Pilots, Revisited (2000), **Prevost MC**, Folga RV,

Olmo OJ, Annual Meeting of the Aerospace Medical Association, Houston, TX.

Nutritional Supplement Use in Aircrew, Considerations for the Aerospace Professional (2001)

**Prevost MC**, Folga RV, Annual Meeting of the Aerospace Medical Association, Reno, NV.

## BIOGRAPHICAL SKETCH

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

NAME	POSITION TITLE
David J. Blower, Ph.D.	Senior Research Psychologist

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

INSTITUTION(S) AND LOCATION	DEGREE(S) (if applicable)	YEAR(S)	FIELD(S) OF STUDY
Ohio State University	B.Sc.	1968	Psychology
Stanford University	Ph.D.	1979	Psychology

### 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.

Senior Research Scientist (1994 to 1995), GEO-CENTERS, Inc., Newton Centre, MA. Consulting work to Naval Aerospace Medical Research Laboratory on Naval personnel selection and classification.

Aerospace Experimental Psychologist (1977 to 1994) in the Medical Service Corps of the US Navy.

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.

1985-1988 Naval Training Systems Center, Orlando, FL. Collaborated with University of Central Florida on developing artificial intelligence and computer graphics for F-14 tactics. US Navy representative to NATO Research Study Group on Man-Machine Interaction in Weapons Systems.

1982-1985 Naval Air Development Center, Warminster, PA. Developed knowledge-based software systems using LISP and rule-based pattern-directed approach to assist tactical planners in the airborne military environment.

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.

Counterintelligence agent (1968 to 1971). US Army, West Berlin, Germany.

#### **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 June30, 2002.

*A Bayesian Approach to Navy Enlisted Compensation Models*. Monograph for Naval Personnel Research Studies and Technology Command project on Bayesian approaches to military compensation issues. Draft version of May 15, 2001.

*Race, Gender, and Probability of Success in Naval Aviation Flight Training*, NAMRL Technical Report (draft), 2001.

*The Statistical Foundation of the Pilot Prediction System*, NAMRL Special Report 01-1, 2001.

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

*A Cost-Benefit Analysis of the LCAC Selection System*, NAMRL Special Report, 2000.

*Predicting Primary Flight Grades by Averaging Over Linear Regression Models :Part 1*, NAMRL Technical Report-1410, 2000.

*Predicting Primary Flight Grades by Averaging Over Linear Regression Models :Part 2*, NAMRL Technical Report-1411, 2000.

*Statistical Analysis of Isoperformance Issues in Navy Flight Training*, NAMRL Technical Report-1408, 2000.

*Some General Quantitative Considerations for the Statistical Analysis of Isoperformance Curves*, NAMRL Technical Report-1406, 1999.

*Selection of Officers for U.S. Naval Aviation Training (co-author)*, NATO Human Factors and Medicine Panel Workshop, Monterey, CA, 1999.

*Analysis of Rejection and Attrition Data from the Landing Craft Air Cushion (LCAC) Selection System*, NAMRL Special Report 99-1, 1999.

*Monitoring Operational Selection Systems Through Frequency Counts: An Application of Bayesian Predictive Inference*, NAMRL Technical Report-1405, 1999.

*Probability of Success in Primary Flight Training as a Function of ASTB Scores and API Grades: An Example of the Statistical Inferencing Component of the Pilot Prediction System*, NAMRL Technical Report-1404, 1998.

*The Effect of Presentation Medium on Pilot Selection Test Battery Scores*, NAMRL Technical Report-1400, 1998.

*Landing Craft Air Cushion (LCAC) Navigator Selection System: Initial Model Development*, NAMRL Technical Report-1399, 1998.

*The Development and Initial Validation of the Unmanned Aerial Vehicle (UAV) External Pilot Selection System*, NAMRL Technical Report-1398, 1998.

*A Quantitative Framework for Conducting Cost-Benefit Analyses of Selection Tests*, NAMRL Technical Report-1397, 1997

*The Prediction Algorithm for the Landing Craft Air Cushion Vehicle (LCAC) Selection System*, NAMRL Technical Report, NAMRL-1395, 1996.

*Performance-Based Testing and Success in Naval Advanced Flight Training*, NAMRL Technical Report 1378, 1992.

*Operational Implementation of a Validated Personnel Selection System for a Landing Craft Air Cushion Vehicle Operators*, Proceedings of the 13th Psychology in the Department of Defense, Colorado Springs, CO, 1992.

*Using Constraint Satisfaction Networks to Study Aircrew Selection for Advanced Cockpits*, NAMRL Special Report 92-1, 1992.

*An Evaluation of Performance-Based Tests Designed to Improve Naval Aviation Selection*, NAMRL Technical Report 1363, 1991.

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

*An Evaluation of Performance-Based Tests Designed to Predict Success in Primary Flight Training*, Proceedings of the 34th Annual Human Factors Society, Orlando, FL, 1990.

*Analysis of Naval Aviation Selection Test Data with Non-Linear Models Part I: Parameter Estimation*, NAMRL Technical Report, 1990.

*Embedded Training and Help: Opportunities for User Support*. Proceedings of the NATO Panel VIII Workshop on Computer-Human Interaction in Command and Control, Berchtesgaden, Germany, 1987.

*An Educational Animation System Based on Class Inheritance*. Proceedings Computer Graphics 87, Orlando, FL, 1987.

*A Spreadsheet-Based Visual Language for Freehand Sketching of Complex Motions*. Proceedings of the Workshop on Visual Languages, Linkoping, Sweden, 1987.

*Expert Systems: A Potential Asset to Maintainability Design*. Proceedings of the NATO Defense Research Group Conference, Shrivenham, England, April 1984.

*The Maximum Amount of Measurement Error Allowable in Visual Acuity Threshold Estimates*. Proceedings of the 1982 meeting of the Aerospace Medical Association, Bal Harbour, FL, May 1982.

*Determining Visual Acuity Thresholds: A Simulation Study of Stimulus Presentation Strategies*. NAMRL Technical Report 1282, August 1981.

*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

*Investigating Information Processing in a Simple Visual Choice Task with Cortical Evoked Potentials*. Ph.D. Dissertation, Stanford University, 1979.