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THESIS

**EFFECTS OF STRESS INOCULATION TRAINING
ON BRIDGE SIMULATOR SKILLS ACQUISITION
AND PERFORMANCE**

by

Clarese L. Neill

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Thesis Advisor:
Second Reader:

Nita L. Shattuck
Robert L. Bassett

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SKILLS ACQUISITION AND PERFORMANCE**

Clarese L. Neill
Lieutenant, United States Navy
BS, The Citadel, 2013

Submitted in partial fulfillment of the
requirements for the degree of

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from the

**NAVAL POSTGRADUATE SCHOOL
March 2020**

Approved by: Nita L. Shattuck
Advisor

Robert L. Bassett
Second Reader

W. Matthew Carlyle
Chair, Department of Operations Research

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ABSTRACT

In 2017, the U.S. Navy experienced several ship incidents in the Western Pacific that resulted in 17 fatalities. Follow-on investigations reported that the Surface Warfare community needs to refocus attention on basic ship handling and stress management. This research investigates the effects of stress inoculation training (SIT) on ship handling and navigation performance of novice ship drivers.

Participants were randomly assigned to one of three groups: Cold pressor test (CPT) stress group 1, whose participants received stress training while one foot was in a bucket of ice water; cold water perfusion sleeve (CWPS) stress group 2, which received stress training with an ice-cold bladder on their lower backs; and the control group, which received no stress training.

This thesis represents one part of a two-part study and focused only on the stress group 2 participants, comparing them with the control group.

The results of this research indicate that the CWPS does induce stress as demonstrated by changes in physiological response data; however, the stress response from CWPS appears to be less than the CPT. There is not a statistically significant improvement in performance on the simulator following SIT using CWPS. However, stress measured by heart rate is lowered by SIT with the CWPS to a non-congruent stressor such as the CPT.

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LIST OF ACRONYMS AND ABBREVIATIONS

BDOC	Basic Division Officer Course
CIC	Combat Information Center
COVE	Conning Officer Virtual Environment
CPT	cold pressor test
CR	Comprehensive Review
CWPS	cold water perfusion system
ECG	electrocardiogram
EDA	electrodermal activity
GSR	galvanic skin response
HPA	hypothalamic-pituitary adrenal
MSE	mean squared error
SIT	stress inoculation training
SNS	sympathetic nervous system
TA	Task Acquisition
VBA	visual basic and applications

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EXECUTIVE SUMMARY

In 2017, the Navy experienced a series of incidents that demonstrated what happens when insufficiently trained watchstanders are expected to perform under extremely stressful conditions. The subsequent Comprehensive Review noted that fundamentals of seamanship and navigation in the Surface Warfare community were deficient. In each incident of 2017, poor seamanship and poor navigation of the ship were listed as factors contributing to the collision or grounding (Davidson, 2017).

This project aims to evaluate whether Stress Inoculation Training (SIT) enables participants to perform better in a ship navigation exercise when they are exposed to a significant external stressor (ice cold water). It also seeks to explore the effects of stress on learning and skill acquisition. The effectiveness of cold exposure to induce stress and affect performance is vital to this project.

There are two primary objectives of this research. The first objective is to determine if Stress Inoculation Training using a Cold Water Perfusion System improves ship-driving skill acquisition and performance. The second objective is to determine if the Cold Water Perfusion System effectively elevates stress levels by increasing physiological responses.

The Stress Inoculation Training used for this experiment was thermal stress via cold water exposure using two methods. This study used a Cold Pressure Test (CPT) which involved immersing an extremity in ice water, and a Cold-Water Perfusion System (CWPS), a rubber bladder that circulates ice-cold water applied to the lower back. The CWPS would be much simpler to implement in a standard Naval training facility such as the Basic Division Officer Course (BDOC) so one goal of this study was to test the effectiveness of the CWPS versus the more traditional CPT stressor.

The results of this research indicate that CWPS does induce stress as demonstrated by the changes in the physiological response data; however, the stress response from CWPS appears to be somewhat less than that seen in CPT. There is not a statistically significant improvement in performance on the simulator following SIT using CWPS.

However, stress as measured by heart rate is lowered by Stress Inoculation Training with the CWPS to a non-congruent stressor such as the CPT.

The results of this study will be shared with the U.S. Navy Surface Warfare Officer School to inform them about the effects of stress inoculation to aid training in bridge simulators, which may enable them to better prepare fleet-bound junior officers.

References

Davidson, P. S. (2017). *Comprehensive review of recent surface force incidents*. U.S. Fleet Forces Command , Department of the Navy. http://s3.amazonaws.com/CHINFO/Comprehensive+Review_Final.pdf

I. INTRODUCTION

A. THE NAVY UNDER STRESS IN 2017

For many years, reports of reduced surface force readiness have plagued the Navy. The “increased deployment lengths, reduced training time, overworked sailors and deferred maintenance” have taken their toll on Navy warships and Navy sailors (*Viewpoint*, 2017). Some ships struggle to receive required maintenance to get underway while other ships are forced to remain at sea in order to cover operations. Meanwhile, with reduced training and less time underway, junior officers and sailors may fail to learn the seamanship skills required to safely drive and navigate a ship (“Viewpoint,” 2017). When force readiness is diminished as a result of these challenges, unintended consequences can include increased risk and higher levels of stress on sailors. If stress is too high, it causes many physiological effects that can impair performance (Matthews, Davies, Westerman, & Stammers, 2000, p 166) with the Navy has experiencing devastating consequences of high stress levels in underway watchteams in recent history.

In 2017, the Navy had a series of incidents that demonstrated what happens when insufficiently trained watchstanders are expected to perform under extremely stressful conditions (Davidson, 2017). In January 2017, the USS Antietam (CG-54) attempted to anchor in Tokyo Bay before conducting training in the local area. In an attempt to anchor, the USS Antietam (CG-54) ran aground as a result of the watchteam’s poor seamanship and delayed responses while steering into danger (Davidson, 2017). Following this, in May 2017 the USS Lake Champlain (CG-57) collided with a fishing vessel while escorting an aircraft carrier. The Bridge and Combat Information Center (CIC) watchstanders had failed to communicate and agree on safe navigation of the ship to properly conduct escorting maneuvers (Davidson, 2017). Only one month later in June 2017, the USS Fitzgerald (DDG-62) collided with another vessel when it attempted to cross a traffic scheme at night. The watchstanders did not use all available means to establish closest point of approach for two surrounding vessels within the area before crossing. The USS Fitzgerald (DDG-62) collided with the commercial vessel ACX CRYSTAL as a result of failing to act on sound navigating and watchstanding principles and proper use of navigation tools (Davidson,

2017). Finally, in August 2017, the USS John S. McCain (DDG-56) was preparing to enter the Singapore Strait. Confusion emerged about operation of the Ship's Control Console (SCC) and ultimately about throttle control. This confusion caused the ship to take an inadvertent turn to port and collide with the commercial vessel ALNIC MC. Primary cause of the collision was loss of situational awareness, failure to follow safe navigational practices, and "failure to take clear and decisive action to avoid collision when in extremis" (Davidson, 2017, p. 12).

In each of these cases, the watchstanders responsible for the safe navigation of the ship failed to effectively take action when in extreme circumstances, demonstrating loss of situational awareness (Davidson, 2017). Once the situation became dangerous or extreme, the watchstanders began to deviate from proper procedures. They also failed to perform many emergency actions including sounding alarms or communicating with other ships (Davidson, 2017). These failures were key players in the error chain that led to each collision or grounding.

B. FINDINGS FROM THE COMPREHENSIVE REVIEW

The Comprehensive Review (CR) that followed these incidents yielded several key action items relevant to this research (Davidson, 2017). In each incident of 2017, poor seamanship and poor navigation of the ship were listed as factors contributing to the collision or grounding. Recommendations for improvements to the basic skills acquisition and stress management training for Surface Warfare sailors were given after the CR noted that fundamentals of seamanship and navigation in the Surface Warfare community were deficient.

In addition, the CR noted that the surface warfare community does not offer stress management training (Davidson, 2017). A prominent finding from each incident was that the watchstanders were not able to maintain proper procedures or communications when in *extremis*. Subsequently, the review recommended that teams be tested with "realistic and challenging scenarios" that are incorporated into career milestone training and enlisted leadership courses (Davidson, 2017, p. 8). Stress inoculation training (SIT) provides individuals with an opportunity to experience high levels of stress, to learn what happens

to them when they are in extreme stress, and to learn how to perform while undergoing stressful situations. Incorporating SIT into the existing training pipeline could potentially address some of the Navy's needs.

Sailors require time and manpower to train the “most basic and critical seamanship skills” (“Viewpoint,” 2017). Strengthening seamanship and navigation training must be the priority of the surface fleet. Junior and senior surface warfare officers need safe training environments where they can rehearse basic seamanship while experiencing the effects of stress through a program such as SIT. SIT will allow them to become familiar with their own physiological responses and potentially lowering their response to stress, while maintaining performance in a safe scenario.

C. SURFACE WARFARE TRAINING AT BDOC/SWOS

The Surface Warfare Officers School Command is the primary site for training navigational tactics for all Navy Surface Warfare Officers surface (*Surface Warfare Officers School, 2020*) . This command includes schooling for the newest officers to the senior officers preparing to take command. The Basic Division Officers Course (BDOC) is a 9-week course that introduces mariner skills training and navigation to prospective surface warfare officers (SWOs) (“Viewpoint,” 2017). BDOC is the most basic and fundamental course provided as it is designed to teach the most novice officers. BDOC does not provide SWOs with in-depth training that was previously given to them in a six-month in-residence curriculum. The course is designed to assume no prior knowledge of seamanship and shiphandling and prepare the officer with sufficient knowledge to begin sea duty. After junior officers receive training at BDOC, they are sent to their first ship and are expected to qualify as Officer of the Deck within their first tour having only received only on-the-job training. In addition to an already stressful environment, the Officer of the Deck has the added stressors of managing sea traffic, flight operations, small-boat operations, driving at night and many other additional potentially hazardous situations. Under these high levels of stress and having never received SIT, junior officers are likely to be unfamiliar with how to perform while managing their physiological stress responses.

The Conning Officer Virtual Environment (COVE) is the current tactical trainer used for teaching new officers the tactics and traditions related to Surface Warfare. The COVE has the capability to simulate most routine ports of call for the U.S. Fleet. (Surface Warfare Officers School, 2020) Training conducted in the COVE provides the officer with a safe environment to practice skills learned in the classroom environment. The officer will then be expected to graduate from training with a basic, intermediate and advanced level of proficiency in seamanship and shiphandling adequate to begin fleet duty. The Cove 3 stations consists of three 50-inch displays which provides the officer with view of their surroundings. A voice recognition system allows the officers to give commands to the virtual helmsman (Surface Warfare Officers School, 2020).

This research attempts to simulate a potential training environment for candidates undergoing Surface Warfare Officer training. The participants in our research are novice ship drivers with no prior knowledge of seamanship and shiphandling. The bridge simulator used for our research is made by Kongsberg, is similar to the COVE and allows for a safe environment for the participant to practice the navigation skills required in our research scenario.

D. RESEARCH QUESTIONS

There are two primary questions for this research. The first question is to determine if the CWPS effectively induces stress as measured by elevated physiological responses. The second question is to determine if SIT, administered using CWPS, improves subsequent ship-driving performance of participants when they perform while experiencing acute stress (CPT).

II. LITERATURE REVIEW

This research project aims to determine whether SIT improves performance when operating under stress. Research regarding stress and performance has been conducted since the 1920s starting with Hans Selye (Fink, 2010). Matthews et al. (2000) reviewed past studies which used cold exposure as a stressor. The effectiveness of cold exposure to induce stress and affect performance is relevant to this project. This research will use a Cold Water Perfusion System (CWPS) and a bucket of ice water (CPT) as a means to induce stress.

A. STRESS AND PHYSIOLOGICAL RESPONSES

Stress, as defined by Merriam-Webster, is “a physical, chemical, or emotional factor that causes bodily or mental tension” (*Definition of Stress*, 2020). A stressor is a high-demand situation that poses a threat to an individual, often occurring suddenly and unexpectedly and demanding quick responses. Stress represents an adaptive and normal response to a perceived threat or stressor, in fact our bodies are designed to cope with stress such as the stress of hunting or being hunted (Flanagan et al., 2012). Stress is not just a property of the task or external situation, but the interaction between the individual and situation or tasks. (Matthews et al., 2000, p 162). Stress is the result of an individual’s appraisal and his or her feeling of anxiety in conjunction with physiological responses such as increased heart rate or blood pressure (Driskell & Salas, 1996).

When an individual encounters a stressful situation, he or she must begin an evaluation process which is known as primary or secondary appraisal (Driskell & Salas, 1996, p 11). The primary appraisal determines the actions necessary to neutralize the threat associated with the event. The secondary appraisal evaluates the resources available to meet these actions. Driskell and Salas demonstrate that the act of appraising the situation determines the degree of discrepancy between the primary and secondary appraisal, or the discrepancy between the demand and capacity (Driskell & Salas, 1996). How one conducts the appraisal process can significantly impact their ability to perform under high-demand conditions as the appraisal process forms expectations of performance. If the perception of

resources exceeds the demands of the perceived threat, good performance is expected. If demand exceeds perceived resources, poor performance or failure is expected. Driskell and Salas state that the appraisal process will result in formulation of feelings of self-efficacy or inadequacy (Driskell & Salas, 1996, p. 199). The ability for one to develop a sense of capability and proficiency is a crucial factor for positive performance under highly demanding and highly stressful conditions.

When performing a task, performance can be altered if the individual is experiencing stress (Driskell et al., 2001). There are two major theories surrounding this idea: 1) stress restricts attentional capacity of the individual, and 2) stress distracts from the task at hand. According to Driskell, Johnston, and Salas, there are two types of stressors, those that increase distraction and those that decrease distraction. The authors continue, an individual under noise or time pressure will experience a decrease in distraction from the task, while an individual who experiences fatigue may experience an increase in distraction (Driskell et al., 2001).

The Easterbrook hypothesis described by Matthews et al. proposes an effect of arousal on performance (2000). As a stressor increases intensity, the individual will become increasingly aroused. The Easterbrook hypothesis uses a searchlight to symbolize an individual's scope of attention or performance, as the level of arousal increases, the breadth of a searchlight decreases. In a low level of arousal, the individual has a broad searchlight and attends to both task and task-irrelevant stimuli. As arousal increases toward a moderate level, the individual reaches an optimal level of performance as task-irrelevant stimuli are rejected but task stimuli are processed fully. As arousal continues to further increase, the breadth of searchlight narrows and task-relevant stimuli will be excluded from the scope of attention which will impair performance (Matthews et al., 2000). The relationship between arousal and performance describes an inverted-U relationship. If imagining a graph of stress versus performance, as stress increases from low to high, performance will increase to an optimal level before diminishing (Matthews et al., 2000).

Yerkes and Dodson were the first to demonstrate the Easterbrook hypothesis in stress and performance research (Yerkes & Dodson, 1908). Three trials of low, moderate, and high levels of stimuli were used to compare the learning response of rats, with a weak

but definite relationship between level of stimulus and response. It was discovered that as stressor stimulus increased to a moderate level, performance on task improved. However, as the stimulus level increased beyond that moderate level, performance on the task diminished (Kavanagh, 2005).

Since the Yerkes and Dodson study, many other instances of the inverted-U relationship have been found in performance research. Srivastava and Krishna studied performance in the industrial environment and found the inverted-U between performance and stress exists (Srivastava & Krishna, 1991). The effect of stress on performance was researched by Selye (Selye, 1976) and McGrath (McGrath, 1976) who also demonstrated that the inverted-U relationship existed. Research from Sanders (Sanders, 1983) and Gaillard and Steyvers (Gaillard & Steyvers, 1989) support the inverted-U relationship by finding that optimal performance exists when arousal is neither too high or too low. When arousal is at either extreme, too high or too low, it will cause performance to diminish.

Other models suggest alternative relationships between stress and performance. Jamal found that stress degrades performance, regardless of its intensity (Jamal, 1985). Jamal claims that stress strictly impairs an individual's energy and concentration and therefore proposes a negative linear relationship between stress and performance (Jamal, 1985). Vroom also found that performance was impaired at any level of stress due to physiological responses (Vroom, 1964). Muse, Harris, and Field point out, however, that despite any evidence that supports alternative relationships between stress and performance, the inverted-U hypothesis is the most used model for stress and performance (Muse et al., 2003).

A stressor is a high-demand situation that poses a threat to an individual, often occurring suddenly and unexpectedly and demanding quick responses. Many stressful situations may result in catastrophic results if the stressed individual does not effectively perform. Stress is the result of an individual's appraisal of the situation. It is his or her feeling of anxiety in conjunction with physiological responses such as increased heart rate or blood pressure (Driskell & Salas, 1996). Since feelings of anxiety are difficult to measure and record, stress and performance research monitors physiological responses to determine stress (Kavanagh, 2005).

B. PHASES OF STRESS INOCULATION TRAINING

One method for learning to manage stress is by administering stress through stress inoculation training (SIT). SIT is a psychological and multidimensional treatment intervention. It does not remove stress, but rather teaches effective mitigation of stress while problem solving (Jamshidifar et al., 2014). SIT provides a familiarization with stressful conditions that allows individuals to learn skills to maintain task performance under stress (Driskell & Johnston, 1998). The training familiarizes the individual with their own physiological responses to a particular stressful situation and allows them to adjust their primary and secondary appraisal of the scenario, leading to a reduction in stress, as well as allowing skill rehearsal in stressful conditions (Kavanagh, 2005). It is not simply training, but stress training.

Three approaches have been developed to use during SIT to reduce stress (Driskell & Salas, 1996). The first approach focuses on stress itself. Theoretically, if an individual can be taught to manage their reaction to stress, performance will improve. The second approach assumes that stress is inevitable and therefore training to deal with it is essential. This approach promotes achieving automaticity and durability of skill so that stress cannot diminish performance. The third approach teaches strategies to manage interpersonal stress using team resources to deal with stressful situations (Driskell & Salas, 1996).

All of these approaches to reduce stress are incorporated into SIT. SIT repeatedly or continuously exposes a trainee to a particular stressor and asks the trainee to perform a task. Training under stress is a highly effective method to reduce the negative effects of stress (Kavanagh, 2005). It is also a convenient method in that training can be developed, altered, and controlled as needed to improve its effectiveness.

Most training environments are designed to maximize learning of initial skills by using a quiet classroom, which can be beneficial for the initial presentation of information. However, the ability to transfer training from the classroom to the operational environment can be very poor if stress training is not included (Driskell & Johnston, 1998). Stress training involves environments specific to the task conditions and relevant stressors. Stress training should be set up so as to replicate situation-specific stressors even though real-

world environments may be rapidly changing and dynamic (Kavanagh, 2005). SIT allows individuals to practice tasks while confronted with a stressor (Kavanagh, 2005). Performing under stress will allow them to build and practice strategies to manage their stress and maintain task proficiency. They will have a chance to experience their personal reactions to stress and form accurate expectations of how they will react and perform in real-world situations. Kozlowski concluded that simulated training in conditions that models the operational environment is effective in reducing the effect of stress on the decision-making process (Kozlowski, 1998).

There are three primary goals and three correlating phases as part of SIT (Hancock & Szalma, 2008). Phase I: Provides education about stress to form accurate expectations and predictions about stressful situations. Education decreases the distraction that occurs when focused on the emotions and excitement evoked in a stressful situation. Phase II: Acquire and rehearse skills relevant to performance. Individuals train in behavioral, cognitive, and specialized skills which they are expected to maintain effectively under stress. Phase III: Practice skills under realistic conditions which allow individuals to become confident in their ability to perform the required skills in a stressful operational environment (Hancock & Szalma, 2008).

Phase I of SIT provides training to understand the nature and effects of stress (Hancock & Szalma, 2008). From these early stages, trainees should understand the goals of SIT and have appropriate expectations regarding the stress environment. They should also be educated on typical physiological, emotional, and cognitive responses to stress and how it may affect their performance (Hancock & Szalma, 2008). Trainees may review case studies and lessons learned from prior SIT cases or real-life events relevant to the training. Educating the trainees of the effects of the stressors allows them to mentally prepare and helps minimize the distraction of the stressor (Driskell & Johnston, 1998).

The information provided to the trainees in Phase I is focused on three areas: sensory, procedural, and instrumental (Driskell & Johnston, 1998). Sensory information includes physical and emotional sensations the trainee may feel under the stressor. Driskell and Johnston specify that the physical reactions include an increased heart rate, sweating, muscle tension, fear, frustration, and confusion. Understanding how the body reacts to

stress allows the trainee to be less distracted when focusing on a task. Driskell and Johnston describe procedural information as discussing the events likely to occur inside and outside the training environment which closely reflects the real-life environment (Driskell & Johnston, 1998). Finally, instrumental information includes how to counteract the reactions to stress and includes steps to take to overcome the physical and emotional reactions while not taking away from the task at hand (Driskell & Johnston, 1998).

Phase II of SIT is used to teach individuals skills to resist the mental and physical effects of stress. These skills arm the trainee with coping mechanisms to respond to stress positively and minimize the negative effects on performance (Saunders et al., 1996). Various methods are used to teach coping skills including active efforts to try and control the situation or inactive efforts such as rethinking one's attitude (Matthews et al., 2000). Each coping method will influence the efficiency of task performance differently. Problem-focused coping targets the cause of stress in the individual and tends to have the most beneficial effects (Matthews et al., 2000).

Mental practice is a technique wherein the trainee "walks through" the scenario in their head and visualizes the steps to perform the task (Driskell & Johnston, 1998). Trainees imagine the stress and mentally rehearse employing their coping skills. Driskell and Johnston state that this rehearsal allows the trainee to remember the skills and form mental images to aid in recall of the different coping mechanisms. Mental rehearsal also allows for preparation of overly complex or dangerous scenarios in a safe manner.

Additionally, time-sharing skills focus on teaching the ability to perform multiple tasks concurrently under pressure (Driskell & Johnston, 1998). Since stressful situations often require the trainee to perform more than one task, time-sharing skills teach the trainee to handle increased tasks simultaneous to time pressure (Driskell & Johnston, 1998). Naturally, the tasks should be two that often occur together.

Physiological control strategies recognize the physical effects of stress and teach control over these reactions. Muscle-tensing caused by stress is remedied by teaching relaxing exercises supplemented with imagery training. Imagery training is teaching people to maintain control, calmness, and relaxation through a stressful situation (Driskell &

Johnston, 1998). The military commonly uses overtraining as a method to resist the effects of stress (Driskell & Johnston, 1998). By using repetitive drills and forming routine and habitual responses, attentional capacity that the task requires from the individual is reduced. Therefore, the task performance is automatic and resistant to degradation by the effects of stress. Cognitive control strategies allow the individual to control the distracting negative emotions brought about by stressors and redirect them into task-focused thoughts (Driskell & Johnston, 1998). This strategy helps convert the dysfunctional thoughts and emotions into task-oriented energy and focus. Hyper-vigilant decision making is the practice of making critical decisions with limited alternatives and information. Many high-stress environments are under the pressure of time, which requires decision makers to make the best choices with little or no investigation or question-asking. This practice teaches how to rapidly evaluate data and close on a decision (Driskell & Johnston, 1998).

Phase III of SIT is the application and practice of the skills learned in Phase II. Phase III allows the skills to be transferred to an operational setting in a safe environment. The scenario, however, should replicate a situation that potentially could occur in the “real world.” Pre-exposure to stressors reduces anxiety and likeliness of becoming overwhelmed and increases the individual’s confidence of achieving the task. The ability to control emotions in stressful operational situations becomes more natural as the individual becomes more familiar with the stressful environment (Driskell & Johnston, 1998).

C. BIOMETRICS TO OBSERVE STRESS RESPONSES

Several biometrics can be monitored to determine if SIT is effectively increasing the stress level of the trainee. The key factor in SIT is the induction of stress during training. Thus, it is imperative that the trainee display appropriate physiological responses to indicate that they are actually encountering stress.

Stressful events challenge the homeostasis of the body. While under stress, the amygdala in the brain activates the hypothalamic-pituitary adrenal (HPA) axis and sympathetic nervous system (SNS) to produce a stress response (Flanagan et al., 2012). In response, the adrenal glands produce and release cortisol, adrenaline and glucocorticoids into the bloodstream (Kavanagh, 2005). The influx of hormones in the blood influences

cardiovascular function, inflammatory reactions, learning, and memory ability. Physiological stress response can be observed via heart rate, galvanic skin response (GSR), or increased blood pressure (Kavanagh, 2005). Selye discovered that the body increases heart rate and blood pressure to stimulate the central nervous system in order to perform more effectively under the challenging situation ahead and are, therefore, adaptive responses (Goldberger & Breznitz, 1993).

During SIT training, biometrics can be collected from the trainee before and after a scenario in order to establish a change in stress level. Heart rate is expected to increase during stressful environments and is a primary indicator of psychophysiological arousal that and can be easily monitored throughout the training (Arnetz et al., 2009). Moderate increases in heart rate versus extreme increases, explain Arnetz et al., indicate experience or adaptation to stress exposure. The heart sends more signals to the brain than the brain sends to the heart (Arnetz et al., 2009). Therefore, stress control may rely heavily on the ability to regulate one's heart rate. A coherent heart rate is strong and regular and indicates an easy cognitive performance (Cohn et al., 2010).

An electrocardiogram (ECG) records the P wave that depicts atrial activity. The heart rate is the number of times the heart pulses over the course of one minute and is often used to depict pilot workload (Hasbrook & Rasmussen, 1970). Hasbrook and Rasmussen measured heart rate stress response as participants conducted an in-flight simulated flying task. They recruited forty experienced pilots to conduct ten Instrument Landing System (ILS) approaches in ten-minute intervals under equivalent instrument conditions. They determined that stress response, indicated by heart rate, was increased during each aircraft landing for each pilot. But they also discovered that pilots demonstrated decreasing stress levels as they conducted subsequent approaches (Hasbrook & Rasmussen, 1970).

In addition, salivary samples can be taken before and after the task scenario or applied stressor to determine the change in cortisol and alpha-amylase levels (Arnetz et al., 2009). Alpha-amylase is an abundant salivary enzyme in humans and is a biomarker that indicates nervous system activation. Secretion of alpha-amylase from the salivary gland is controlled by the nervous system and reveals that alpha-amylase is a correlate of sympathetic activity under stress (Salimetrics, LLC, 2019a). Alpha-amylase has been

shown to directly correlate to levels of physical and psychological stress in human subjects. However, studies show that cortisol levels often do not correlate with alpha-amylase (Salimetrics, LLC, 2019a).

Cortisol is the primary glucocorticoid produced in the adrenal cortex (Salimetrics, LLC, 2020). Production of cortisol in the human body maintains a circadian rhythm where it peaks early in the morning and drops concentration at night. However, cortisol levels will fluctuate independently of its natural circadian rhythm as the body responds to stress (Salimetrics, LLC, 2020). About 90–95% of cortisol is bound to serum proteins. The remaining 5–10% of cortisol in the blood is unbound or biologically active and enters the saliva. “Cortisol levels are unaffected by salivary low rate and are relatively resistant to degradation from enzymes or freeze-thaw cycles” (Salimetrics, LLC, 2019b). Studies consistently show that salivary cortisol levels estimate serum cortisol levels and demonstrate reliably high correlation (Salimetrics, LLC, 2019b).

Galvanic skin response (GSR) offers a non-intrusive manner to collect continuous and objective stress data. As an individual experiences increasing stress levels, the electrical resistance of the skin changes. By monitoring the electrical resistance of the skin using small electrodes, it captures the autonomic nerve response of the sweat gland. The GSR of the trainee can also be collected and monitored throughout the entire training scenario (Perala & Sterling, 2007).

D. EXISTING RESEARCH ON COLD WATER PRESSOR (CPT) TEST

A study with police officers was conducted to assess the effectiveness of mental practice to reduce physiological responses to stressful environments (Arnetz et al., 2009). Half of the participants underwent 10 weekly 2-hour sessions in which they practiced muscle relaxation, skill training, and imagery rehearsal. Their sessions involved having the police officers practice relaxation methods regardless of their environment. Arnetz et al. had the participants use scripts to rehearse scenarios which created mental images for them to rehearse their responses (2009). They practiced visualization to strengthen cognitive and behavioral skills to effectively cope with their stress. The participants were encouraged to practice these cue-controlled techniques at home with recorded scripts. Arnetz et al. (2009)

demonstrated that stress inoculation training which incorporated a police-specific environment, decreased police officers' physiological stress response and improved performance during real-world incident simulation.

Deikis studied the effects of similar relaxation training for students in a scuba diving class during an underwater task (Deikis, 1982). Among the three groups he found that students who received relaxation training reported lower levels of anxiety and higher levels of self-confidence while performing the underwater task. Both of these indicators imply a reduction of the effects of stress on performance (Kavanagh, 2005).

Van Orden, Benoit and Osga (1996) assessed the ability of a cold stressor to induce stress and affect performance (Orden et al., 1996). The study used Navy personnel to perform a simulated command-and-control warfare task. The personnel managed a military engagement including various sublevel tasks such as monitoring ship and aircraft movement, firing missiles, and conducting queries. The participants were divided between a 4 degree Celsius (4°C) environment and a 22 degree Celsius (22°C) environment. Matthews et al. found that for the overall completion of the simulation, participants performing in the cold 4°C environment performed at a comparable level to participants in the 22°C environment. However, individual sublevel tasks within the simulation faltered with the participants in the colder 4 degree Celsius (4°C) environment. These participants tended to be less responsive to explicit commands or fired missiles when not prompted. Van Orden et al. (1996) showed that cold is associated with elevated heart rate, secretion of stress hormones, and may affect performance and decision-making capability (Orden et al., 1996).

Most recently, McClernon (2009) conducted an experiment that demonstrated how stress training improves performance in a stressful situation, decreases physiological stress responses, and decreases subjective appraisals of stress of trainees. McClernon's research trials required participants to put their left foot in a bucket of ice water in order to induce stress. His study produced findings that further validated the research of Friedland and Keinan's (1992) "three elementary phases of training: task acquisition, stress exposure, and practice under stress" (McClernon, 2009, p 52). Friedland and Keinan (1992) tested five

training approaches which were combinations of the training phases and found that performance of task under stress relied heavily on *both* skill acquisition and stress training (Friedland & Keinan, 1992). They also determined that for stress-trained participants, performance was enhanced and arousal was decremented compared to those without stress training (McClernon, 2009).

Cold exposure can be a stressor that causes physiological responses in an individual and is associated with the loss of motor skills such as movement of the hands, as well as the ability to perform cognitive or mental tasks to a lesser extent (Driskell & Salas, 1996). If cold exposure only influences the skin temperature, but not body core temperature, it shows no disruption of thermoregulation of the individual (Matthews et al., 2000). To observe the effects of cold exposure on performance, Horvath and Freedman conducted a study using 22 men (Horvath & Freedman, 1947). They kept the men in a -20 degree temperature for up to 2 weeks. The subjects showed diminished capability to perform manipulative and writing tasks. However, mental performance on code tests or visual tests was unaffected. Enander (1987) reported that effects of a moderate cold environment on attention and alertness are observed only if the task is made sufficiently demanding (Enander, 1987). In addition, Hancock (1986) stated that cold exposure diminished attention depending on the amount of change of body temperature (P.A. Hancock, 1986). These conditions imply that if the task is too easy or if the cold is not penetrating the body enough, the effects of the stress induced by the cold will not impair performance. Furthermore, Ellis, Wilcock, and Zaman showed that loss of accuracy increased as task complexity increased while exposed to cold (Ellis et al., 1985). As Figure 1 depicts, in a simple 4-choice task, errors increase as the cold exposure increases. For an 8-choice task, the number of errors is higher initially and increases more rapidly than the 4-choice task as cold exposure increases.

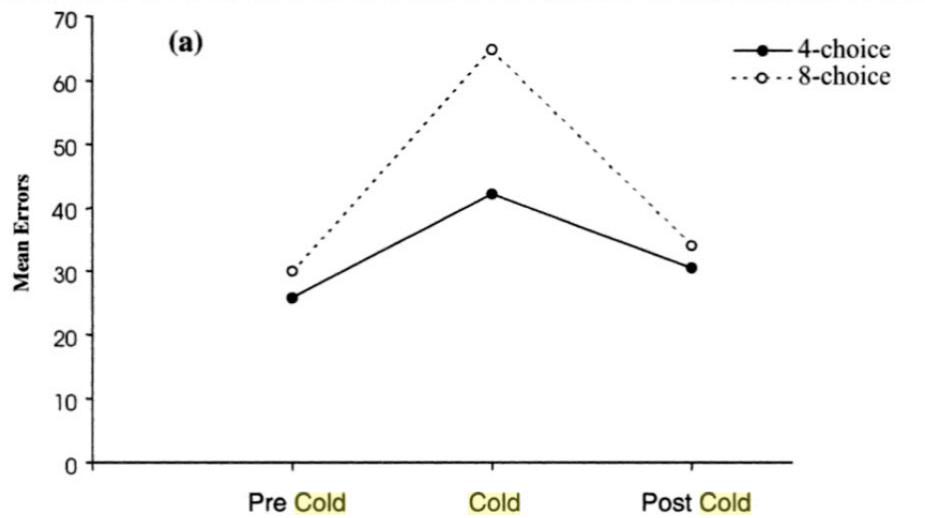


Figure 1. Task Complexity with Cold Exposure. Source: Matthews et al. (2000).

McClernon (2009) set the “gold standard” for implementing a cold stressor by using a bucket of ice water. He was able to prove that the physiological responses of an individual while performing a task in a stressful event (flying an actual aircraft) mimicked the physiological responses of an individual with their foot in a bucket of ice water (McClernon, 2009). However, he also recognized that the practical application of a bucket of ice water is impossible in the majority of stressful events. In fact, he suggested future research in finding alternative stressors which better adhere to practical applications in military and civilian communities (McClernon, 2009).

III. METHODOLOGY AND EXPERIMENTAL DESIGN

A. OVERVIEW

Participants for this study were volunteers who had no prior knowledge of ship driving. All participants were randomly assigned to one of three experimental groups: a control group with no cold exposure training, a CPT group (foot submerged in ice water), and a CWPS group. The first phase of the experiment was Simulator Familiarization where the participant was trained on the basic skills to operate the ship simulator. After Simulator Familiarization, the two SIT groups received Stress Training while under the stress of the cold pressor respective of the group they were assigned. The Control group during this time the Control group watched a video of similar length without stress training. The stress training received by the two SIT groups involved teaching relaxation techniques to help them control their breathing, focus their attention on the task, and making clear decisions. Next, the participants performed Task Acquisition which was navigating a simple buoy course in the simulator. The two SIT groups conducted this task while under the cold pressor of the group they were assigned. The final task, Criterion Task, was conducted exactly the same way as the Task Acquisition. During the Criterion Task, however, each participant was exposed to the CPT cold stressor. Figure 2 shows the timeline of each group's progression through the experiment.

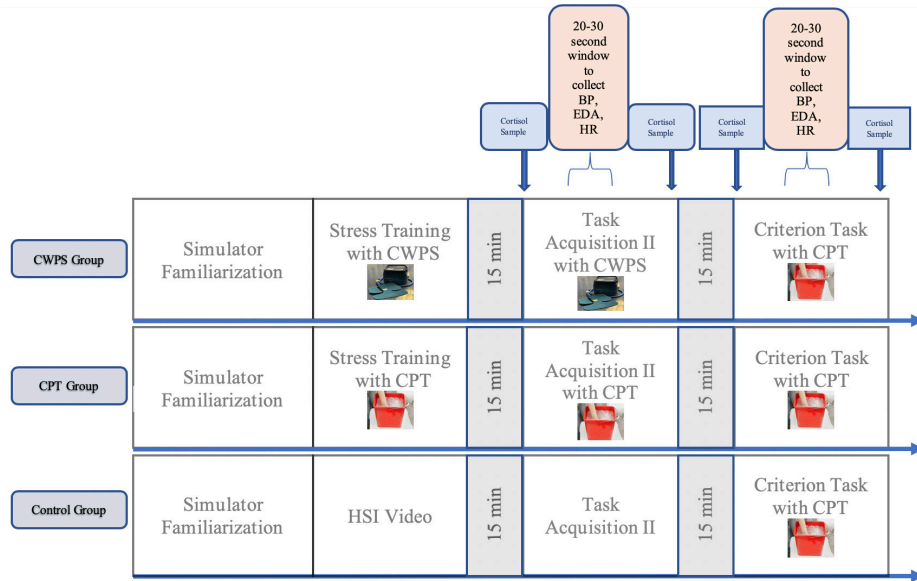


Figure 2. Timeline for Each Experiment Group

The data were analyzed to compare the effectiveness of the CPT versus the CWPS. Each cold stressor group was compared to the control group who received no stress inoculation training. The goal was to find the impact of stress inoculation training on performance in a simulated ship-driving scenario.

B. APPROACH

The SIT method used for this experiment was thermal stress via cold water exposure. This study used the CPT, or cold pressor using ice water, and introduced a Cold-Water Perfusion System (CWPS), which allowed the participant to wear a lower-back wrap that circulates cold water versus being directly exposed to ice water. One goal of this study was to test the effectiveness of the CWPS versus the traditional CPT because this method will be simpler to implement in a standard Naval training facility such as the BDOC.

C. EQUIPMENT

1. Kongsberg Simulator

The bridge simulator used for this research was the Kongsberg Polaris Ship bridge simulator depicted in Figure 3. The participant’s virtual environment consisted of four

visual displays, helm, and throttle controls. The four visual displays included an integrated SPS-79 Radar, panorama view, steering panel, and forward view from bridge of ship. The participant had control of both the helm and throttle controls during the experiment.



Figure 3. Kongsberg Polaris Ship's Bridge Simulator

The unique scenario used for this research was developed in order to test the participant's performance based on steering and speed control. The simulated scenario required the participant to navigate a slalom course through a series of smoke floats and oil rigs placed in open water. Other variables, such as weather, sea state, visibility, ship traffic, ship type and capabilities, and location were held constant across all participants. The same scenario file was used for each participant for both the Task Acquisition and Criterion Task. A bird's eye view of the course is shown in Figure 4.

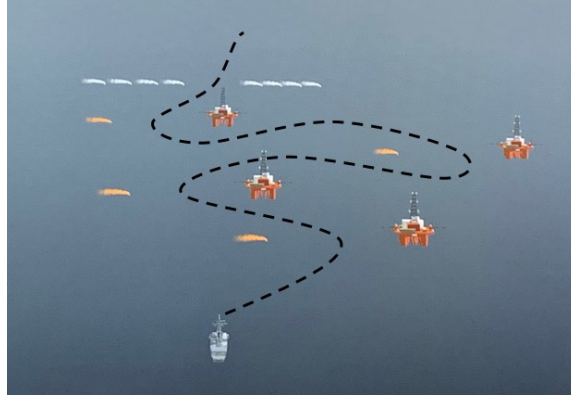


Figure 4. Scenario Course

The data that the Kongsberg system produced that was later used for analysis were the ship's latitude and longitude, speed, rudder changes, and heading. The data were collected in two-second intervals throughout the entire scenario.

2. Physiological Devices

The BioNomadix Wireless Photo Plethysmogram (PPG) and Electrodermal Activity (EDA) Transmitter was used to monitor eccrine (skin sweating) activity during each scenario for each participant (see Figure 5) (BIOPAC Systems, Inc, 2020a). The BioNomadix Wireless Respiration (RSP) and ECG Transmitter was used to monitor electrical activity generated by the heart (see Figure 5) (BIOPAC Systems, Inc, 2020b). The EDA monitor was connected to electrodes placed on the participant's left palm about 1 to 2 inches apart (see Figure 6). The electrodes used by the ECG transmitter were attached to the participant's left and right collar and below the left rib (see Figure 7). The electronic signal from both transmitters were automatically recorded in the *AcqKnowledge* program. The *AcqKnowledge* software lets the user view, transform, replay, and analyze data.

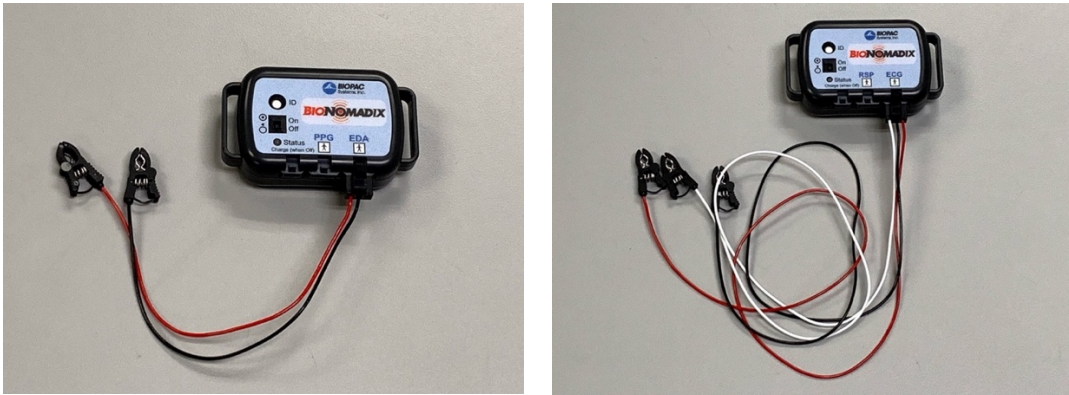


Figure 5. EDA Monitor (left) and ECG Monitor (right)

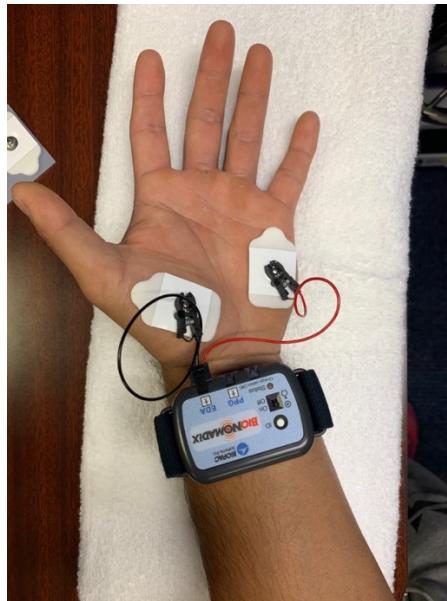


Figure 6. EDA Monitor Connected to Electrodes Placed on the Participant's Left Palm about 1 to 2 Inches Apart

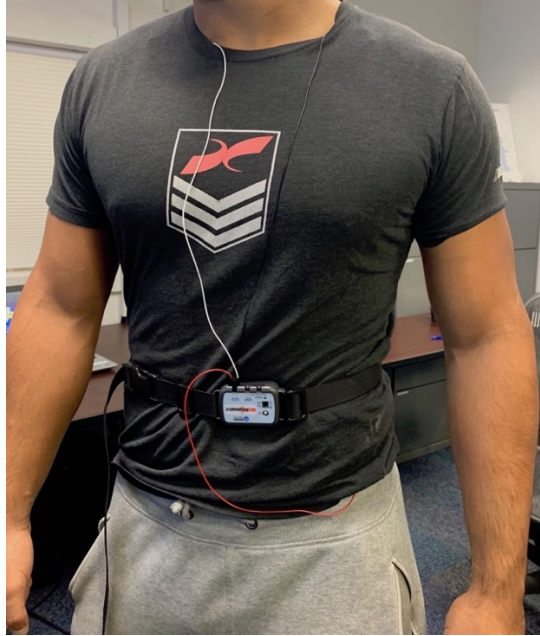


Figure 7. ECG Transmitter Connected to Electrodes Placed on the Participant's Left and Right Collar and below the Left Rib

The CNAP Monitor 500 was used in order to monitor each participant's blood pressure throughout each scenario (see Figure 8). The CNAP provides real-time systolic (SBP), diastolic (DBP), mean arterial (MAP) blood pressure and pulse rate. Each participant conducted the scenarios while standing in front of the helm with their left arm connected to the CNAP Monitor and EDA transmitter (see Figure 9). Their left arm was stabilized using an adjustable height table which was adjusted to put their arm at heart level (see Figure 10). The CNAP Monitor was directly connected to the *AcqKnowledge* program for instantaneous and synchronized recording along with the EDA and ECG transmitters.



Figure 8. CNAP Monitor 500



Figure 9. Participant's Left Arm Stabilized by Table and Connected to CNAP and EDA Transmitter



Figure 10. Participant with CNAP, ECG, and EDA Connected and Left Arm Stabilized by Table

The BIOPAC system was the primary tool used to consolidate physiological data from each participant. The BioNomadix Wireless EDA and ECG Transmitter and CNAP Monitor 500 transmitted to the BIOPAC which displayed real-time data using the *AcqKnowledge* software. For each participant, the transmitter collected data continuously from initial hook up to the end of the experiment. Event markers were placed in the data to identify when each phase of the experiment occurred. For each phase of the experiment, a 20–30 second window was selected to collect mean heart rate, blood pressure, and EDA measures. Every effort was made to find a 20–30 second window where each physiological reading could be recorded. However, if technical issues or recalibration occurred for an instrument, a separate 20–30 second window within the same phase of the experiment was used.

Four saliva samples were collected from each participant. Before and after both the Task Acquisition and Criterion Task, the participants provided 1.0 mL of saliva using a Salimetrics collection kit (see Figure 11) via the passive drool method. The samples were collected and stored in a U.S. Scientific Under-Counter Freezer (-86°). Each participant's saliva sample was labeled with the participant's ID and pre/post scenario identifier.



Figure 11. Salimetrics Collection Kit

Cortisol and alpha amylase were collected for each participant for Task Acquisition and Criterion Task. Saliva collection was conducted immediately prior to performing both Task Acquisition and Criterion scenario and immediately following each scenario. Between the start of the post Task Acquisition saliva collection and the pre-Criterion saliva collection there was a 15-minute time lapse. This allowed the participant's physiological responses to return to baseline as much as possible. A 15-minute time lapse was also allowed for the experiment group between the end of the stress training and the pre-Task Acquisition saliva collection.

3. Noldus Observer

The Noldus MediaRecorder was used in order to record each participant's scenarios from three different cameras around the lab. This element of the experiment allows playback for each scenario in order to identify possible behaviors related to particular physiological responses or stressful situations.

The Noldus Observer XT is a software package used to code behavior, synchronize data streams, and calculate statistics (*Data Integration & Visualization* | Noldus, 2020). The MediaRecorder and AcqKnowledge data were uploaded into the Noldus Observer XT to allow synchronization of video with physiological responses.

4. CWPS: BREG Polar Care Cube

The BREG Polar Care Cube was used to provide a cold stressor to the participants in the experiment group (see Figure 12). The Polar Care Cube can provide 6–8 hours of

cold therapy by adding ice to the water. In this research, the Multi-Use Wrap was used to apply cold to the lower back.



Figure 12. BREG Polar Care Cube

5. CPT: Bucket of Ice Water

The cold pressor used in the Criterion Task for each participant was a bucket of ice water. The bucket was filled with 4 inches of cold water and ice until the temperature of the water was recorded at $33 \pm 2^{\circ}\text{F}$.

6. Microsoft Excel

A macro was written in Visual Basic for Applications (VBA) in Microsoft Excel to transform the data exported from the Kongsberg to an easily imported format for both Nodus and R. Figure 13 shows the data that is exported from the Kongsberg which needed cleaning before being imported into Nodus in order to properly read the rudder angles and eliminate some unnecessary data. The data we wanted to analyze within Nodus was the speed, rudder changes, and heading. The cleaned data is shown in Figure 14.

Another macro was written in VBA to transform the data exported from the Kongsberg to a format relevant for mean squared error (MSE) calculations in R. For this

analysis, we needed the latitude and longitude from the Kongsberg data. Figure 15 shows the data received after applying the macro.

	A	B	C	D	E	F	G	H
1		Ownship	Ownship 1	Ownship 1	Ownship 1	Ownship 1	Ownship 1	Ownship 1
2		Parameter	Heading	Speed	Latitude	Longitude	Rudder order (1)	Rudder (1)
3			deg	kn	deg	deg	deg	deg
4			156	19.9	#DIV/0!	#DIV/0!	s2.2	s2.2
5			0	11.1	0	0	s35.0	s35.0
6			360	30.5	0	0	p35.0	p35.0
7	400	0:06:40	26	30.5	N32°42.715	W117°19.174	s17.8	s13.4
8	398	0:06:38	27	30.3	N32°42.701	W117°19.184	s14.6	s4.5
9	396	0:06:36	29	30.2	N32°42.686	W117°19.194	s1.7	p2.0
10	394	0:06:34	31	30.3	N32°42.672	W117°19.205	s1.6	p10.7
11	392	0:06:32	34	30.3	N32°42.659	W117°19.216	p13.0	p13.0
12	390	0:06:30	37	30.3	N32°42.645	W117°19.229	p13.0	p13.0
13	388	0:06:28	39	30	N32°42.632	W117°19.242	p13.0	p13.0
14	386	0:06:26	39	29.6	N32°42.619	W117°19.253	p13.0	p12.7
15	384	0:06:24	39	29.2	N32°42.606	W117°19.265	p13.0	p6.6
16	382	0:06:22	36	28.9	N32°42.592	W117°19.275	p13.0	s2.9
17	380	0:06:20	33	28.8	N32°42.579	W117°19.284	p13.3	s11.9
18	378	0:06:18	29	29	N32°42.564	W117°19.293	p11.8	s21.4
19	376	0:06:16	25	29	N32°42.550	W117°19.301	p1.2	s26.4
20	374	0:06:14	22	28.6	N32°42.535	W117°19.308	s18.0	s23.6
21	372	0:06:12	21	27.7	N32°42.520	W117°19.315	s29.5	s14.5
22	370	0:06:10	21	26.5	N32°42.507	W117°19.322	s19.3	s5.5
23	368	0:06:08	23	25.3	N32°42.494	W117°19.330	s19.3	p4.0
24	366	0:06:06	26	24.1	N32°42.481	W117°19.337	s18.8	p13.5
25	364	0:06:04	29	22.8	N32°42.470	W117°19.344	s14.6	p21.3
26	362	0:06:02	31	21.1	N32°42.460	W117°19.352	p3.1	p22.3
27	360	0:06:00	31	19.3	N32°42.449	W117°19.358	p26.3	p15.2
28	358	0:05:58	30	17.7	N32°42.441	W117°19.364	p28.1	p6.1
29	356	0:05:56	28	16.1	N32°42.432	W117°19.368	p25.4	s3.3
30	354	0:05:54	25	15.1	N32°42.423	W117°19.371	p10.2	s12.8

Figure 13. Kongsberg Data

	A	B	C	D	E	F	G
1	Time	Heading	Speed	R_Order	R_Order_Delta	R_Actual	R_Actual_Delta
2	seconds	degrees	knots	degrees	degrees	degrees	degrees
3	0	0	20	12.7	0	0	0
4	2	0	20	28.6	15.9	5.1	5.1
5	4	0	20.1	30.5	1.9	14.6	9.5
6	6	2	20.3	30.5	0	24	9.4
7	8	4	20.3	13.8	16.7	30.1	6.1
8	10	6	20.3	-3.7	17.5	28.4	1.7
9	12	9	20.3	-20.5	16.8	19.8	8.6
10	14	12	20.2	-34.6	14.1	10.8	9
11	16	15	20.3	-34.6	0	1.3	9.5
12	18	16	20.4	-34.6	0	-8.2	9.5
13	20	17	20.5	-34.6	0	-17.2	9
14	22	17	20.4	-34.5	0.1	-26.7	9.5
15	24	15	20.3	-34.6	0.1	-33.9	7.2
16	26	14	20.2	-17	17.6	-34.4	0.5
17	28	11	20.2	12.9	29.9	-28.7	5.7
18	30	8	20.3	15.1	2.2	-19.2	9.5
19	32	6	20.4	16.1	1	-10.2	9
20	34	3	20.6	16	0.1	-0.7	9.5
21	36	2	21	16.1	0.1	8.8	9.5
22	38	1	21.4	8	8.1	15.7	6.9
23	40	2	21.8	-10.4	18.4	14.7	1
24	42	3	22.2	-14.8	4.4	6.4	8.3
25	44	4	22.5	-2.6	12.2	-3.1	9.5
26	46	5	22.8	0.1	2.7	-8.4	5.3
27	48	4	23	12.7	12.6	-6.3	2.1
28	50	4	23.2	15.5	2.8	2.5	8.8
29	52	4	23.5	12.6	2.9	11.7	9.2
30	54	4	23.6	-4.4	17	14.8	3.1

Figure 14. Kongsberg Data after Macro for Noldus

	A	B	C	D	E	F	G	H	I	J	K
1			degrees	minutes	seconds		degrees	minutes	seconds	Latitude	Longitude
2	0 N		32	40	941 W		117	19	147	32.92805556	117.3575
3	2 N		32	40	953 W		117	19	147	32.93138889	117.3575
4	4 N		32	40	965 W		117	19	147	32.93472222	117.3575
5	6 N		32	40	976 W		117	19	147	32.93777778	117.3575
6	8 N		32	40	987 W		117	19	147	32.94083333	117.3575
7	10 N		32	40	999 W		117	19	147	32.94416667	117.3575
8	12 N		32	41	10 W		117	19	146	32.68611111	117.3572222
9	14 N		32	41	21 W		117	19	144	32.68916667	117.3566667
10	16 N		32	41	32 W		117	19	143	32.69222222	117.3563889
11	18 N		32	41	43 W		117	19	140	32.69527778	117.3555556
12	20 N		32	41	54 W		117	19	137	32.69833333	117.3547222
13	22 N		32	41	65 W		117	19	134	32.70138889	117.3538889
14	24 N		32	41	76 W		117	19	130	32.70444444	117.3527778
15	26 N		32	41	87 W		117	19	126	32.7075	117.3516667
16	28 N		32	41	98 W		117	19	123	32.71055556	117.3508333
17	30 N		32	41	109 W		117	19	120	32.71361111	117.35
18	32 N		32	41	119 W		117	19	117	32.71638889	117.3491667
19	34 N		32	41	131 W		117	19	115	32.71972222	117.3486111
20	36 N		32	41	143 W		117	19	113	32.72305556	117.3480556
21	38 N		32	41	154 W		117	19	112	32.72611111	117.3477778
22	40 N		32	41	166 W		117	19	112	32.72944444	117.3477778
23	42 N		32	41	178 W		117	19	111	32.73277778	117.3475
24	44 N		32	41	191 W		117	19	110	32.73638889	117.3472222
25	46 N		32	41	203 W		117	19	109	32.73972222	117.3469444
26	48 N		32	41	216 W		117	19	108	32.74333333	117.3466667
27	50 N		32	41	228 W		117	19	107	32.74666667	117.3463889
28	52 N		32	41	242 W		117	19	106	32.75055556	117.3461111
29	54 N		32	41	254 W		117	19	105	32.75388889	117.3458333
30	56 N		32	41	268 W		117	19	104	32.75777778	117.3455556

Figure 15. Kongsberg Data after Macro for R

7. R Studio

The Kongsberg simulator records each participant's course by sequencing the latitude and longitude coordinates of the ship every two seconds. The distance between the ideal course and participant course was computed for each coordinate in the ideal course using the haversine formula in R.

D. PERFORMANCE ANALYSIS

An ideal course was created in the Kongsberg scenario comprised of the two performance measures that were asked of each participant. Participants were instructed to remain centerline between each pair of oil rigs and smoke floats and to complete the course within seven minutes. For MSE calculations, we only needed the latitude and longitude of each participant's course. The ideal course was created in the simulator and the latitude and longitude data was collected. The Kongsberg collects latitude and longitude of the ship from the simulation every two seconds.

The ideal course data was cleaned with the Excel macros and uploaded into R. Each participant's data from the Kongsberg was then first compared graphically to the ideal course in R. Figure 16 shows an example of the ideal course with the overlay of a participant course for both Task Acquisition and the Criterion trials.

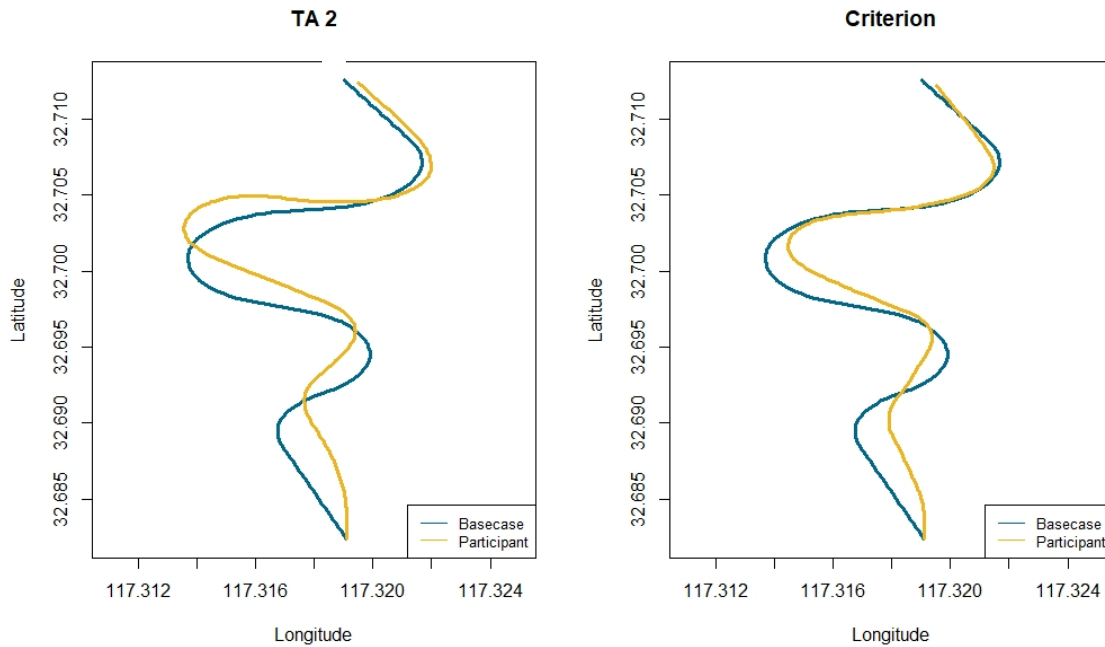


Figure 16. Example Participant Course versus Ideal Course

Let x_1, \dots, x_n be the sequence of latitude and longitude pairs corresponding to the participant's course, and let y_1, \dots, y_m be the sequence of latitude and longitude pairs corresponding to the ideal course. The RMSE of the participant's course is formed by aggregating the distances from each point x_i to the nearest point among the y_1, \dots, y_m . Let $h(x,y)$ be the haversine distance between two points x and y . We calculated the RMSE as shown in Equation 1.1. The percent improvement in performance was calculated using Equation 1.2. Some improvement in performance was expected simply due to familiarity with the course, but otherwise, the change in performance should be due to distraction or a response to the cold pressor.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n \min_{j=1, \dots, m} (h(x_i, y_j))^2} \quad \text{Equation (1.1)}$$

where:

$RMSE = RMSE$ for each participant

$n =$ coordinates in participant's course

$m =$ coordinates in ideal course

$$RMSE \text{ Percent Improvement} = \frac{\text{Task Acquisition } RMSE - \text{Criterion } RMSE}{\text{Task Acquisition } RMSE} \quad \text{Equation (1.2)}$$

E. PARTICIPANTS

Participants were recruited for the study from a pool of NPS students, DOD personnel, military personnel, NPS civilian employees and general public. Each participant must have had either no or very little experience in ship-driving. Basic training conducted in undergraduate commissioning sources was permissible. However, formal training such as BDOC was not permissible. Pregnant women and individuals under the age of 18 were not recruited for the study. Prior to participation in any research activity, all participants were screened for contraindications to the CWPS in accordance with the Standard Operating Procedures of the BREG Polar Care Cube Cold Water Perfusion System.

F. EXPERIMENTAL PROCEDURE

The experiment for each participant followed the schedule presented in Table 1 and Figure 2. Participants first arrived at the Human Systems Integration Lab (HSIL). Upon arrival, they completed the Informed Consent Form and Consent CPT and CWPS (see Appendix A–E) where, at any point, they could decline further participation. Participants were then given the CA Bill of Rights, Pre-Study Questionnaire, Saliva Sample Collection Notes, and Cohen Stress Scale. The Pre-Study Questionnaire acquired personal information and experience with video games and drones as well as simulator and ship-driving experience. Next, the experiment followed a randomized block design to assign the

participant to either the control group or an experiment group (Addelman, 1969). Blocking was the preferred method since it was unsure how many people would ultimately volunteer to participate in the experiment. The physiological equipment was then connected and calibrated.

Table 1. Experiment Protocol

Event	Duration
Administration (Participant Surveys, Informed Consent, etc.)	15 min
Physiological Equipment Set-up	15 min
Ship Familiarization Video and Practice	7 min
Stress Training (for treatment group) or HSI Video	3 min
Break	15 min
Task Acquisition: Data collected while undergoing one of the three conditions (CPT, CWPS, or neither)	10 min
Break	15 min
Criterion Task with CPT for everyone	10 min
Total	90 min

The first part of the experiment design involved training the participant in how to navigate the ship in the simulator. While the participant stood behind the helm, they watched a video which taught them how to use the helm, throttles, and information provided from the screens in front of them. They also received an overview of the course and specifics regarding the performance criteria, which they were graded on as they navigated through the scenario. See Appendix F–I for more details. Following the verbal instructions, the participant took a short verbal quiz in order to test knowledge of the skills required in the experiment. If an answer was incorrect, more instruction was provided.

Immediately following the quiz, the participant watched another video determined by whether they were in the control or experiment group. The experimental groups watched a 3-minute SIT video while those in the control group watched a 3-minute video not related to the SIT training to mimic the time lapse of the experiment group. The SIT video guided the participant through techniques which they used to manage and control their stress. The stress training was specific to the task of driving a ship and the performance criteria they

were given. After the stress training, each participant was given a 15-minute break where they sat on a chair and remained connected to the physiological devices.

Next, each participant began Task Acquisition. First, each participant provided a saliva sample. Next those in the experiment groups were exposed to either the CWPS or the CPT. Finally, the participants navigated the course and performed the skills they were taught during Ship Familiarization. Upon completion of the course, the cold pressor was removed if necessary, and the participant provided another saliva sample. Then, they were offered a chair to relax for another 15-minutes. This block of time was necessary in order to allow the participant's cortisol levels to return to their baseline levels before beginning their Criterion Task.

Finally, the participant began the final phase of the experiment. Participants first provided a saliva sample and then were exposed to the CPT. Then, they navigated through the course while still performing the skills they were taught and maintaining the performance criteria. After completion of the task, their foot was removed from the ice water and they began their final saliva collection. As they collected their saliva, the physiological connections were removed. This completed the participant's involvement in the experiment.

After the Criterion Task was completed, the data from the Kongsberg and *AcqKnowledge* was imported into the Noldus Observation for that participant. The data from the Kongsberg had to be cleaned by two Microsoft Excel Macros to be in the proper format for upload into the Noldus and R Studio.

G. VARIABLES

The independent variable in the experiment was the training protocol: stress training (CPT and CWPS) and no stress training. Performance on the ship bridge simulator (completion time and course error) and physiological measures, such as heart rate, blood pressure, electrodermal activity, cortisol, and alpha amylase, were dependent variables.

H. HYPOTHESIS

Friedland and Keinan (1992) and McClernon (2009) demonstrated that a bucket of ice water was a valid method for inducing physiological responses that indicate stress. In both studies, performance was enhanced after implementing SIT while the physiological effects of stress were diminished (McClernon, 2009).

This study hypothesized similar results by using the CWPS as the cold stressor. These two hypotheses are described below. The null hypothesis indicates that performance and physiological measures between stress and no-stress trained groups will be the same. The alternative hypothesis indicates performance improvement and less physiological response from the stress-trained treatment group.

$$H_0 : p_T = p_C, b_T = b_C, h_T = h_C, c_T = c_C$$

$$H_a : p_T > p_C, b_T < b_C, h_T < h_C, c_T < c_C$$

where,

p_T : criterion performance of stress-trained treatment group

p_C : criterion performance of no-stress-training control group

b_T : criterion blood pressure arousal of stress-trained treatment group

b_C : criterion blood pressure arousal of no-stress-training control group

h_T : criterion heart rate arousal of stress-trained treatment group

h_C : criterion heart rate arousal of no-stress-training control group

eda_T : criterion electrodermal arousal of stress-trained treatment group

eda_C : criterion electrodermal arousal of no-stress-training control group

c_T : criterion cortisol arousal of stress-trained treatment group

c_C : criterion cortisol arousal of no-stress-training control group

aa_T : criterion alpha amylase arousal of stress-trained treatment group

aa_C : criterion alpha amylase arousal of no-stress-training control group

IV. RESULTS

At the end of the experiment, there were 33 participants in the CWPS and Control groups. Two participants were not included; their data was removed due to technical failure on the Kongsberg simulator to properly change speed as ordered by the participant. Another participant was removed due to failure to collect baseline physiological data. The data from the remaining 30 participants included 26 males and 4 females. One female was in the CWPS group while three females were in the Control group. The participants' ages ranged from 22 to 47 with a median of 33. There were 15 participants in the Control group and 15 participants in the CWPS group.

A. DID THE COLD WATER PERFUSION SYSTEM INDUCE STRESS?

The baseline for each physiological measure was collected from a 20–30 second window when the participant is initially hooked up to the physiological equipment and before they begin Simulator Familiarization training. This measurement was considered their baseline level because it was taken before they began any training, stress exposure, or task performance. The Rate Pressure Product (RPP) is the product of the SBP and heart rate which is the global measure of work being done by the heart. The RPP allows us to get a better picture of how hard the participant's heart is working when exposed to the stressor since all participants do not respond with both blood pressure and heart rate. The distribution for each physiological measure can be found in Appendix K. There is significant difference in the baseline for EDA between the two groups, all other measures were similar at baseline. The median value for the Control group baseline is 7.5690 microsiemens whereas the median value for the CWPS group baseline is 4.0480 microsiemens. Because none of the measures was normally distributed, a non-parametric approach, the Wilcoxon Rank Sum Tests, was used for statistical analysis.

Appendix L contains baseline measures for all physiological responses from the BIOPAC and saliva samples for both CWPS and Control groups. Saliva samples were taken immediately before each task as shown in Figure 2. The EDA baseline for the two groups has a Wilcoxon Rank Sum p-value of 0.0591 and effect size of -0.3446. Figure 17

shows the EDA baseline for each group. This indicates that the median Control baseline for EDA was higher than the median CWPS baseline for EDA at the beginning of the experiment for EDA. In addition to EDA, the median MAP between Control and CWPS baselines have a high effect size of 0.2575. The median baseline for the CWPS group was higher than the Control group. Figure 18 shows the difference in baseline MAP between the two groups.

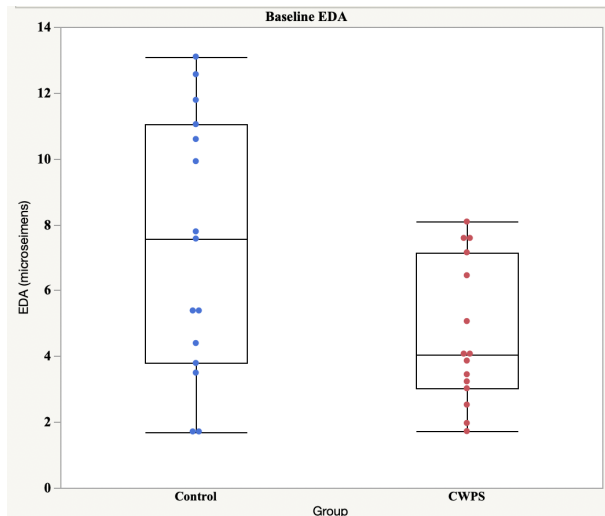


Figure 17. Baseline EDA for Control and CWPS Group

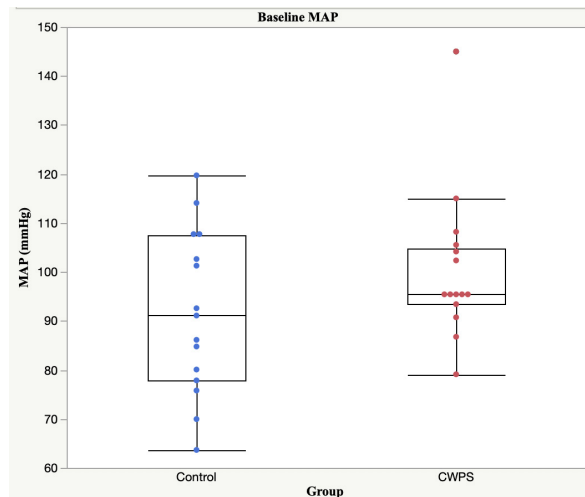


Figure 18. Baseline MAP for Control and CWPS Group

During Task Acquisition, our research null hypothesis tests whether the alpha amylase and cortisol arousal for both control and treatment group will be equal. For evidence against the null hypothesis, we use the Wilcoxon Rank Sum test and determine the effect size to find significance in difference in the change of alpha amylase and cortisol during Task Acquisition and Criterion Task. During Task Acquisition, we wanted to see if there were differences in stress hormones between groups to indicate the effectiveness of the CWPS. We compared the change in stress hormone during the Criterion to see if the treatment group effectively managed their stress.

Appendix M shows median post-task measures for alpha amylase and cortisol for each group. These samples were taken immediately after each task as shown in Figure 2. We see that the alpha amylase measure post Task Acquisition demonstrates the most significant difference. The table in Appendix M also includes the Wilcoxon Rank Sum tests significance values and effect size for the change in alpha amylase and cortisol during Task Acquisition and Criterion Task. There is sufficient evidence to claim that alpha amylase absolute delta and percent change during Task Acquisition was significantly more in the CWPS group than for the Control group. Figure 19 shows the percent change and absolute delta in alpha amylase between groups during Task Acquisition.

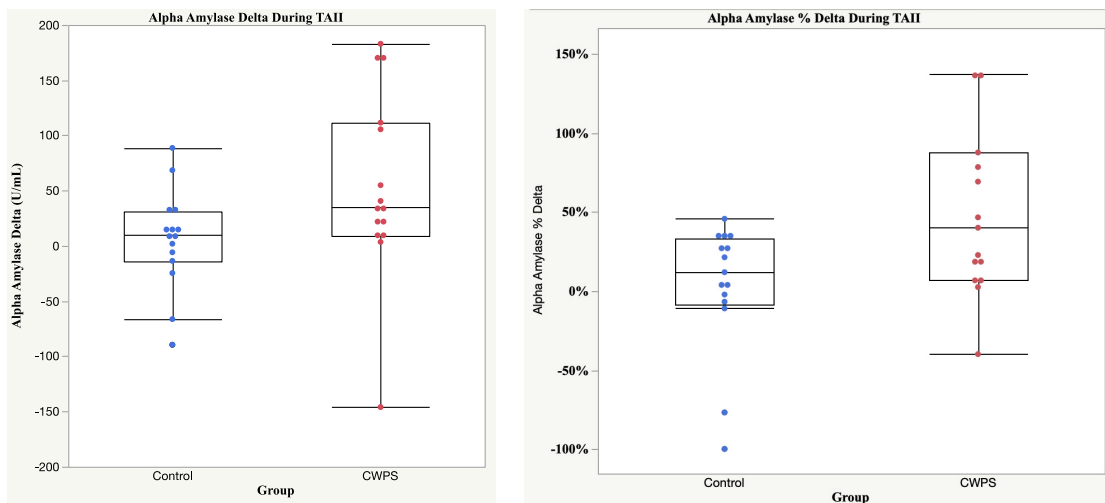


Figure 19. Alpha Amylase Delta and Percent Change during Task Acquisition

Wilcoxon Rank Sum tests and effect size were also calculated on percent change and absolute values for heart rate, MAP, EDA, SBP, DBP, and Rate Pressure Product (RPP) for CWPS and Control group during Task Acquisition. Appendix N includes significance values and effect size for each physiological measure. Table 4 includes significance values for the percent change in physiological measures and Table 5 includes significance values for absolute difference in physiological measures. There was a fairly large effect size of 0.3386 for the percent change in EDA during Task Acquisition.

Figure 20 shows the percent change for SBP percent change during Task Acquisition for all participants. Although not statistically different between Control and CWPS group, it was another physiological measure that demonstrated a different response between groups worth noting. We can see that the CWPS group experienced a larger SBP percent increase with a smaller variability. The Wilcoxon Rank Sum Test p-value is 0.5069 with an effect size of 0.1212.

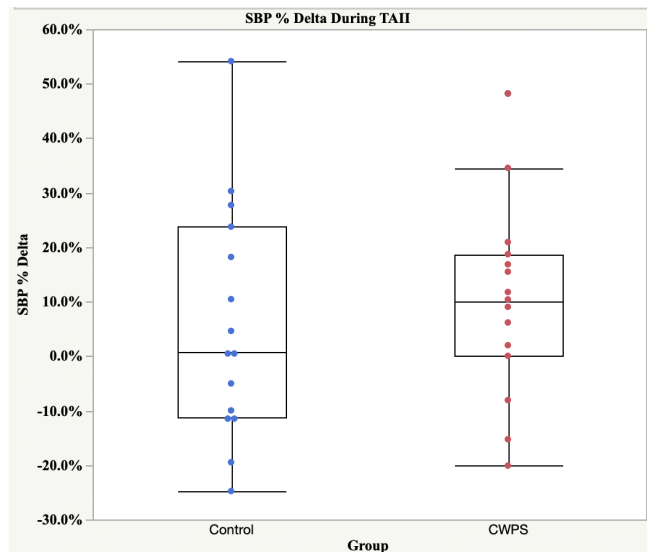


Figure 20. Percent Change for SBP during Task Acquisition

B. DOES SIT IMPROVE SHIP-DRIVING SKILL ACQUISITION AND PERFORMANCE?

The second research question was to determine if SIT using a Cold Water Perfusion System (CWPS) improves ship-driving skill acquisition and performance. For this study,

our primary metric for performance was to compare the RMSE for each participant between Task Acquisition and the Criterion Task trials. Our secondary metric for performance was the time to complete the Criterion Task. To test whether the CWPS improves ship-driving skill acquisition and performance, we needed to determine whether the RMSE scores of the CWPS group improved more than the Control group or whether the CWPS group performed the Criterion Task faster than the CWPS group.

Task Acquisition was considered complete if the participant completed the course without incurring a collision. The participants were instructed to complete the course within 7 minutes but they were allowed to continue driving until 10 minutes if they were not complete by 7 minutes. With the extended time constraint at 10 minutes, three participants crashed, two failed to complete the course, and 25 passed Task Acquisition. A collision or failure to complete the Criterion Task within 7 minutes constituted a failure. Completion of the Criterion Task under the 7 minute time limit is considered a pass. For the Criterion Task, the 30 participants included 0 collisions, 10 task failures, and 20 passes. There were four Criterion Task failures in the Control group and six failures in the CWPS group.

An improvement in performance would be indicated by a decrease in RMSE from Task Acquisition to Criterion Task. The RMSE percent improvement tells how much the participant was able to learn from Task Acquisition both with and without Stress Inoculation Training. Appendix O contains the distribution of RMSE during both tasks and completion time for the Criterion Task. Three participants who crashed during Task Acquisition were removed since they were outliers in the data. The distribution of RMSE and Criterion completion time are not normally distributed which justifies use of non-parametric statistics during analysis.

The null hypothesis of the research tests equality of performance between treatment group and the non-treatment group. To find evidence against the null hypothesis, we compare the median performance for each group during Task Acquisition and Criterion Task. We compare absolute RMSE, percent improvement of RMSE, and Criterion Task completion time using Wilcoxon Rank Sum tests. These statistics included those

participants who crashed during Task Acquisition and can be found in Appendix P. There were no significant differences in performance between Control and CWPS groups.

The CWPS group had a higher median score for RMSE during the Task Acquisition trial, likely due to experiencing a response to the CWPS. During the Criterion Task, both groups' RMSE performance was almost equal. Both groups demonstrated performance improvement which, in part, may have been due to being more familiar with the course. The CWPS group was able to more significantly improve their performance despite the cold pressor due to their Stress Inoculation Training although the absolute delta or percent improvement of RMSE was not statistically significant.

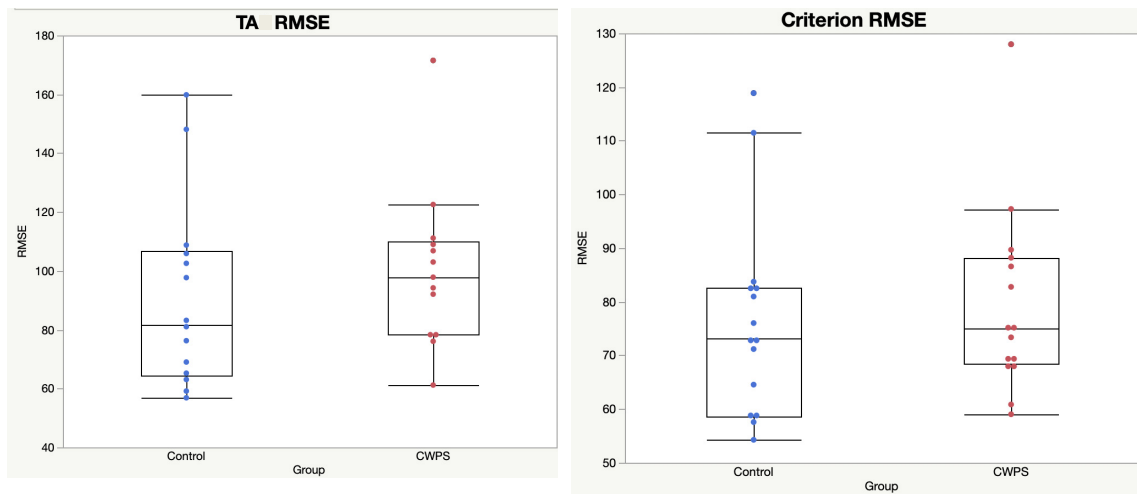


Figure 21. Absolute RMSE During Task Acquisition and Criterion Task for Both Control and CWPS Groups

C. DID SIT HELP MANAGE THE STRESS RESPONSE?

Stress Inoculation Training taught the CWPS group how to control their physiological responses to the cold stressor. To see the effects of the stress training, we compared the physiological responses of both groups during the Criterion Task. Appendix Q includes tables with the significance values of the differences in physiological responses during the Criterion Task for the Control and CWPS group. There was a relatively large effect size of -0.2877 for the percent increase in heart rate between the groups, meaning the Control group experienced a much larger spike in heart rate during the Criterion Task

than the CWPS group. This difference could easily be attributed to the stress training received by the CWPS group.

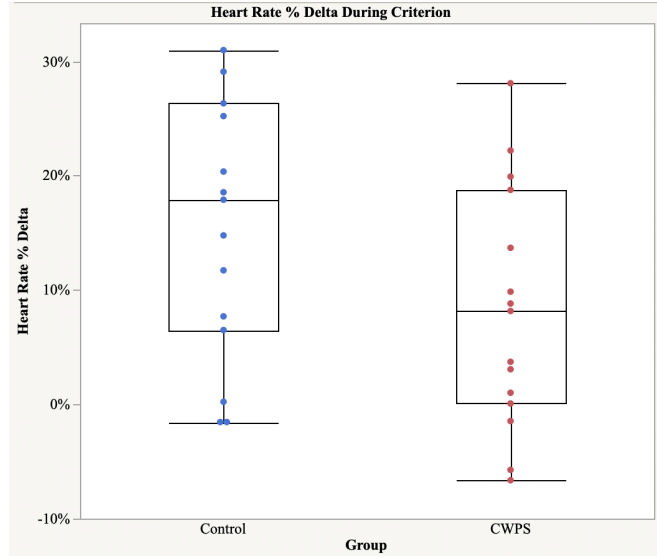


Figure 22. Heart Rate Percent Delta during Criterion Task for Control and CWPS Group

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V. CONCLUSIONS

This section provides the results obtained from the experiment using the data analysis described above.

A. EFFECTIVENESS OF COLD WATER PERFUSION SYSTEM TO INDUCE STRESS

The first objective of this research was to determine if the Cold Water Perfusion System effectively induces stress by increasing physiological responses. To answer this research question, we looked at the change in physiological responses during Task Acquisition for the Control and CWPS group. For alpha amylase, we have sufficient evidence to claim that the CWPS group experienced significantly more stress than the Control group during Task Acquisition. The CWPS did induce stress and caused a greater physiological response during Task Acquisition for the CWPS group than for the Control group. The Wilcoxon Rank Sum Test p-value was 0.0344 for the percent difference in alpha amylase between the CWPS and Control group. The Control group only experienced stress from the task whereas the CWPS group experienced stress from both the task and the cold pressor. These results would perhaps be more robust if there had been a larger sample size.

B. PERFORMANCE DIFFERENCES DUE TO CWPS

The primary objective of this research was to determine if Stress Inoculation Training using a Cold Water Perfusion System improves ship-driving skill acquisition and performance while operating in a stressful situation. To answer this question, we looked at the RMSE percent improvement from Task Acquisition to the Criterion Task. If Stress Inoculation Training improves participant skill acquisition and performance, the percent improvement for the CWPS group would be significantly higher than for the Control group. This research did not provide sufficient evidence to claim that the RMSE percent improvement for the CWPS group was greater than the Control group. However, there is still a difference in performance between the groups. The CWPS did have a greater median RMSE percent improvement than the Control group.

C. SIT REDUCES STRESS RESPONSE DURING CRITERION TASK

As additional findings during analysis, we found that the CWPS group, by having a smaller percent increase in heart rate, was more effective than the Control group at managing their response to stress during the Criterion Task. The Wilcoxon Rank Sum Test did not provide a significant p-value, but the effect size was 0.2877. This shows that the stress training received by the CWPS group was effective in training the participants to manage their stress response not only while experiencing the CWPS, but also while experiencing the CPT.

D. FUTURE WORK

Further studies on additional types of cold pressors or stressors could enhance the conclusions of this thesis as well as including a larger sample size of participants which would allow for more robust analysis.

APPENDIX A. PRE-STUDY QUESTIONNAIRE



Naval Postgraduate School

Date: _____ Participant ID: _____

Pre-Study Questionnaire

Instructions: Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.

1. What is your age: _____ years	
2. Gender (Check one <input checked="" type="checkbox"/> <input type="checkbox"/> Male <input type="checkbox"/> Female	
3. Height: _____	
4. Weight: _____	
5. Which best describes your affiliation:	
<input type="checkbox"/> DOD EMPLOYEE <input type="checkbox"/> NAVY <input type="checkbox"/> OTHER _____	
Military, what is your rank and paygrade: _____	
Years on active duty: _____	
6. Do you have simulator experience? (Check one <input checked="" type="checkbox"/> <input type="checkbox"/> Yes <input type="checkbox"/> No	
7. Do you have ship driving experience? (Check one <input checked="" type="checkbox"/> <input type="checkbox"/> Yes <input type="checkbox"/> No	
If YES to either question 5 or 6, please specify all experience you have:	
8. Are you feeling well and healthy today? (Check one <input checked="" type="checkbox"/> <input type="checkbox"/> Yes <input type="checkbox"/> No	
9. How much experience do you have with each of the following: VIDEO GAMES <input type="checkbox"/> A lot <input type="checkbox"/> Some <input type="checkbox"/> Average <input type="checkbox"/> A little <input type="checkbox"/> None	DRONES <input type="checkbox"/> A lot <input type="checkbox"/> Some <input type="checkbox"/> Average <input type="checkbox"/> A little <input type="checkbox"/> None

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APPENDIX B. CALIFORNIA BILL OF RIGHTS

California Experimental Subject's Bill of Rights (California Informed Consent Form Guidelines, 2012)

Any person who is requested to consent to participate in a research study involving a medical experiment, or who is requested to consent on behalf of another, has the right to:

1. Learn the nature and purpose of the study.
2. Receive an explanation of the procedures to be followed in the medical study, and a description of any drug or device to be used.
3. Be informed of any related discomforts and risks that can reasonably be expected from participating in the study.
4. Learn about any benefits you might expect from the study, if applicable.
5. Be told about any other procedures, drugs or services that might be helpful to you and the relative risks and benefits of these alternatives.
6. Be informed of the medical treatment, if any, available to you if you are injured because of the study.
7. Ask any questions about the study.
8. Stop the study at any time without any effect on your healthcare benefits or medical care, even if you stop the study.
9. Receive a copy of the signed and dated consent form when one is required.
10. Decide to consent or not to consent to a medical study without feeling forced to participate

Printed Name of the Participant

Signature of the Participant

Date: _____

Research Sponsor: Navy Advanced Medical Development Program (NAMMD)

Study Protocol Number:

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APPENDIX C. COHEN PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and the thoughts during the last month. In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate (*A Global Measure of Perceived Stress on JSTOR*, n.d.) (Cohen, 1994) (Cohen & Janicki-Deverts, 2012).

For each question choose from the following alternatives:

- 0 = Never
- 1 = Almost Never
- 2 = Sometimes
- 3 = Fairly Often
- 4 = Very Often

	0	1	2	3	4
1. In the last month, how often have you been upset because of something that happened unexpectedly?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. In the last month, how often have you felt that you were unable to control the important things in your life?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. In the last month, how often have you felt nervous and "stressed"?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. In the last month, how often have you felt that things were going your way?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. In the last month, how often have you been able to control irritations in your life?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. In the last month, how often have you felt that you were on top of things?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. In the last month, how often have you been angered because of things that were outside of your control?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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APPENDIX D. PARTICIPATION SCREENING FORM

Cold Pressor Test / Cold Water Perfusion System Study Participation Screening Form

This study uses cold exposure to investigate the effects of stress on performance. Please carefully review the following criteria to determine if you are eligible to participate in this study. DO NOT participate in this study if you have any of the following:

- History of cold injury, frostbite, adverse reactions to cold, or pathologic sensitivity to cold
 - History of a circulatory condition, such as Raynaud's disease, Buerger's disease, peripheral vascular disease, vasoplastic disorders, sickle cell anemia, or clotting disorders
 - History of peripheral neuropathy
 - History of cardiovascular disease, hypertension, or diabetes
 - History of anxiety disorder or Post Traumatic Stress Disorder (PTSD)
 - Use of medications or products that negatively affect circulation, such as beta blockers, tobacco, excessive alcohol, or excessive caffeine
 - Areas of the body that have compromised circulation, open wounds, infection, or other skin conditions
- I do not have any of the above conditions and would like to participate in the Cold Water Perfusion System study.

Print Name

Signature

Date

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APPENDIX E. CONSENT FORM

Naval Postgraduate School Consent to Participate in Research

Introduction. You are invited to participate in a research study entitled “Evaluation of Stress Inoculation Training on Ship Simulator Training Retention”.

The purpose of this research is to investigate the effects that stress training has on stressful ship navigation in order to mitigate the human factors preconditions to ship collisions or accidents. Stress training implementation strategies are also investigated in order to develop pedagogy pertinent to stress training. Participants will be asked to perform real ship navigation tasks in a virtual ship simulator while under the stress of cold.

Your participation in this experiment will last approximately one and a half hours. The experiment consist of verbal instructions, practical instructions, training sessions, and a final criterion trial. If you are placed in an experimental stress exposure group, your foot will either be submerged in 3 inches of ice cold water or an ice cold sleeve will be placed on your lower back for the duration of the initial ship driving task (approximately 10 minutes). For all groups, during the final ship driving scenario lasting approximately 10 minutes, your foot will be submerged in 3 inches of ice cold water.

Prior to participation, physiological sensors will be placed on your body. These sensors will measure responses to the tasks that you will perform. The data collected by these sensors will not be analyzed for any purpose other than this study, and any findings in this study can in no way disqualify you or military service.

Due to the immersive nature of the simulator, you may experience slight simulator sickness. You may also experience discomfort associated with the cold stressor. Potential conditions you may experience include nausea, dizziness, headache, numbing of the limbs, and skin discomfort. If at any time you experience any of these or other symptoms, you are asked to notify the experimenter immediately.

This study will involve up to 75 participants. If any of the following contraindications apply to any participant, they will be excluded from participation in this research:

1. Pregnancy
 2. History of cold injury, frostbite, adverse reactions to cold, or pathologic sensitivity to cold
 3. History of a circulatory condition, such as Raynaud’s disease, Buerger’s disease, peripheral vascular disease, vasospastic disorders, sickle cell anemia, or clotting disorders
 4. History of peripheral neuropathy
 5. History of cardiovascular disease, hypertension, or diabetes
 6. History of anxiety disorder or Post Traumatic Stress Disorder (PTSD)
 7. Use of medications or products that negatively affect circulation, such as beta blockers, tobacco, excessive alcohol, or excessive caffeine
 8. Application areas that have compromised circulation, open wounds, infection, or other skin conditions
 9. Reduced ability to understand study instructions or communicate with research personnel
- The experiment will take place in the Crew Endurance and Stress Laboratory at NPS, located in Glasgow 221.

Cost. There is no cost to participate in this research study.

Compensation for Participation. There is no direct benefit to you for participating in the research. No tangible compensation will be given. A copy of the research results will be available at the conclusion of the experiment by contacting the experimenters at laclemen@nps.edu or clarese.neill@nps.edu.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research records confidential but total confidentiality cannot be guaranteed. No information will be publicly accessible which could identify you as a participant, and only code numbers will be used on all research forms/databases. Your name on any signed document will not be paired with your code number in order to protect your identity. Records of your participation will be kept on secure servers and/or in locked facilities in accordance with NPS policies, and then destroyed. However, it is possible that the researcher may be required to divulge information obtained in the course of this research to the subject's chain of command or other legal body.

The subject's information or biospecimens collected as part of the research, even if identifiers are removed, will not be used or distributed for further research studies.

Audio Video Recordings. Audio and/or video recordings will be obtained during this study. These may be used for data collection and analysis, shared with students and instructors, and/or shared with individuals or entities outside of NPS, with permission from the individuals portrayed in the recordings. Any digital copies of recordings retained by NPS will be safeguarded and stored on secure computers and servers; any hard copies of recordings will be stored in a cipher-locked room.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, Dr. Nita Shattuck at nlshattu@nps.edu, (831) 656-2281. The primary research monitor, Dr. Heather Clifton, can be reached at heather.clifton@nps.edu, (831) 656-2277. Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Vice Chair Mr. Bryan Hudgens at bryan.hudgens@nps.edu, (831) 656-2039.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights. I understand that the alternative to participating in the research is to not participate.

Study participation. I consent to participate in this research study.

Audio/video recordings. I grant permission for the Naval Postgraduate School to record, review and analyze any audio or video recordings of me generated during this study for research purposes,

Audio/video internal release. I grant permission for audio or video recordings of me, or summaries or transcripts of these recordings, to be used and/or distributed for research, educational, or reporting purposes with individuals from the Naval Postgraduate School. I understand that I may revoke this permission at any time, but must communicate this in writing to the Principal Investigator.

Audio/video external release. I grant permission for audio or video recordings of me, or summaries or transcripts of these recordings, to be used and/or distributed for research, educational, reporting, and promotional purposes with individuals or entities outside of the Naval Postgraduate School. I understand that I may revoke this permission at any time, but must communicate this in writing to the Principal Investigator.

Signature of Participant

Date

APPENDIX F. SIMULATOR FAMILIARIZATION SCRIPT

SIMULATOR FAMILIARIZATION

This script was adapted from the scripts used by McClernon's in his experiment studying stress effects on performance in a flight simulator environment (McClernon, 2009).

The following are the verbal instructions which will be read to the participant.

INTRODUCTION

We will now begin the first phase of the experiment. During this phase you will be read instructions regarding how to use the controls and instruments for the bridge simulator. The ship you will be driving for this experiment will be a Flight II Arleigh Burke Destroyer.

CONTROLS

This is the Kongsberg Ship Bridge Simulator. There are three screens in front of you. The screen to your right is the panorama screen which indicates rudder position and ship speed. The screen to your left is the ships' SPS-73 RADAR, which will provide you with situational awareness of your surroundings. The screen in the center is your viewpoint while standing centerline on the bridge of the Arleigh Burke Destroyer.

The ship you will be driving will be controlled at the helm. Please step up to the helm and place your right hand on the wheel. Please practice each skill as I describe how to use each control.

To turn the ship to the right, gently turn the helm to the right. By adjusting the helm, you are directly swinging the ship's rudder. To turn left, gently turn the helm left.

As you are swinging your rudder, you will notice a notch in the helm. At this point, the helm is indicating the rudder to amidships. At this time, turn your rudder to amidships.

The screen on the helm, directly in front of you, will indicate the Rudder Command in red and green font. The red numbers indicate a left degree rudder angle and the green indicate a right degree rudder angle. These numbers reflect the rudder ordered by you at the helm. The Rate of Turn indicator on the screen will give you an indication of how fast the ship is turning.

The throttles to the right on the helm will allow you to control the speed of the ship. By pushing the throttles forward, you will increase the speed of the ship. By pulling toward you, you will decrease the speed. As you pull back on the throttles you will notice a notch at 0. This is the point where all engines are at zero power and any point beyond this point will be a reverse engine order.

The screen to your right, the panorama screen, will give you an indication of the speed of the ship through the water. This may vary from the speed ordered with the throttles due to ocean current or if the ship is in a tight turn.

Do you have any questions regarding the simulator controls? (Pause video if questions arise)

QUIZ

You will now take a short quiz regarding the training you just received.

What information will you receive from the panorama view, the screen to your left?
Rudder and Speed

Turn the ship using a left 15 degree rudder.

Increase the speed of the ship using the throttle controls.

During the scenario, you will be placed at the start of a course which you will navigate using the helm and throttle controls. During the course, you will pass through pairs of oil rigs and orange smoke floats. You will always pass the orange smoke floats to your left and oil rigs on your right.

Your goals throughout the course is to remain centerline between oil rigs and smoke floats and to complete the course under seven minutes. You will complete the course when you pass through the white smoke floats after the fourth oil rig.

You have 7 minutes to complete the course. If you hit an oil rig or smoke float, your scenario will end and you will continue to the next phase of the experiment.

You will now be given 2 minutes to practice driving the ship. This time should be used to become familiar with the way the ship moves as you adjust the helm and throttles.

This concludes your training. Do you have any questions at this time?

APPENDIX G . TASK ACQUISITION SCRIPT

TASK ACQUISITION

This script was adapted from the scripts used by McClernon's in his experiment studying stress effects on performance in a flight simulator environment (McClernon, 2009).

The following are the verbal instructions which will be read to the participant.

You are about to begin the second test session. This session will be similar to the previous practice session you just accomplished, and it will last approximately 10 minutes. Please wait to ask any other questions you may have until after the session, although do let me know if you become ill, are very confused, or need to stop for any other reason.

To review, please try to maintain the following parameters:

Stay in the center of the course by driving center between oil rigs and smoke floats. The smoke floats should always pass on your left and oil rigs on the right. Complete the course in 7 minutes or less.

Do you have any questions before we begin?

The simulator will begin at the entrance of the course. Are you ready?

If a participant is in the treatment group apply the cold pressor now.

This concludes the second test session. No additional simulator guidance will be provided at this time, but you are welcome to relax. The next part of the experiment will begin in 15 minutes.

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APPENDIX H. STRESS EXPOSURE SCRIPT

STRESS EXPOSURE

This script was adapted from the scripts used by McClernon's in his experiment studying stress effects on performance in a flight simulator environment (McClernon, 2009).

The following are the verbal instructions which will be read to the participant.

For the following test session, you will be exposed to a stressful cold pressor. During exposure to the cold pressor, or any stress, it is important to, first, maintain your normal breathing as best as possible. This will help calm and relax you. Next, attempt to focus on the task at hand, and ignore the distractions of the stressor. Focus on navigating the course and staying as close to the center of the course as possible.

Now, the cold pressor will be applied.

Wait one minute.

Notice how your breathing has increased. For the next few minutes focus on slowing and regulating your breathing while attempting to relax.

Wait a few minutes.

Now, attempt to ignore the stress of the cold and focus your attention on the ship driving task you have been assigned.

Wait a few minutes.

Finally, visualize the performance parameters you will have to maintain during the next session. They are:

Staying in the center of the course by driving center between the oil rigs and smoke floats. Completing the course in 7 minutes or less.

Wait a few minutes.

You may now remove the cold pressor.

The next phase of the experiment will begin in 15 minutes.

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APPENDIX I. CRITERION SCRIPT

CRITERION

This script was adapted from the scripts used by McClernon's in his experiment studying stress effects on performance in a flight simulator environment (McClernon, 2009).

The following are the verbal instructions which will be read to the participant.

You are about to begin the third and final test session. For the following test session, you will be exposed to a stressful cold pressor. This session will be similar to the previous test sessions you have accomplished, and it will last approximately 10 minutes. Please wait to ask any other questions you may have until after the session, although do let me know if you become ill, are very confused, or need to stop for any other reason.

You are required to maintain the following parameters:

Staying in the center of the course by driving center between oil rigs and smoke floats.
Completing the course in 10 minutes or less.

The simulator will begin at the entrance of the buoy course. Are you ready?

Now, the cold pressor will be applied.

This concludes the experiment.

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APPENDIX J. RECRUITMENT POSTER

The poster features a background image of a large white research vessel at sea, with a coastal town visible on the left. At the top center is the NPS logo, which includes a shield with 'NPS' and the motto 'FRAUSTANTIA PER SCIENTIAM'. The main title 'Volunteers Needed!' is in a large, white, serif font, underlined. Below it, the subtitle 'Learn How To Navigate A Ship!' is in a smaller, white, sans-serif font. The main text describes the study: '60-75 volunteers are needed to participate in an exciting research study! You will navigate a ship through a real-world scenario while exposed to a cold stressor in the HSI lab.' A note in smaller font states '*Total participation time is approximately 90 minutes'. A list of criteria follows: 'All Volunteers must meet the following criteria: - Limited or no experience navigating a ship - Limited or no experience in a ship simulator - No history of circulatory, cardiovascular, neurological, or anxiety conditions'. At the bottom, contact information is provided: 'If you are interested in volunteering and meet the above criteria, please contact: Clarese Neill (clarese.neill@nps.edu) Principal Investigator: Nita Shattuck (nlshattu@nps.edu - (831) 656-2281) IRB Vice Chair: Mr. Bryan Hudgens (bryan.hudgens@nps.edu - (831) 656-2039)'.


Volunteers Needed!
Learn How To Navigate A Ship!

60-75 volunteers are needed to participate in an exciting research study! You will navigate a ship through a real-world scenario while exposed to a cold stressor in the HSI lab.

*Total participation time is approximately 90 minutes

All Volunteers must meet the following criteria:

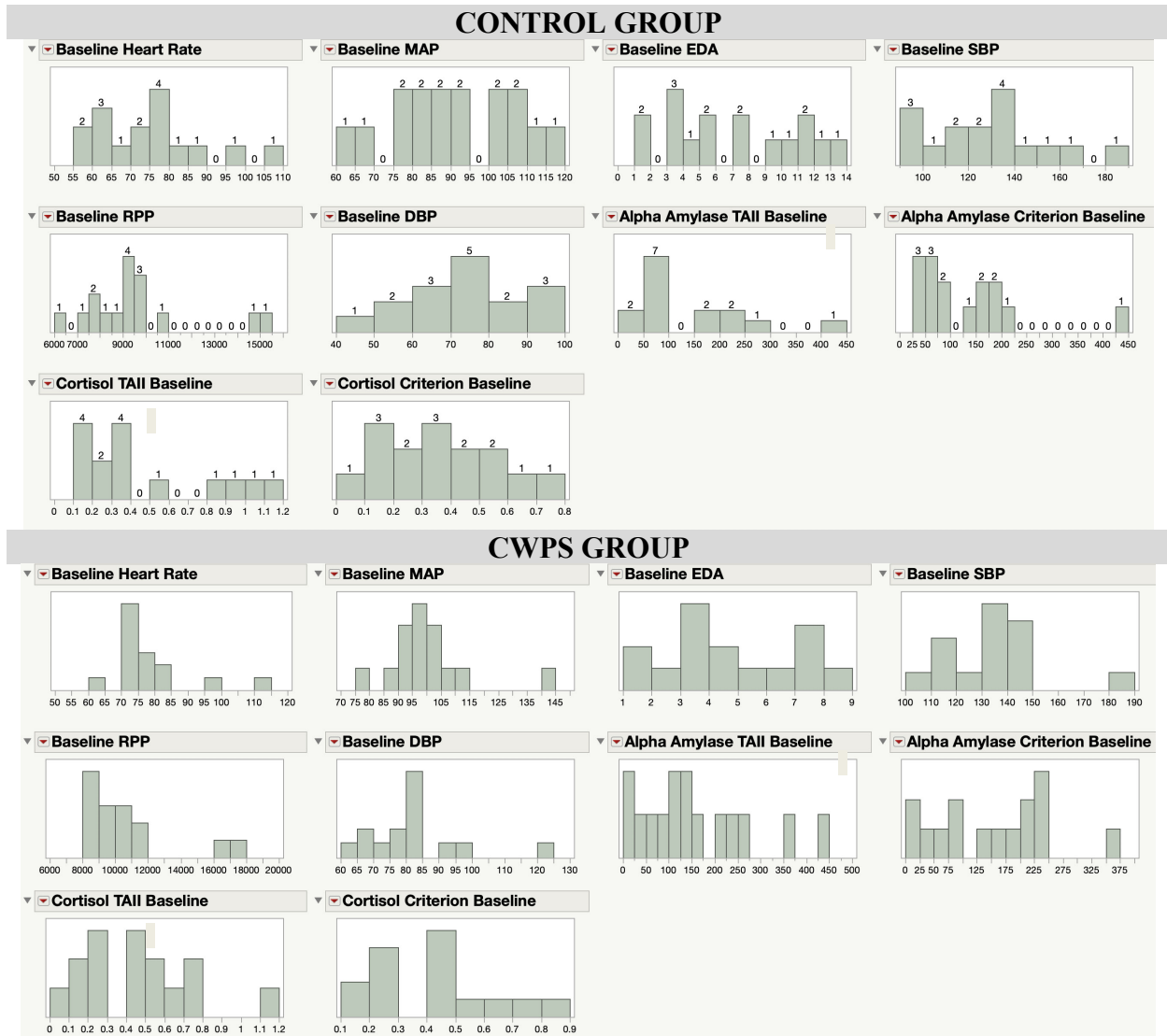
- Limited or no experience navigating a ship
- Limited or no experience in a ship simulator
- No history of circulatory, cardiovascular, neurological, or anxiety conditions

If you are interested in volunteering and meet the above criteria, please contact:
Clarese Neill (clarese.neill@nps.edu)
Principal Investigator: Nita Shattuck (nlshattu@nps.edu - (831) 656-2281)
IRB Vice Chair: Mr. Bryan Hudgens (bryan.hudgens@nps.edu - (831) 656-2039)

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APPENDIX K. PHYSIOLOGICAL DISTRIBUTION OF BASELINE MEASURES

Figure 23. Distribution for Baseline Values for each Physiological Measure



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APPENDIX L: PHYSIOLOGICAL BASELINE MEASURES

Table 2. Significance Values for Baseline Physiological Measures for Control and CWPS Group

Baseline Measures for All Physiological Measures				
	<i>Control (n=15)</i> <i>Median and IQR</i>	<i>CWPS (n=15)</i> <i>Median and IQR</i>	<i>Z</i>	<i>Wilcoxon Rank Sum Test P-Value and Effect Size</i>
Heart Rate (bpm)	75.4730 (61.6750, 80.6570)	74.9250 (70.7470, 80.3420)	0.7881	0.4306 (0.1439)
MAP (mmHg)	91.0990 (77.8590, 107.4460)	95.4480 (93.4150, 104.8460)	1.4102	0.1585 (0.2575)
EDA (microsiemens)	7.5690 (3.7910, 11.0440)	4.0480 (3.0220, 7.1510)	-1.8875	0.0591 (-0.3446)
SBP (mmHg)	134.4370 (108.4800, 149.1400)	132.2600 (117.4690, 141.5320)	0.3733	0.7089 (0.0682)
DBP (mmHg)	72.8190 (65.925, 89.5360)	80.3410 (70.1620, 83.8760)	1.2443	0.2134 (0.2272)
Rate Pressure Product (RPP) (bpm*mmHg)	9198.2095 (7895.0919, 9674.4885)	9868.3574 (8529.0647, 11046.1151)	1.2858	0.1985 (0.2348)
Alpha Amylase TA (U/mL)	89.7774 (58.7450, 205.6885)	126.0830 (74.8170, 232.6670)	0.3733	0.7089 (0.0682)
Cortisol TA (µg/dL)	0.3195 (0.1935, 0.8250)	0.4305 (0.2035, 0.6155)	0.0415	0.9669 (0.0076)
Alpha Amylase Criterion (U/mL)	91.84 (54.7776, 176.0705)	163.1635 (50.7910, 227.4515)	0.9125	0.3615 (0.1666)
Cortisol Criterion (µg/dL)	0.3280 (0.1495, 0.5125)	0.4500 (0.2105, 0.5735)	0.6637	0.5069 (0.1211)

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APPENDIX M. ALPHA AMYLASE AND CORTISOL MEASURES

Table 3. Significance Values for Difference in Alpha Amylase and Cortisol Measures

Significance of Difference for Alpha Amylase and Cortisol Measures				
	<i>Control (n=15) Median and IQR</i>	<i>CWPS (n=15) Median and IQR</i>	Z	Wilcoxon Rank Sum Test P-Values (n=31) and Effect Size
Post TA Alpha Amylase (U/mL)	100.07 (54.87, 201.51)	220.8585 (114.56, 293.31)	1.8665	0.0620 (0.3478)
Post TA Cortisol (µg/dL)	0.368 (0.2225, 0.638)	0.493 (0.209, 0.596)	0.463	0.6482 (0.0845)
Post Criterion Alpha Amylase (U/mL)	143.78 (104.026, 182.96)	226.09 (122.08, 288.59)	0.9125	0.3615 (0.1666)
Post Criterion Cortisol (µg/dL)	0.3035 (0.2075, 0.563)	0.313 (0.19, 0.542)	-0.2074	0.8357 (-0.0379)
TA Alpha Amylase Absolute Delta (U/mL)	8.7577 (-11.6686, 27.6668)	34.9315 (8.544, 111.5855)	2.2398	0.0251 (0.4089)
TA Cortisol Absolute Delta (µg/dL)	-0.00075 (-0.16125, 0.052625)	0.0155 (-0.02, 0.0625)	0.7260	0.4678 (0.1325)
TA Alpha Amylase % Increase	0.08176 (-0.06943, 0.319755)	0.40120 (0.071045, 0.87711)	2.1154	0.0344 (0.3862)
TA Cortisol % Increase	0.001332 (-0.28569, 0.20908)	0.02755 (-0.06834, 0.14518)	0.7881	0.4306 (0.1439)

Significance of Difference for Alpha Amylase and Cortisol Measures				
Criterion Alpha Amylase % Increase	0.25104 (-0.00609, 0.72387)	0.29418 (0.04187, 0.55874)	0.0415	0.9669 (0.0076)
Criterion Cortisol % Increase	0.03699 (-0.10475, 0.37496)	-0.097387 (-0.244873, 0.09164)	-1.1199	0.2628 (-0.2044)

APPENDIX N: DIFFERENCES IN PHYSIOLOGICAL MEASURES

Table 4. Significance Values for Percent Delta in Physiological Measures between Control and CWPS Group during Task Acquisition

Significance in Difference for each Physiological Measure				
<i>Percent Change</i> during Task Acquisition				
	<i>Control (n=15)</i> <i>Median and IQR</i>	<i>CWPS (n=15)</i> <i>Median and IQR</i>	<i>Z</i>	Wilcoxon Rank Sum Test P-Value and Effect Size
Heart Rate (bpm)	0.0375 (0.0046, 0.0996)	0.0274 (-0.0175, 0.1049)	-0.5807	0.5614 (-0.1060)
MAP (mmHg)	0.0400 (-0.0229, 0.2823)	0.1049 (0.0128, 0.2802)	0.2489	0.8035 (0.0454)
EDA (microsiemens)	0.4340 (0, 0.9275)	0.8166 (0.3023, 1.8516)	1.8548	0.0636 (0.3386)
SBP (mmHg)	0.0077 (-0.1115, 0.2375)	0.1014 (0.0004, 0.1869)	0.6636	0.5069 (0.1212)
DBP (mmHg)	0.0730 (-0.0419, 0.3009)	0.1427 (0.0692, 0.4387)	0.4563	0.6482 (0.0833)
RPP (bpm*mmHg)	0.0922 (-0.0100, 0.2931)	0.1662 (-0.0222, 0.2350)	0.4148	0.6783 (0.0757)

Table 5. Significance Values for Absolute Difference in Physiological Measures between Control and CWPS Group during Task Acquisition

Significance in Difference for each Physiological Measure				
<i>Absolute Difference</i> during Task Acquisition				
	<i>Control (n=15)</i> <i>Median and IQR</i>	<i>CWPS (n=15)</i> <i>Median and IQR</i>	<i>Z</i>	Wilcoxon Rank Sum Test P- Value and Effect Size
Heart Rate (bpm)	2.8320 (0.2790, 7.0080)	1.9400 (-1.0520, 10.3840)	-0.4977	0.6187 (-0.0908)
MAP (mmHg)	4.0920 (-2.7370, 21.9830)	11.9500 (1.0180, 29.1890)	0.4977	0.6187 (0.0908)
EDA (microsiemens)	2.2305 (0.4098, 4.2522)	3.0605 (2.2630, 6.2525)	1.7230	0.0849 (0.3146)
SBP (mmHg)	1.1460 (-15.3530, 25.7690)	13.2010 (0.0530, 26.5320)	0.9125	0.3615 (0.1666)
DBP (mmHg)	6.7410 (-4.0540, 22.0270)	10.5500 (5.7220, 35.4340)	0.4977	0.6187 (0.0909)
RPP (bpm*mmHg)	801.8191 (-97.0266, 2654.8656)	1720.6385 (-203.3824, 2485.8894)	0.6637	0.5069 (0.1212)

APPENDIX O: DISTRIBUTION OF RMSE AND CRITERION TIME

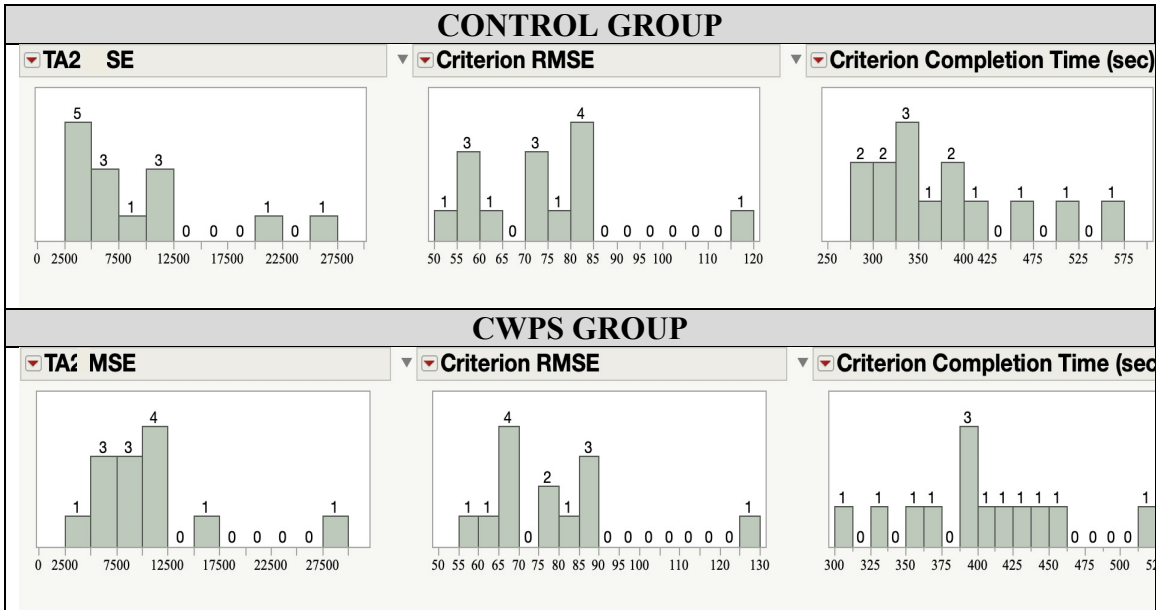


Figure 24. Distribution for Participant RMSE During Task Acquisition and Criterion and Criterion Completion Time in Seconds

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APPENDIX P: PERFORMANCE SIGNIFICANCE OF DIFFERENCE

Table 6. Significance Values for Performance Differences between Control and CWPS Group

Performance Significance Between Control and CWPS Groups				
	<i>Control (n=15)</i> <i>Median and IQR</i>	<i>CWPS (n=15)</i> <i>Median and IQR</i>	<i>Z</i>	Wilcoxon Rank Sum P-Value and Effect Size
TA RMSE	81.9506 (64.9752, 108.7564)	103.0002 (78.5656, 122.5493)	1.2443	0.2134 (0.2272)
Criterion RMSE	73.1577 (58.7171, 82.6667)	75.0192 (68.4379, 88.1970)	0.7466	0.4553 0.1363
RMSE Delta	21.5841 (-11.0492, 41.3441)	24.5506 (2.1451, 47.2433)	0.7881	0.4306 (0.1439)
RMSE % Improvement	0.2105 (-0.1701, 0.3904)	0.2666 (0.0351, 0.4091)	0.6222	0.5338 (0.1136)
Time to Complete Criterion Task (Sec)	361 (307, 451)	409 (374, 450)	1.5144	0.1299 (0.2765)

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APPENDIX Q: PHYSIOLOGICAL DIFFERENCES DURING CRITERION TASK

Table 7. Significance Values for Difference between Physiological Responses During Criterion Task Between Control and CWPS Group

Significance of Difference for Physiological Responses During Criterion Task				
	<i>Control (n=15) Median and IQR</i>	<i>CWPS (n=15) Median and IQR</i>	<i>Z</i>	<i>Wilcoxon Rank Sum Test P- Value and Effect Size</i>
Heart Rate % Delta	0.1789 (0.0649)	0.0816 (0.0007, 0.1875)	-1.5761	0.1150 (-0.2877)
MAP % Delta	0.2609 (0.0508, 0.3979)	0.1849 (0.1113, 0.3536)	-0.7051	0.4807 (-0.1287)
EDA % Delta	0.6993 (0.1679, 1.1075)	1.1174 (0.4181, 1.7449)	-0.9213	0.3569 (-0.1682)
Heart Rate Absolute Delta	11.2840 (6.0000, 18.4570)	6.2930 (0.0440, 15.0670)	-1.3688	0.1711 (-0.2499)
MAP Absolute Delta	22.1240 (5.4800, 34.6460)	16.9020 (10.4030, 30.8840)	-0.3733	0.7089 (-0.0681)
EDA Absolute Delta	3.7280 (0.6895, 6.0795)	4.4050 (2.3940, 7.4370)	-0.9213	0.3450 (-0.1682)

Table 8. Significance of Difference for Physiological Responses during Criterion Task

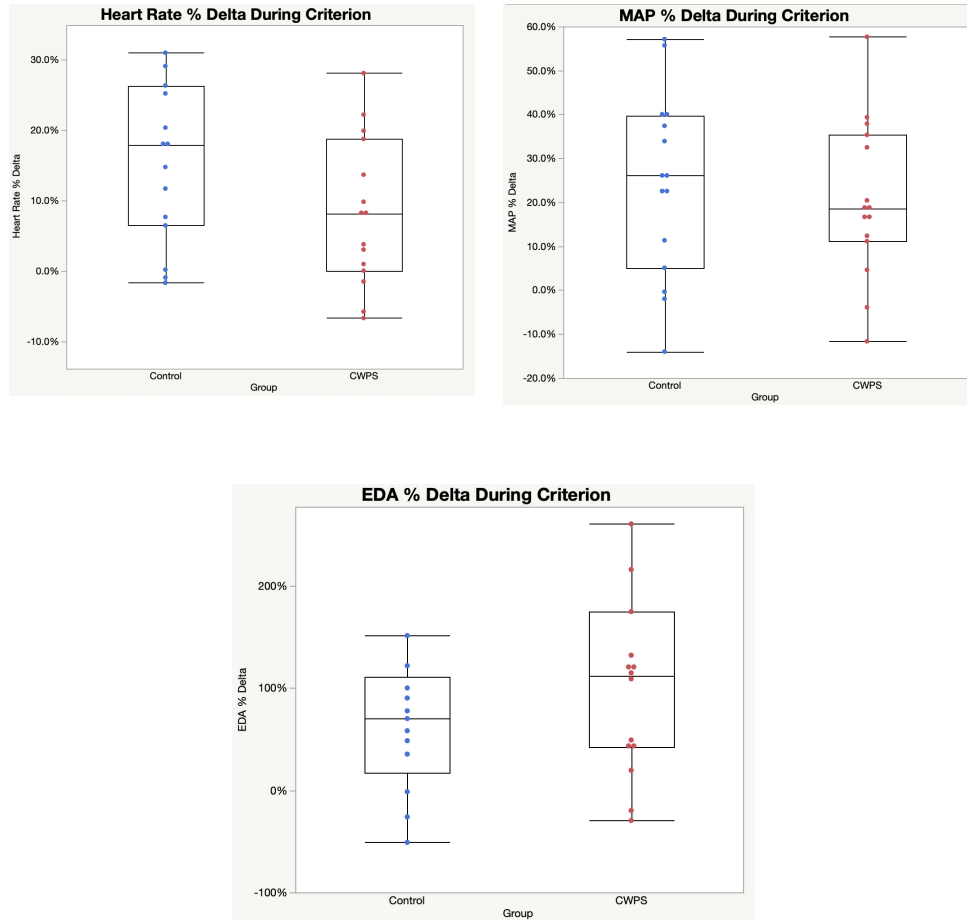


Figure 25. Percent Delta of Physiological Measures during Criterion Task for Control and CWPS Groups

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