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Perception vs. Reality: Improving Mission Commander Decision-Making Capabilities by use of Heart Rate Zone Feedback in Training Environments

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THESIS

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Abstract

In the military environment, it is common for commanders to rely exclusively on perceptional information (e.g., visual observations) to make decisions on their personnel's physical capabilities. There is little evidence to support the idea that the information provided by physiological feedback technology, typically made available to the individual visually, could improve assessments and decision-making capabilities of outside observers (e.g., mission commander in a remote location). Through experimental examination this research shows that commanders who have Heart Rate Zone (HRZ) biofeedback information about their Airmen by use of physiological technology were able to more accurately predict the level of effort and how much longer their Airmen were able to continue an AF relevant endurance activity (e.g., rucksack march) than those commanders without the biofeedback information.

Dedication

I want to thank my family, especially my husband whom no matter what has always supported me through this journey. I love you. I also want to thank AFRL specifically Dr. Fischer and Dr. Strang for their mentorship and also allowing me the chance to work on such an interesting project. I hope that AFRL and AFIT will continue this relationship for future research opportunities. I also want to say thank you to Dr. White for always being willing to help and staying patient with me when statistics just did not come easy. Finally, thank you to Lt Col Parr and Lt Col Overstreet for being a part of my committee and supporting me through this adventure. I am forever grateful.

Caitlin M. Oviatt

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PERCEPTION VS. REALITY: IMPROVING MISSION COMMANDER DECISION-MAKING CAPABILITIES BY USE OF HEART RATE ZONE FEEDBACK IN TRAINING ENVIRONMENTS

I. Introduction

Background

Currently, the Air Force Research Laboratory (AFRL) conducts studies to support their Quantified Warrior Initiative (QWI). The goal of the QWI is to effectively integrate real-time physiological technology into existing Air Force (AF) training and mission platforms. This type of technology is expected to enhance performance with the focus on building warfighter readiness while simultaneously providing either the warfighter or mission commander with valuable physiological information to improve decision making capabilities while increasing the career longevity of the warfighter (Blackhurst, Gresham, & Stone, 2012).

Current technology does allow for real-time tracking of human physiological (e.g., heart rate (HR)) responses during physically demanding activities (e.g., rucksack marches). Friel (2006: 8) identifies HR technology as the “window to the body,” telling an individual what his/her physical systems are experiencing. The sports community uses and promotes this type of technology to provide performance guidance based on an individual’s current level of fitness. HR training is a powerful tool for athletes, yet it is not as highly utilized within military populations as it could be. However, current literature identities the development of technology that could be used to enhance performance stamina in military communities while allowing critical biofeedback indicators to be tracked and monitored to ensure better decisions can be made to optimize human performance within training environments (Hoyt & Friedl, 2016).

Furthermore, utilizing physiological monitoring technology in military performance settings may be especially beneficial for populations whom are required to operate in high levels of physical stress. For example, a population that may highly benefit from physiological monitoring is the special operation forces (SOF) community. The physical requirements of SOF personnel are similar to those of elite athletes; however, while elite athletes focus specifically on one event SOF personnel have to be well trained on an all-encompassing level of fitness. SOF personnel must train rigorously for long durations in order to prepare for missions and deployments that often include: special reconnaissance, counterterrorism operations, direct actions, and counter proliferations (Carlson & Jaenen, 2012). Similar to the actual operational environment, SOF training requires individuals to perform at high physical levels while being sleep deprived, under-nourished, dealing with endocrine changes, muscle atrophy, and weight loss (O'Hara, Henry, Serres, Russell, & Locke, 2014).

While the intense training of these elite warfighters is necessary; without proper monitoring and recovery the decrements in physical performance can be detrimental to real-world operational performance. However, utilizing biofeedback to gather valuable information on the physical state of an individual in this type of career field may allow leaders to make a more well-informed decision on their ability to continue training or make adaptations to their training based on their current physiological condition.

Although real-time perception (i.e., observation only) of an individual's physical state may be the only available avenue in an operational setting, real-time perceptions alone may provide a skewed determination of the actual well-being and the true physiological state of an individual. Thus, relying on physiological monitoring should be of focus in training environments where more time can be spent on ensuring the physiological well-being on an individual. Therefore, the purpose of this study is to determine if providing Heart Rate Zone (HRZ) biofeedback information might improve a mission commander's ability to more accurately predict the level of effort their Airmen are expending and how much longer their Airmen will be able to continue an AF relevent endurance activity (e.g., rucksack march).

Problem Statement

In the military environment, it is common for commanders to rely exclusively on perceptional information (e.g., visual observations) to make decisions on their personnel's physical capabilities. Due to this fact, there is little evidence to support the idea that the information provided by physiological feedback technology, typically made available to the decision maker visually, could improve assessments and decision-making capabilities of outside observers (e.g., mission commander in a remote location).

Research Question and Hypothesis

Research Question 1: How does real-time physiological HRZ feedback affect commander perceptions of individual training performance outcomes (level of exertion, how much longer an individual will be able to perform a military relevant strenuous activity)?

Hypothesis 1: Having HRZ information allows commanders to more accurately predict how much longer an individual can continue an endurance activity.

Hypothesis 2: Having HRZ information allows commanders to more accurately predict how hard an individual is working (RPE score).

Research Question 2: How does the condition that the marcher is in correlate with how long they can continue the rucksack march and their level of exertion (RPE score)? Specifically, can categories be created to match training performance outcomes that are desired?

Hypothesis 3: The condition (easy, moderate, hard) the marcher is in will correlate with how long they can last during the endurance activity and their level of exertion (RPE score). The prediction is that on average the marchers in the "easy" condition will be able to last the longest with the lowest average RPE score. Those in the "moderate" condition on average will be able to last longer than those in the "hard" condition but not as long as those in the "easy" condition; while on average having a slightly higher RPE score than that of the "easy" condition. Finally, on average those in the "hard" condition will be able to last the shortest amount of time of all conditions while having the highest average RPE score.

Research Scope

The purpose of this research is to advance current knowledge focusing on physiological feedback as a means to optimize warfighter readiness and provide valuable information that can be used to make a more well-informed decision in relevant military environments. More specifically, this research focuses on military communities where high physical demands are required in mission and training environments, often for extended durations. This is due to the increased probability of factors that impact mission readiness such as fatigue, overtraining and injury. The study will use a previously generated set of visual stimuli (a video recording of 25 Active Duty Airmen performing a loaded rucksack march on a laboratory treadmill) that participants whom are acting as remotely located commanders will observer. Data will be collected from these observers to determine if the inclusion of HRZ information within the videos elicits an accurate sense of perceived fatigue and also to determine if HRZ information enables the commanders to more accurately estimate how much longer an Airmen can continue performing the activity before they have to stop due to exhaustion.

Assumptions & Limitations

Assumptions

1. It will be assumed that participants may not be familiar with the physiological information provided by HR data.

2. It will be assumed that the video recording shown to the observers and the subsequent rucksack march information depicts an accurate representation of time to physical exhaustion.

3. This research is applicable for training environments only.

Limitations

1. Provided data (i.e., videos and HRZ information) may not have provided enough contextual cues for commanders to make an informed decision about the longevity of warfighter performance.
2. Rucksack march participants may not have performed the task to physical exhaustion, thus decreasing the likelihood of obtaining accurate duration estimations.
3. The population size in the experiment was reduced from N=46 to N=34 due to the fact that12 participants were double counted, thus lowering the overall population size for the experiment. Additionally, the control group and the experimental group did not have the same number of participants.
4. The experiment did not control for age and gender information.

Implications

This study supports the integration of real-time physiological technology into existing AF training and mission platforms under the purview of the AFRL QWI (Blackhurst et al., 2012). As referenced earlier, the QWI is based on the premise that using technology such as HR monitors to optimize warfighter readiness and gathering valuable real-time information that may lead to improved decision making by commanders in training environments.

Chapter Summary

The primary objective of this experimental research study is to determine if providing HR feedback will improve a mission commander's ability to recognize an individual's effort level more accuretly and assess the future capabilities of Airmen performing physically demanding activities (e.g., rucksack march) in environments relevant to AF operations and training. Chapter 2 addresses the current interest in developing optimization programs within the military, using physiological monitors to capture HR information to be used to make more informed decisions, and the relevance of this research to support AFRL's QWI. Chapter 3 reviews data collection procedures and proposed methodology and presents the results of the applied methodology. Finally, Chapter 4 summarizes and discusses the results, outlines research limitations, and suggests recommendations for future research.

II. Literature Review

Chapter Overview

This chapter begins with an evaluation of the literature on the current interests in the development of optimization training technology for elite warfighters such as special operation forces (SOF) who are forced to operate at a high physical capacity. Next, the review introduces and defines the HRZ training structure as a method to provide future optimization strategies for use in military settings. The review closes by discussing AFRL's QWI and its relation to a similar initiative in the United States (U.S.) Army where the use of HR technology is being incorporated into training environments.

Current Interests in Technological Developments and Optimization Strategies

Interest is growing in the development of technology and training programs to monitor and optimize human performance in elite warfighters such as SOF. Vrijkotte et al., (2009) provide an example of the physical requirements within a typical deployed environment for these elite warfighters:

> In Iraq, Afghanistan and Bosnia Soldiers are exposed to extreme, complex and sustained (72-hour continuous performance) operations in urbanized and irregular terrain. During these operations, along with the threat of physical and chemical attack, the mountainous terrain and the changing climatological, these circumstances are considered to the 'stand' environments in which Soldiers have to operate. (2009: 2)

Additionally, distinctive physical tasks that elite warfighters such as SOF face include: carrying heavy loads for a long period of time, short bursts of high-intensity physical activities, lifting heavy loads, and climbing while wearing heavy equipment (Austin & Deuster, 2015). The physical abilities required of SOF to handle stressful combat situations rely heavily on their ability to train at an intensity level which matches the various scenarios that they may face within battle (O'Hara et al., 2014). Therefore, the use of technology to optimize performance in training is likely to be a valuable tool to ensure these personnel are physically prepared for the demands of the operational environment while minimizing potential negative training outcomes (e.g., overtraining, injury).

Original training programs for SOF were based heavily on intuition and the experience of past SOF personnel, not necessarily from scientific data (Austin & Deuster, 2015). However, without data and scientific reasoning behind a training program, human performance is likely to be impacted due to fatigue and injury (Austin & Deuster, 2015). For these reasons physiological monitoring became a central focus of the Army in 1996 and the Warfighter Physiological Status Monitoring (WSPM) initiative was developed. The goal of WPSM was and still is, to make real-time performance predictions that leaders can use to assess the readiness of their troops (Friedl, 2003). The concept would later bring forth the creation of minimally invasive sensors for service members to wear that would help identify the status of their internal responses. This is important due to the fact that when performance levels drop below the required level needed to fulfill a job personnel become more vulnerable to making mistakes or getting injured (Vrijkotte et al., 2009). This highlights the importance of gaining understanding on how to optimize performance while mitigating negative ramifications from occurring (e.g., over-training, injury).

Development and utilization of physiological technology can positively influence the longevity and performance of the warfighter by turning real-time data into actionable information (Blackhurst et al., 2012). Though SOF must train and operate as a unit, it is important to acknowledge that individuals within that unit possess a wide range of diverse physical characteristics (e.g., age, fitness level). Due to the variation of physical characteristics some individuals within the unit may not respond positively to the presented training program and may become more susceptible to things such as injury, fatigue and over-training (Austin & Deuster, 2015). However, monitoring the physiological status of each person in the training environment may help to prevent such things from occurring by allowing the individual in charge (i.e., commander) the ability to identify which Soldiers have reached their current physiological limits. By identifying these individuals, they can then be separated from the remaining group and provided with a training program that will optimize performance based on their own current level of fitness and reduce the likelihood of physiological and performance degradation (Vrijkotte, Valk, Veenstra, & Visser, 2009).

Recently, an important category of military wearable technology that tracks an individual's physiological ecosystem emerged known as Real-Time Physiological Status Monitoring (RT-PSM) (Friedl et al., 2016). "RT-PSM addresses a gap by providing individual Soldiers and small unit leaders with actionable information needed to ensure individual and squad performance readiness" (Friedl et al., 2016: 1). Examples of useful applications of RT-PSM include: thermal strain (based on heart rate and core temperature) and workload management, alertness and neurocognitive status assessments, physical fatigue management and avoidance, as well as hydration and metabolic fuel management (Friedl et al., 2016). As seen in Figure 1, developing monitoring systems to help establish an overall readiness score of the soldier is the ultimate goal of RT-PSM applications.

An application of RT-PSM technology was recently tested while observing thermal work-strain monitoring in United States Marine Corps (USMC) populations where trainees were performing highly demanding physical tasks. Field research by U.S. Army Research Institute of

Environmental Medicine (USARIEM) reports that a high thermal strain index specifies that an individual is working close to their upper cardiovascular and thermal tolerance limits which help to indicate when their own physiological limits will impact their performance (Hoyt & Friedl, 2016). Similar to what is seen in Figure 2, a chest-mounted RT-PSM system was used to communicate internal thermal strain status information to the instructors on each trainee (Hoyt & Friedl, 2016).

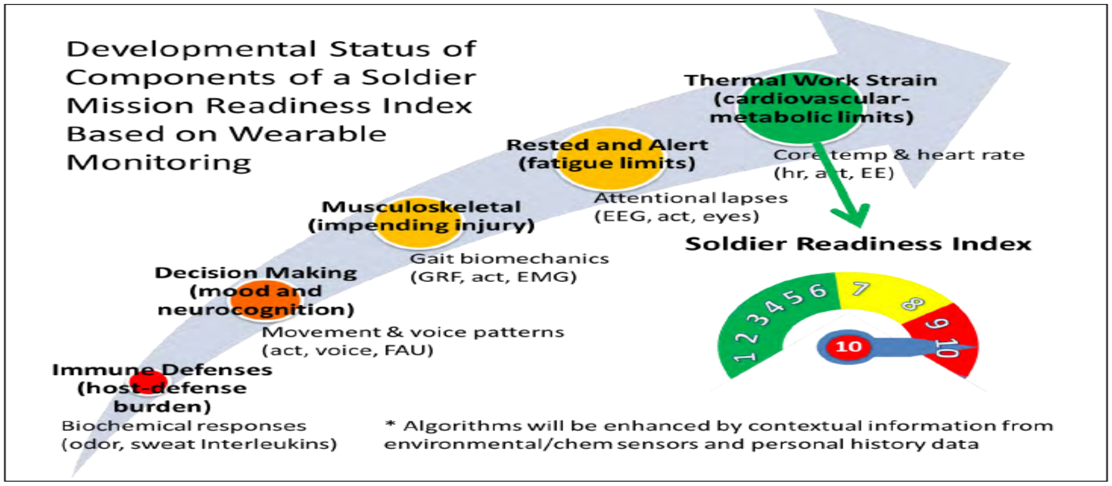


Figure 1. Soldier Readiness Index (Friedl et al., 2016)

With the use of RT-PSM the instructors were able to use the real-time feedback to identify the physical stress of the trainees, which at the time were noted to be working at fairly low thermal work strains. Within this information, the instructors were able to make a more well-informed decision to increase the physical demands on the trainees based on actual physiological data rather than reliance on largely anecdotal input of trainee ability (Hoyt & Friedl, 2016). This type of information can be critical for providing third party entities the ability to make better decisions about their subordinates. However, valuable information of physiological monitoring can be provided even with a singular biofeedback marker such as HRZ information (Friel, 2006).

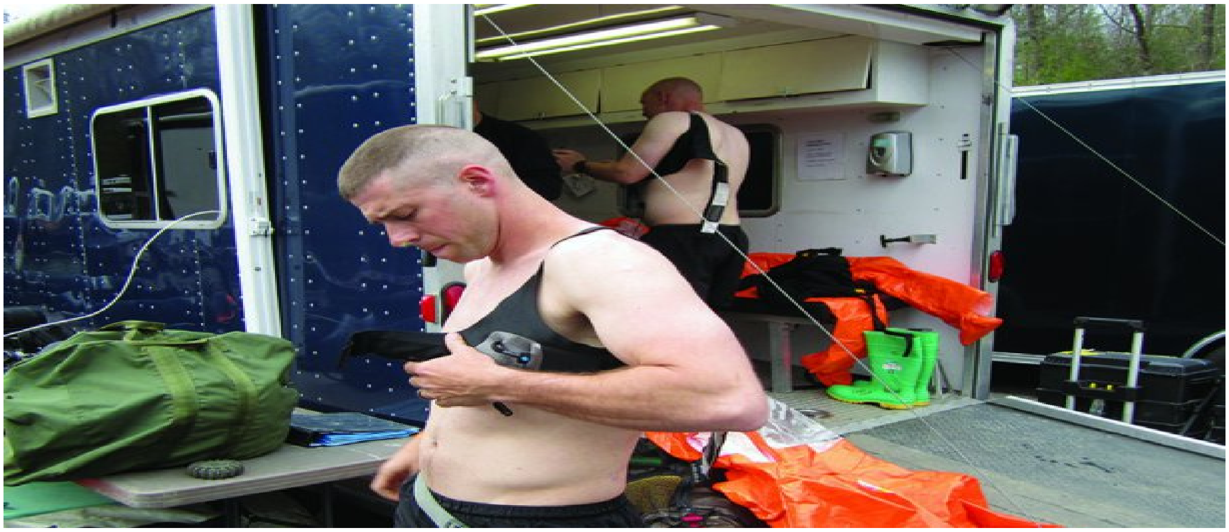


Figure 2. A chest-worn physiological sensor system such as this one can provide information on a Soldier's work and heat-related strain to team members downrange and leaders at a command post. (Photo by William Tharior. USARIEM)

Perception and Physiological Monitoring by HR Technology

Oftentimes, the perception of what an individual looks like while performing an activity may provide a false reality of their actual performance outcome and/or ability. The rating of perceived exertion (RPE) scale has been widely used in the exercise community to allow a subject performing a physically demanding task to measure their own level of exertion. Some studies have suggested that observers could use RPE scales to assess how hard someone is working as well. Perceptions are often determined by observing the facial gestures provided by the one performing the demanding task (e.g., grimacing, squinting, or smiling) (Huang, Chiou, & Chen, 2015). However, little research has indicated if an observer's own perception is enough to identify the actual physical state of an individual and their ability to continue the demanding task. This makes using physiological monitoring that much more of a valuable tool.

As reported by the Institute of Medicine (US) Committee on Metabolic Monitoring for Military Field Applications,

> Physiological monitoring is not just a nice-to-have technological replacement for common sense or for good leadership (which includes understanding the signs of an individual combat service member's limits). Combat service members may not be aware that they are reaching dangerous levels of overheating, dehydration, physical exertion, stress, fatigue, or sleep deprivation. They could develop performance-degrading problems unbeknownst to their team leaders, particularly if they are fully encapsulated in chemical protective suits, are flying aircraft, or are operating in a remote location. An alert or warning signal to the individual and his or her squad leader could permit prompt intervention to alleviate the physiological danger and potentially save a mission. (2004: 1)

Though there is interest in developing sophisticated technology to enhance optimization and decision-making capabilities in a variety of human performance facets, something as simple as HR information can provide aqequate insight into an individual's physiological state.

HR monitoring technology consists of a transmitter, which is a chest strap that contains two electrodes that track the activity of the heart through the surface of the skin. The information gathered by the chest strap then travels to the receiver (i.e., watch) (Friel, 2006). HR technology may provide operators and commanders the tools to enhance their physical abilities through: minimizing fatigue, evaluating and improving fitness, and creating objective time frame goals to improve specific mission-related tasks (Austin & Deuster, 2015). As previously noted, although SOF personnel must operate and train as a unit, HR technology can be used to understand and determine the capabilities and limits of each individual based on their own current fitness level (Austin & Deuster, 2015).

Specifically, the ability to track and collect data via heart rate technology has previously allowed endurance athletes to collect valuable information in regards to their physiological adaptations within their training and performance. While heart rate technology in SOF populations is sparse, generalizations between an elite athlete and SOF populations can be made with moderate reassurance. Elite endurance athletes train roughly 11 months or more of the year and are likely to perform more than 600 training sessions all at various intensity levels. Elite endurance athletes in sports such as running, cycling, and skiing tend to use the concept of "long-term periodization" which refers to conducting an annual training cycle in which the entire cycle is split into phases which last from several weeks to several months (Seiler, 2010). The intensity (percent of their VO_2 max) and duration manipulation within each phase is critical for maintaining an athlete's health and physical capabilities throughout training to ensure they are physically ready for competition and not dealing with the physiological limitations (i.e., over-training, injury).

The tool most utilized to monitor the intensity level is a HR monitor (Seiler, 2010). Using a HR monitor allows for not only the athlete but the coach as well to identify and program how hard the body is and should be working during each phase of training. However, to effectivity use HR technology within the training environment, one must first understand the concept of HR training zones training as a modality to optimize performance.

Introducing the Heart Rate Training Zone Concept

Friel (2006) five-zone model provides specific HRZ to use for optimal performance during various durations. Friel (2006) proposes that each individual has a target HRZ that they should strive to maintain in order to enhance physical performance while deterring fatigue.

Within this model, HRZs are identified using a VO_2 max test to determine an individual's current fitness level. Knowing an individual's baseline fitness is critical to proper development of an optimization strategy. Friel's model is shown in Table 1.

Table 1. Friel (2006) Heart Rate Zones

Zone	Duration of Event	% Lactate Threshold
1	Greater than 12 hours	50-59%
2	8-12 hours	60-69%
3	3-8 hours	70-79%
4	1-3 hours	80-89%
5a	20 minutes-1 hour	90-100%
5b	2-20 minutes	90-100%
5c	Less than 2 minutes	90-100%

In order to set up HRZs there must be a reference point which is known as an individual's lactate threshold (LT) or maximum heart rate. LT is the level of intensity at which an individual begins to "red-line" and may only be able to maintain the effort for a few minutes or up to an hour for highly fit, elite athletes (Friel, 2006). In order to determine an individual's LT level, metabolic testing must be conducted. VO_2 max also known as maximal oxygen consumption refers to the maximum amount of oxygen an individual uses during maximal effort exercise ("VO2 Max Testing," 2017). The more oxygen a person can use during intense exercise, the more energy produced ("VO2 Max Testing," 2017). Once the LT or maximum HR is determined, HRZs are created based on workout intensity (percentage of the individual's maximum HR) and the amount of time the individual should spend in that zone (see Table 1). Each zone has its own purposes for overall performance (as shown in Table 2).

Table 2. Friel (2006) Heart Rate Zone Descriptions

Zone	Zone Title	Description
1	Active Recovery	Exercising in this zone will allow the body to recover from previous hard training and the stressors are low enough that the body should not be stressed enough to impact future workouts.
2	Aerobic Threshold	Exercising in this zone improves and maintains basic endurance ability, regardless of the events for which you train. This is the classic long distance, slow distance zone.
3	Tempo	The individual is working somewhat hard with the first indication of heavy breathing. The physiological benefits are not much greater than those achieved in upper-Zone two training, although the need for recovery afterward is considerably greater. In this zone, long steady state efforts or intervals are conducted.
4	Sub-Lactate Threshold	Training in this zone occurs slightly below LT. Acid production is significant, but the body copes with it well. This is the intensity that most athletes gravitate to in steady-state competitions
5 a, b, c	Lactate Threshold and Anaerobic Capacity	Training in this zone causes the production of so much lactic acid that exercise duration is greatly limited.

The concept of HRZ training is synonymous with the idea of periodization of training, involving manipulations of training intensities and duration, rest interval modulations at set intervals to induce both fitness (i.e., physiological adaptations), and fatigue (i.e., stress responses and associated negative health outcomes) (Seiler, 2010). By training in zones based on individual's current maximum HR the less likely an individual will fall into the training intensity "black hole" (i.e., all training sessions end up being the same intensity level and duration) (Seiler, & Tønnessen, 2009). In short, when adhering to HRZ training the physiological adaptations needed to gain fitness while mitigating negative health outcomes are less likely to occur.

Though Friel's model reflects the most detailed HRZ-based model available, it has yet to be empirically validated in a military setting as a way to provide an informative strategy to help individuals stay within their optimal ranges of performance and deter possible negative physiological ramification. The concept of using HR technology is in accordance with the AF QWI for using technology to monitor and optimize performance.

Air Force Research Laboratory's (AFRL) Quantified Warrior Initiative (QWI)

In recent years, the Department of Defense (DoD) has established a vested interest in using real-time physiological monitoring technology to optimize human performance (loosely defined via physical and cognitive parameters). Derived in 2012, the concept known as the QWI was born. AFRL has led the QWI venture through the introduction and use of the "Sense-Assess-Augment Paradigm." The paradigm provides a framework to, "close the loop, where the physical and mental states of the operator are fed back into the system, making the human a more seamless part of the overall system" (Blackhurst et al., 2012: 2). This paradigm provides a "data-driven feedback loop," taking the acquired data captured through sensors and using it to enhance an individual's future mission and training performance. In order to understand the paradigm it is important to discuss the three individual stages.

The first stage of the paradigm is "sensing." "Sensing has become the most mature piece of the paradigm, thanks to considerable commercial investments in athletics, health care, and productivity" (Blackhurst et al., 2012: 3). Information on a wide variety of human parameters can be captured through sensors including: hydration states, readiness and alertness, musculoskeletal fatigue, eye responses, voice changes, speech content, breath chemistry, skin temperatures, and lower extremity movement patterns (Hoyt & Friedl, 2016). "Sensing" represents the utilization of instrument technology to capture valuable data that may provide insight on how and why the body is performing in a certain manner.

The next stage of the paradigm takes and uses the data acquired through these sensing stage to gain understanding in what an individual is experiencing both physically and mentally and what factors may be causing the individual to perform in an optimal or suboptimal manner. This stage is called "assessing" and is defined as, "the ability to interpret data from multiple, individual sensors to be merged it into actionable information promptly" (Blackhurst et al., 2012: 4). In short, measuring (i.e., "assess") data collected in stage one in a manner that quantifies it relative to an individual's baseline to better understand performance and the underlying factors that may be impacting it. For example,

> To say a Soldier is tired or injured doesn't reveal how likely it is he will complete or impede the mission. But if it were possible to know, for example, when a Soldier's ability to accurately shoot a target was decreased by 25 percent, a better decision as to how to address the symptom of fatigue could be made (Blackhurst et al., 2012: 4).

Results compiled during the "assess" phase can be interpreted into actions taken to incorporate changes in the training environment. By doing so, this may ensure the underlying issue(s) causing the decrement in performance are being addressed to mitigate any future mission impacting performance issues (e.g., injuries, fatigue, or overtraining). Working military personnel to failure is costly. There are long term costs such as musculoskeletal injury, lost expertise, as well as the additional time and expense of training replacements (Hoyt & Friedl, 2016). However, by utilizing sensor technology to assess biomarkers that can provide a proactive rather than reactive response to training can allow the costly implications to be mitigated.

The final stage, "augment" means to utilize existing technology or develop new technology to help optimize an individual's performance. However, within this stage, it is important to develop and utilize technology that can be easily worn and does not impact or impinge the ability for the individual to execute the mission (Blackhurst et al., 2012). The "Sense-Assess-Augment" paradigm enhances creative technological enhancement increasing the likelihood of a more readied warrior. Therefore, based on research under the QWI initiative, utilizing HR technology via performance and training strategy may help to optimize an individual's physical capabilities in the most efficient manner while providing essential feedback to make more well-informed decisions about the status of an individual.

Chapter Summary

This chapter introduces the current interests in utilizing technology to help optimize human performance in elite warfighters. The review continues by discussing physiological monitoring, Friel's (2006) HRZ training concept as training vector and biofeedback indicator for performance. Finally, the review discusses AFRL's QWI and its concept of using the "Sense-Assess-Augment Paradigm" to induce elite warfighter optimization capabilities. The next chapter, Chapter 3, covers the overall analysis and results from the experimental study.

III. Analysis and Results

Chapter Overview

In the current study we seek to answer the question if, by providing "commanders" with their Airmen's real-time HRZ biofeedback, can we improve their ability to perceive levels of fatigue and more accurately estimate how much longer their Airmen will be able to continue an operationally relevant task (i.e., weighted rucksack march) in a training environment. This chapter discusses the pre-collection rucksack march videos and data conducted by AFRL. The chapter then introduces the statistical methods for analysis which heavily incorporates Analysis of Variance (ANOVA) and contingency table analysis. Finally, the chapter concludes with the results and how those results relate specifically to the overall hypotheses for this experiment as introduced in Chapter 1.

Data Collection Part 1: Rucksack March

AFRL Data Creation.

AFRL created the requisite video footage used by USAFA cadets (i.e. commanders) to view and score rucksack marchers. Before filming, all rucksack marchers signed a consent form and answered a brief demographic questionnaire outlining experience with the task and current levels of physical activity. All protocols adhere to the AFRL's Institutional Review Board (see Appendix A). The total number of marchers equaled 25 Active Duty personnel (4 female and 21 male). Each marcher would march on a treadmill wearing gear totaling approximately 50 pounds (loaded rucksack, armor vest, helmet, and a mock M-16 rifle). Each marcher was randomly selected to one of three conditional groups (see Table 3), which affected treadmill speed and incline.

Before random assignment, each marcher underwent a VO_2 max test to determine aerobic capacity (ml/kg/min) and establish individual HRZs as determined by maximum HR (Friel, 2006). Throughout the march, HR was monitored using a Polar Team 2 system. Videos were taken every 3 minutes for 30 seconds using a GoPro© via a front facing camera angled to capture gait, facial expression, and other potentially relevant perceptual performance metrics. The current HRZ of the marcher during a 30 second video clip was used; however, only 15 seconds of the clip shown during the experiment. Additionally, no sound was recorded. Distance and time were not specified allowing marchers to perform the rucksack march until exhaustion. Exhaustion was based on the capability of no longer being able to continue due to cardiovascular fatigue. However, as mentioned in the limitations section, some marchers did not go to exhaustion due to either being too uncomfortable to continue, mental boredom and/or prior engagements they had to attend.

Table 3. Treadmill Conditions

Treadmill Conditions	
Easy	• 3 mph, 3 percent incline grade
Moderate	• 3.2 mph, 4 percent incline grade
Hard	• 3.5 mph, 6 percent incline grade

HRZ Condition and Information.

Due to the potential level of inexperience with physiologic feedback (i.e., HRZ's) a condensed 3 zone model was created by AFRL researchers based upon Friel's validated five HRZ's (Table 4). This condensed version enabled cadets (i.e., commanders) to more easily understand the feedback presented. Additionally, this ease of task execution decreases the chance of boredom and analytic floor effect when a given performance is near the absolute minimum effort required to perform (Norman & Bobrow, 1976).

Table 4. Condensed 3 HRZ Model Presented to Participants in the Experimental Group

Heart Rate Zones	
Zone 1	• Activity: recovery • Level of difficulty: easy • Places little stress on muscles, comfortable • (Friel Zone 1, 50-59% of LT)
Zone 2	• Activity: maintainable • Level of difficulty: moderate • Places moderate stress on muscles • (Friel Zones 2-4, 60-89% of LT)
Zone 3	• Activity: non-maintainable • Level of difficulty: hard • Rapidly increasing muscle discomfort • (Friel Zones 5a-5c, 90-100% of LT)

The Borg Rate Perceived Exertion (RPE).

Additionally, throughout the rucksack march, the marchers were asked to indicate their perceived effort using Borg's RPE Scale (Borg, 1982) (Figure. 3). The marcher's perception may take into consideration feelings of effort, strain, discomfort, and/or fatigue. Thus all RPE data is subjective.

Data Collection Part 2: Perceived Performance

Participant Overview and Data Collection.

Participants in this study are USAFA cadets in their first year taking Department of Behavioral Science and Leadership (DFBL) courses (BS 110 and BS 310). Their assigned role within this research is to act as a mission commander and view a series of video clips (previously recorded at AFRL's STRONG Laboratory) on a computer monitor located in DFBL's Multimodal Research Laboratory for Innovation. These video clips randomly displayed 25 marchers completing a rucksack march to exhaustion. The study took approximately 25 minutes to complete.

RPE Scale	
6	***No Exertion***
7	**Extremely light**
8	
9	**Very Light**
10	
11	**Light**
12	
13	**Somewhat Hard**
14	
15	**Hard**
16	
17	**Very Hard**
18	
19	**Extremely Hard**
20	***Maximal Exertion***

Figure 3. The Borg RPE scale is used by participants completing the rucksack march to subjectively assess their individual level of exertion

Control Group (No HRZ information provided).

The cadets (i.e., mission commanders) in the control group are given an introduction and set of instructional steps to complete (see Appendix B). Cadets are given how long the marcher in the video had been marching (in minutes), but no biofeedback information (HRZ). Following each clip, cadets rated the perceived exertion of how hard the presented marcher was working using Borg's RPE scale (Figure 3) as well as how much longer they felt the marcher was able to continue.

Experimental Group (HR information provided).

The cadets in the experimental group were given an introduction and set of instructional steps to complete the experiment (see Appendix C). They received biofeedback information

(HRZ) as well as how long (in minutes) the marcher in the video had been marching. Following each clip, cadets rated the perceived exertion of how hard the marcher was working using Borg's RPE scale (Figure 3) as well as how much longer they felt the marcher would be able to continue.

Analysis

The between subjects factor is physio-behavioral feedback, with two levels (No HRZ feedback, HRZ feedback). The independent variable is whether the HRZ information was made accessible on the video clips or not. The dependent variable was the RPE score and the time estimate for how much longer the rucksack marcher would be able to continue. Both the control and experimental group's responses of RPE score and time estimate are compared against the actual RPE score and completion time of the rucksack marcher that was collected during the video creation. Additionally, an analysis is conducted to determine if there is a correlation between the categories that each marcher is assigned and their average RPE score and continuation time completed.

USAFA cadets (N=34) were randomly selected to be in either the control group (N=23) or experimental group (N=11). The reason for the variation between the participant (i.e., cadet) numbers within each group is due to 12 cadets completing the experiment in both treatment conditions (Seeing HRZ information/Not seeing HRZ information). Due to possible biasing that may occur with these cadets completing the experiment with both treatment conditions, we analyzed a possible crossover effect. To test for this, we conducted four ANOVA tests, two for both responses, RPE difference and Time Estimate difference between treatment groups (Seeing

HRZ information/Not seeing HRZ information). Of these two, one included all cadets. The other excluded the 12 cadets for their second sets of responses.

Initial Results

The ANOVAs that investigated RPE difference yielded *p*-values of 0.0637 and 0.1180 for all participants and those excluded respectively. The Time Estimate difference resulted in *p*-values of 0.0536 and 0.1817 for all cadets and those excluded respectively. If no carryover effect existed, we would expect both sets of *p*-value pairs to have similar values; however they do not. Additionally, with all the cadets included the *p*-values are relatively close to an alpha of 0.05, suggesting statistical significance of the treatment effect of having HRZ information. We suspect this borderline statistical significance is more attributable to a carryover effect which means that the cadets who conducted the experiment in both treatment groups (Seeing HRZ information/Not seeing HRZ information) carried over a specific bias due to the prior knowledge they had when conducting the experiment from one treatment group to the next. Therefore, to be conservative, we exclude the second set of response for 12 cadets.

Statistical Methodology on Remaining 34 Data Points

In order to investigate the research hypotheses, multiple statistical analyses were conducted. We used the JMP® statistical software for all analyses. Techniques included ANOVA tests as well as contingency table analysis. Throughout the analysis, a significance level (alpha) of 0.05 was used for comparing *p*-values. Overall, the investigative questions involve the following hypotheses:

Hypothesis 1: Having HRZ information allows commanders to more accurately predict how much longer an individual can continue an endurance activity.

Hypothesis 2: Having HRZ information allows commanders to more accurately predict how hard an individual is working (RPE score).

Hypothesis 3: The condition (easy, moderate, hard) the marcher is in will correlate with how long they are able to last during the endurance activity and their level of exertion (RPE score). The prediction is that on average the marchers in the "easy" condition will be able to last the longest with the lowest average RPE score. Those in the "moderate" condition on average will be able to last longer than those in the "hard" condition but not as long as those in the "easy" condition; while on average having a slightly higher RPE score than that of the "easy" condition. Finally, on average those in the "hard" condition will be able to last the shortest amount of time of all conditions while having the highest average RPE score.

Results on the 34 Remaining Data Points

To begin, we looked at the histogram of the minutes that the cadets thought the marchers could continue marching in order to determine normality or lack thereof. As seen in Figure 4, the majority of cadets did estimate that marchers could continue marching between 0-120 minutes after seeing the video clip. As seen in Figure 4, minute 120 is highlighted due to the fact that there is a clear breaking point indicating where the disparity begins between the majority of continuation estimations (≤120 minutes) and the outliers (>120 minutes). The outliers makeup 13 rows and are linked to only three cadets. For potential outlier effects on the analysis we chose to exclude these outlier data points going forward.

After excluding the 13 rows that indicated large disparity from the rest of group, an ANOVA was conducted to see if there was a significant difference between the two treatment groups (Seeing HRZ information/Not seeing HRZ information) and the ability for the cadets to predict the amount of time in minutes the marcher was able to continue marching. As seen in Table 5, there appears to be no statistical difference (*p*-value>.05) in terms of predicting how long in minutes the marcher could continue.

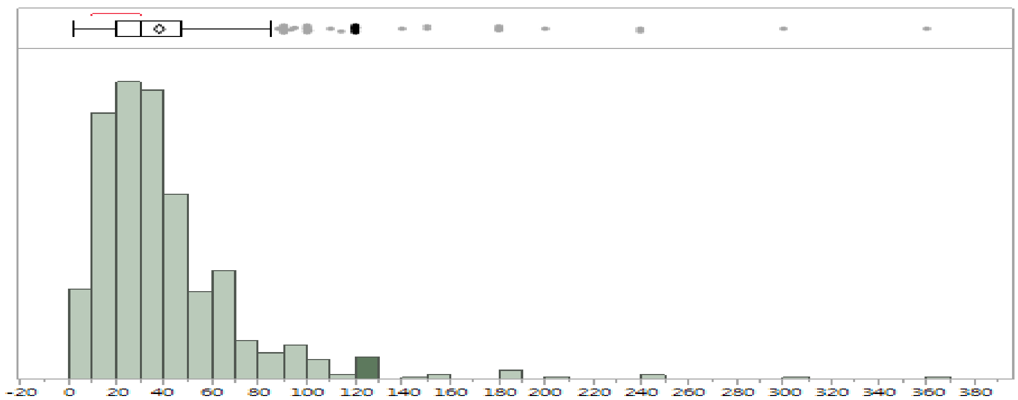


Figure 4. Cadet Perceived Time of How Much Longer the Marcher Could Continue (Mins)

Table 5. ANOVA Output of Minutes Remaining vs. Treatment Group

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	1	3157.9	3157.95	2.1333
Error	835	1236065.0	1480.32	**Prob > F**
C. Total	836	1239222.9		0.1445

For this reason, we went a step further. We decided to create time groupings instead of looking solely at the minute duration alone for a single cadet. In order to evaluate if having HRZ information has an effect on predicting a certain time group duration that the marcher would be able to continue, times were truncated into groups (as seen in Table 6), that were subjectively condensed using the histogram in Figure 4. While still excluding the 13 rows previously discussed, we then examined the differences between how long the marcher continued to march and how long the cadets estimated the marcher could continue but in terms of time grouping (as seen in Table 6) instead of raw minutes. We did this by identifying if there was an agreement between the time grouping given by the cadet and the time grouping that the marcher's actual continuation time fell into.

Table 6. Truncated Time Range Agreement Groups

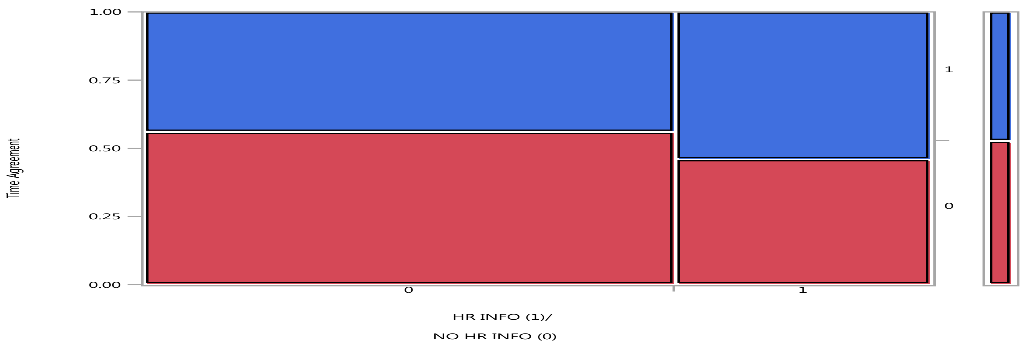
Group	Time Range
1	<30 minutes
2	≥30 minutes<60 minutes
3	≥60 minutes-120 minutes

The Time Agreement coding schematic is specified by: 0= no agreement; 1= there is an agreement. For example, if the marcher continues to march for 50 minutes after the video clip was taken they would fall Group 2, ≥30 mins < 60 mins. If the cadet estimates that the marcher would be able to continue for 55 minutes after they saw the video clip, then that cadet would also fall into Group 2. This would be an agreement, categorized as a 1. After identifying the Time Agreement for each cadet and marcher we were then able to do a contingency table. As seen in Figure 5, it does suggest that when HRZ information is available there is better agreement between the cadet's prediction of how long the marcher could continue and the marcher's actual continuation time when using a truncation of time range groupings (p-value<.05).

We then moved on to examine if having HRZ information allowed the cadet to more accurately predict the RPE level of the marcher. We first assessed to see if the differences between the marchers and the cadet's responses displayed any outliers as seen in Figure 4. As seen in Figure 6, we are working with a fairly normal distribution which means the raw data was satisfactory to use for further analysis.

We then conducted an ANOVA to see if there was a significant difference in the ability to predict RPE scores of marchers for the cadets given HRZ information and those not given

HRZ information. As seen in Table 7, there appears to be no statistical difference (*p*-value>.05) between the cadets given HRZ information and those not, in terms of prediction RPE levels for the marchers (*p*-value>.05).



Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	7.193	0.0073*
Pearson	7.196	0.0073*

Figure 5. Contingency Table of Time Agreement and Treatment Group

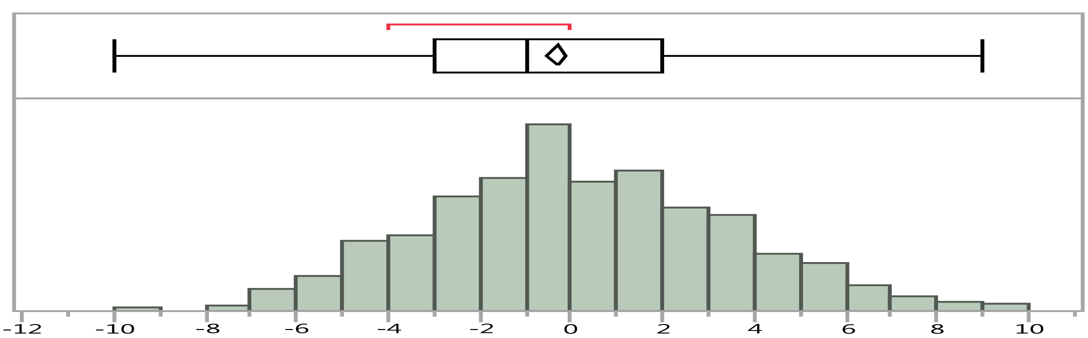


Figure 6. RPE Difference Between Cadet and Marcher Response

However, we chose to go a step further and chose to look at RPE groupings to see if this would show a difference between the two treatment groups. To do so, we did a second contingency table to see if there was an agreement between the RPE grouping given by the cadets and the RPE grouping given by the marchers. Using Borg's RPE scale, the values were truncated into groups as referenced in Table 8.

Table 7. ANOVA for RPE Between Treatment Groups

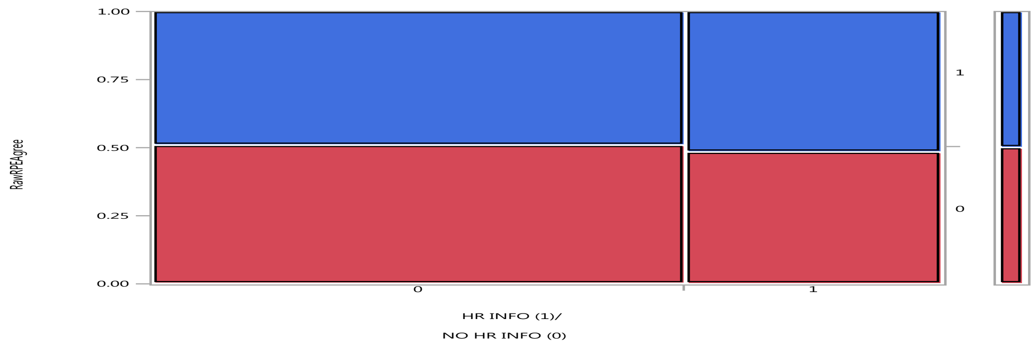
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	25.5709	25.5709	2.4484
Error	848	8856.2985	10.4437	**Prob > F**
C. Total	849	8881.8694		0.1180

Table 8. Borg's RPE Color Scheme Groupings

Group Based on Borg's Color Scheme	RPE Range
1	6-11
2	12-16
3	17-20

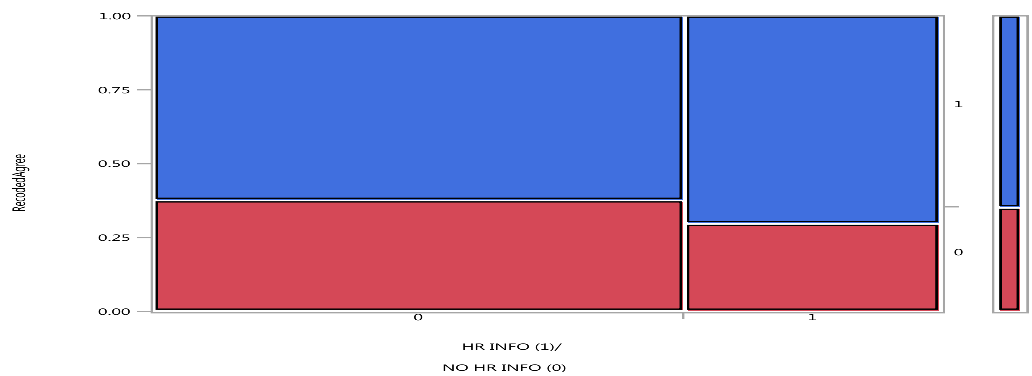
The RPE Agreement is specified by the coding schematic, 0= no agreement; 1= there is an agreement (i.e., coding schematic). For example, if the marcher specifies they are working at a RPE of 12 when the video clip was taken they would fall into Group 2. If the cadet estimates that the marcher was working at an RPE of 13 after they saw the video clip then that cadet would also fall into Group 2. This would be an agreement, categorized as a 1. After identifying the RPE Agreement for each cadet and marcher we were then able to do a contingency table and observed the results. As seen in Figure 7, there was no significant association between HRZ information being able to accurately predict the RPE of the marcher using those default cut-offs.

Since the hard cutoffs identified by Borg's Scale did not show any significance (*p*-value>.05), we then chose to look at Borg's Scale and made a decision to look at two groupings, which essentially cuts Borg's Scale in half. The grouping are 7-13 (easy to "somewhat hard") and 14-20 (past "somewhat hard" to actual exhaustion). We then did a contingency table analysis assessing the two new groups to determine if there is RPE Agreement between both the cadet and marcher responses. As seen in Figure 8, the *p*-value is <.05 which suggests that there appears to be a statistical difference between the two treatment groups and the cadets who had HRZ information were more accurately able to predict what RPE the marcher was working at.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	0.430	0.5121
Pearson	0.430	0.5121

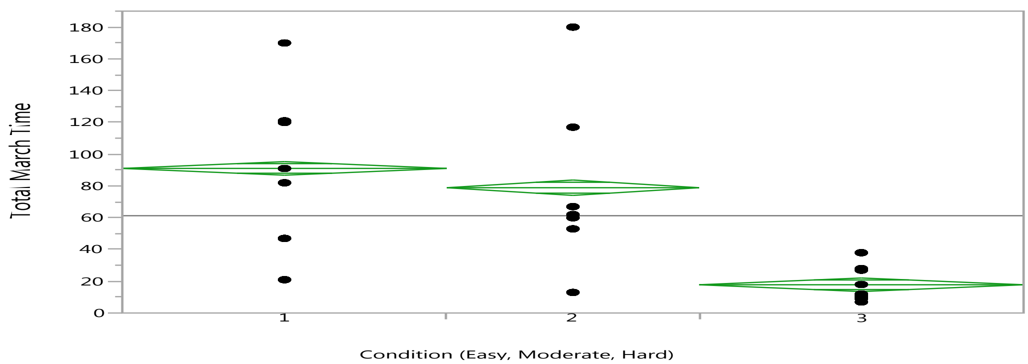
Figure 7. Contingency Table of RPE Agreement (Borg's Color Cut Offs) vs. Treatment



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	5.416	0.0200*
Pearson	5.338	0.0209*

Figure 8. Contingency Table of New RPE Agreement vs. Treatment

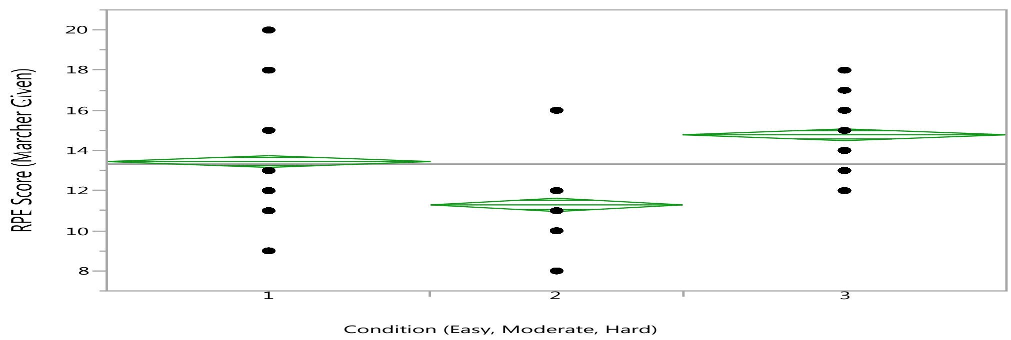
We then wanted to see if the condition (easy, moderate, hard) the marcher is in will correlate with how long they are able to last during the endurance activity and their level of exertion (RPE score). To do so, we first started by examining the total march time against the condition. As seen in Figure 9, those in the "easy" condition lasted the longest (91 minutes); those in "moderate" condition lasted the second longest (78 minutes); and finally those in the "hard" condition lasted the shortest amount of total time (17 minutes).



Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	306	91.0000	2.1755	86.730	95.270
2	238	78.8571	2.4668	74.015	83.699
3	306	17.7778	2.1755	13.508	22.048

Figure 9. ANOVA of Total March Time vs. Condition

We then moved to examining the relationship between the RPE score of the marcher and their designated condition (easy, moderate, hard). As seen in Figure 10, the prediction that the marcher's in the "easy" condition would have the lowest average RPE score was wrong. On average those working in the "easy' condition felt they were working harder (RPE score of 13) than those operating in the "moderate" condition (RPE score of 11). However, as predicted those marchers in the "hard" condition felt they were working harder than those marching in the two conditions (RPE score of 14).



Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	306	13.4444	0.14899	13.152	13.737
2	238	11.2857	0.16893	10.954	11.617
3	306	14.7778	0.14899	14.485	15.070

Figure 10. ANOVA of RPE of Marcher vs. Condition

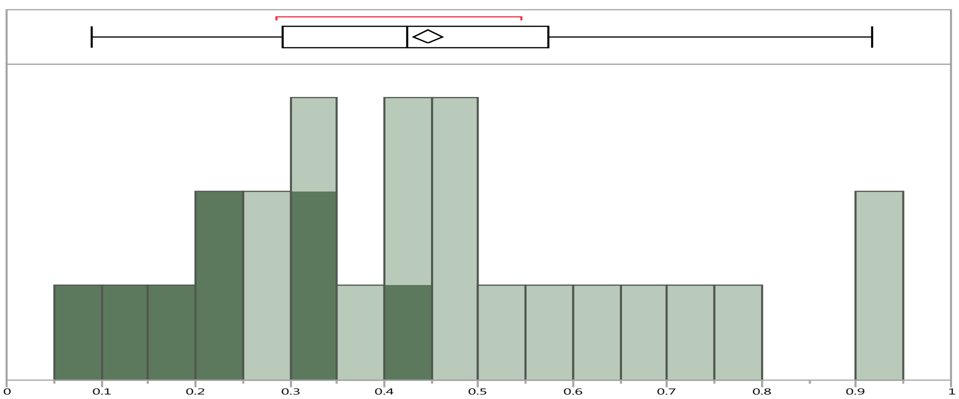


Figure 11. Percent of "Moderate" Condition Marchers during Video Recordings

We then wanted to examine why those in the “easy” condition felt they were working harder than those working in the “moderate” condition. To do so, we looked at the percent of marchers who marched in “moderate” condition when the video clip was taken. For the most part, the videos were provided to the cadets at roughly the 25 percent time mark within the march. However, this was not always the case. As seen in the darker blocks in Figure 11, a large number of videos of a marcher in the “moderate” condition occurred at the beginning of the marching session, which means the ruck marchers would more than likely indicate they felt better or fresher. It may also make sense as to why those marchers working in the “easy” condition may have felt worse simply due to the fact they were marching on the treadmill for a longer period of time and due to things such as mental fatigue, boredom or being uncomfortable from the equipment.

Summary of Analysis and Results

The analysis of this experiment concludes that there appears to be statistically significant relationships when assessing whether having HRZ information is helpful for allowing those in command roles to determine an accurate prediction of how long an individual may be able to continue an endurance activity and the individual’s current level of exertion. However, as shown throughout the analysis, providing truncated grouping options for individuals to choose from allows for a more accurate prediction to occur while singular number estimates do not. In summary, below are the answered hypotheses.

Hypothesis 1: Having HRZ information allows commanders to more accurately predict how much longer an individual can continue an endurance activity.

Findings: The results did suggest that when HRZ information is available, the cadets were more accurately able to predict how much longer the marcher would be able to continue, but only if given a range of time option (e.g., <30 mins). By providing a range of time to choose from as opposed to asking the cadets to specifically pick a number may allow for a more accurate and faster determination to take place. Accuracy and speed are important factors for commanders, especially when assessing more than one Airman at a time. The time groupings can easily correlate to a color in a stop light chart that separates individuals into different categories. A chart such as the one in Table 9, may allow commanders to more easily monitor their troops and make a more informed decision on how much longer they estimate he/she can continue based on the HRZ information being tracked.

Table 9. Stop Light Chart for Continuation Duration Based on HRZ Information

Estimate on Ability to Continue (Mins)	Airmen's Name
< 30 minutes	-Name
≤30 minutes<60 minutes	-Name
≥60 minutes	-Name

Hypothesis 2: Having HRZ information allows commanders to more accurately predict how hard an individual is working (RPE score).

Findings: There appears to be a statistical difference between the two treatment groups (Seeing HRZ information/Not seeing HRZ information) and the ability to predict the marchers RPE score; however this only occurs after providing decreased RPE grouping sizes (7-13 (easy to moderate) and 14-20 (hard to exhaustion) for the cadets to choose from rather than a singular RPE value. A single value may be hard to differentiate from one number value to the next or even the set cut-offs defined by Borg's Scale. Again, these findings suggest that fewer options with less ambiguity for commanders to choose from may be of more value when seeking to identify the exertion levels of their Airmen. Much like the Stop Light Chart in Table 9 for the continuation time estimate based on HRZ information; a similar chart could be used for RPE monitoring based on HRZ information. The below Table is based on the two groupings that were found to have the most predictive capability within the results.

Table 10. RPE Group Estimation Based on HRZ Information

RPE Group	**Airmen's Name**
Easy to Moderate (7-13)	-Name
Hard to Exhaustion (14-20)	-Name

Hypothesis 3: The condition (easy, moderate, hard) the marcher is in will correlate with how long they can last during the endurance activity and their level of exertion (RPE score).

Findings: The results indicated that, as predicted, the marchers in the "easy" condition were on average able to continue for longer than those in both the "moderate" and "hard" conditions. Also, those in the "moderate" condition did not continue for as long as those in "easy" condition, but longer than those in "hard' condition. Finally those in the "hard" condition on average continued for a significantly less amount of time than those in the "easy" and "moderate" conditions. We then looked at the predictions for the RPE correlation within each condition. The prediction for RPE score for the "easy" condition was wrong, though not by much. On average those working in the "easy" condition felt they were working harder than those in "moderate" condition. This may be due to the fact that the large number of videos of marcher working in the "moderate" condition occurred at the beginning of the marching session, which means the ruck marchers would more than likely indicate they felt better and fresher. It may also make sense to why those marchers working in the "easy" condition felt may have felt worse simply due to the fact they were marching on the treadmill for a longer period of time and may have felt bored or increasingly uncomfortable. However, as predicted those marchers in the “hard” condition felt they were working harder than those marching in both the “easy” and “moderate” conditions.

IV. Discussion and Conclusion

As stated in the beginning, the focus of this research is to determine if providing HRZ biofeedback to “commanders” improves their ability to both more accurately perceive levels of fatigue and estimate how much longer their Airmen will be able to continue an operationally relevant task (i.e., weighted rucksack march) in training environments. Though a larger sample may allow for more conclusive results, there are still valuable outcomes that can be grasped from this research. Overall, the results show that HRZ information being present may help commanders to more accurately predict a category of effort level (easy to moderate, hard to exhaustion) and a time range of how much longer their troop will be able to perform the activity.

Research Questions Answered

Research Question 1: How does real-time physiological HRZ feedback affect commander perceptions of individual training performance outcomes (level of exertion, how much longer an individual will be able to perform a military relevant strenuous activity)?

As indicated in Chapter 2, little research has been done to indicate if an observer’s own perception is enough to identify the actual physical state of an individual and their ability to continue a demanding task. When specifically addressing HRZ feedback and its ability to predict a marcher’s level of exertion, the results show that the “commanders” that were presented the video with HRZ feedback more accurately determined the level of exertion (RPE) of the marchers; however, this was only the case when using a more condensed RPE grouping scale (easy to moderate, hard to exhaustion). Grouping Borg’s scale down to only two categories was when predictive capabilities occurred. One can conclude that there is value in scales with less ambiguity (e.g., what truly is the difference between RPE score 7 and 9?). Less ambiguity also means less time wasted deciphering between numbers. In an operational training environment commanders must be able to make decisions quickly and by using a more condensed scale or simple categories may allow them to capture a bigger picture perspective in a more efficient manner. Also, the research shows that cadets with HRZ information are more accurately able to predict the marchers continuation time; however, only when using time range grouping (i.e., <30 minutes, $\geq 30<60$ minutes, ≥ 60-120 minutes). Again, this may be because it is too ambiguous to ask for a specific singular time estimate; thus, using a time range instead may allow for a more suitable estimate to be made in a more efficient amount of time.

Additionally, as identified by Blackhurst et al., (2012), the experimental results uphold the notion that utilizing physiological technology allows real-time data to be transformed into actionable information, which in turn can be used to make better decisions. The results also support the development and use of RT-PSM technology instituted by the Army for use specifically in training environments for continual assessment and monitoring. As discussed in Chapter 2, instructors during USMC basic training were able to use real-time feedback to identify the physical stress of each and every trainee and make more well informed decisions based on the information they had. The experimental results indicate the same.

Research Question 2: How does the condition that the marcher is in correlate with how long they can continue the rucksack march and their level of exertion (RPE score)?

According to this research, the condition in which the marcher is in correlates with how long they are able to continue and also with their level of exertion (RPE score); however, with one exception. The exception being, those marchers in the “easy” condition felt they were working harder than those in the “moderate” condition. This may have been due to the fact that the large number of videos of marchers in the "moderate" condition occurred at the beginning of the marching session, which means the rucksack marchers are likely to indicate they felt better (i.e., lower RPE score). It may also make sense to why those marchers in the "easy" condition felt worse simply due to the fact they were marching on the treadmill for a longer period of time and may have felt bored or became increasingly uncomfortable. However, as predicted those marchers in the "hard" condition felt they were working harder than those marching in both the "easy" and "moderate" conditions, which matches the original predictions.

Additionally, as stated in Chapter 2, the rating of perceived exertion (RPE) scale is widely used in the exercise community to allow a subject performing a physically demanding task to measure their own level of exertion. Though RPE has been found to be a valuable tool, it should not be the sole mechanism used for decision-making. For example, as shown in the results those in the "easy" category felt on average they were working harder than those in the "moderate" category which is not what we expected. This shows the variability involved in the RPE score. A subject's given RPE score can be influenced by a number of things not just how hard they are physically working. This makes using biofeedback devices such as HR technology that much more important for providing a more accurate depiction of an individual's physiological state.

Additionally, the results show the accuracy available in creating training programs to reach a specific objective. In a military context, using HR information based on an individual's current level of fitness can allow commanders or program designers to create a training objective (i.e., category) for a specific phase of training to ensure proper periodization is taking place. This research shows that the categories (i.e., easy, moderate, hard) created for this experiment met the estimated objective of a marchers ability to continue the rucksack march. As discussed in Chapter 2, using the concept of "long-term periodization" which refers to conducting an annual training cycle in which the entire cycle is split into phases which last from several weeks to several months can limit the amount of physiological limitations (e.g., over-training, injury) from occurring (Seiler, 2010).

Furthermore, the periodization concept also interlocks with the QWI's "Sense-Assess-Augment Paradigm" which provides a "data-driven feedback loop," which takes the acquired data captured through HR monitors and even the RPE score/category given by the individual to better understand and thus improve current and future decisions. For example, in a training environment, if an objective is created with the goal of a trainee to operate in a low HRZ indicating a low RPE score/category, yet a trainee, though successfully operating in a low HRZ, reports a high RPE score/category, a trainer or commander can use this information to identify what may be causing the lack of connection. One may find out that the lack of connection is simply due to the trainee's rucksack not fitting correctly (causing a higher RPE score than expected) which can be easily corrected. This becomes valuable information for future use.

Lessons Learned

Upon the conclusion of this experiment, certain decisions could have been changed or adjusted slightly to improve the experiment and possibly produce more definitive results. The first recommendation is to have a larger sample size and also have an equal number of participants in each group. Additionally, the protocol for the experiment was not initially carried out as planned, which is what caused us to exclude 12 of the original participants. In the future, we would have double checked that the data collection procedures were taking place at the

USAFA. Lastly, when executing data creation procedures for the video clips it would have been helpful to document actual participant rationale for ending the rucksack march (e.g., cardiovascular exhaustion, mental exhaustion, local physical pain, prior time engagement) and also why they felt their RPE score was at the value they selected.

Recommendations for Future Research

The research in the area of using physiological technology to enhance decision-making capabilities is pertinent and will continue to be an avenue of exploration in the military. This research was a good stepping stone for examining how real-time HRZ information can allow commanders to gain a better understanding and better estimate on the current and future capabilities of their troops specifically in a training environment. Ease of use and understanding should also be taken into consideration for future research. The less ambiguity the better such as trying to delineate between numbers on a scale. This can be a time consuming activity and may draw away from the task at hand. Additionally, HRZ and RPE do not always align, for this reason future research should work to align and ultimately solidify hard connections between HRZ and RPE. Furthermore, there may be a better way to capture its connection with HRZ than the stop light chart created in this research. Also, an increased and equal number of rucksack march participants per condition would be ideal for better statistical analysis to take place. Finally, future research should work to conduct an experimental study such as this one in a more applied field setting rather than a laboratory using the groupings and/or stop light charts to identify their applicability and ease of use from a real commanders perspective.

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Appendix A: Approved IRB

Date:

HUMAN RESEARCH PROTECTION PROGRAM (HRPP) DETERMINATION REQUEST

DON'T BE AFRAID! The instructions are at the back and are based on feedback from investigators that have gone before you and have had unanswered questions. PLEASE TAKE THE FEW MINUTES NECESSARY TO READ THEM. IT WILL SAVE YOU IN THE LONG RUN.

Has this study been reviewed by an IRB already? Yes No

If YES, STOP HERE and contact the IRB Administrator at 333-6593 or usafa.irb@usafa.edu.

Circle one: Medical Non-medical

Title of Protocol (if applicable use the exact title listed in the grant/contract):
Estimation of Team Member's Running Exertion during Ruck March.

Protocol # (filled out by IRB Administrator): FAC20160022H

Principal Investigator (PI) Information (A cadet cannot be a PI. If there is a 2nd PI; add their information at the end of this form)

Name & Rank: Victor Finomore, PhD, DR-II

Organization & Position: DFBL/ Distinguished visiting researcher.

Telephone number: 719-333-9892

Email Address: victor.finomore@usafa.edu

FWA or DoD Assurance Number (if not USAFA personnel):

Associate Investigator (AI) Information (no limit, please add additional AI information at the end of this form)

John Allen
Cadet
C16John.Allen@usafa.edu

Austin Rohrer
Cadet
C16Austin.Rohrer@usafa.edu

Johnathan Graham
Cadet
C16Jonathan.Graham@usafa.edu

Christopher McClernon
Associate Professor
Christopher.McClernon@usafa.edu

FWA or DoD Assurance Number (if not USAFA personnel):

SUBMISSION

☐ Not RESEARCH involving human subjects

☐ Exempt study
See 32CFR219.101

☐ Full IRB Review
Go to STUDY DESCRIPTION on page 2

Revised Aug 2015

Page 1

Please answer the following questions regarding your activity or study:

Will you be collecting or analyzing information?

☐ Yes ☐ No

Does your study have organized processes or procedures?

☐ Yes ☐ No

Does your study test a hypothesis?

☐ Yes ☐ No

Can the information or outcomes you obtain be applied beyond the context of the activity?

☐ Yes ☐ No

Do you intend to expand understanding of a condition or population, or add to a body of knowledge?

☐ Yes ☐ No

Do you intend to provide results only to improve a program?

☐ Yes ☐ No

Will you use an existing dataset and there is no way to identify any individual in the dataset directly or indirectly?

☐ Yes ☐ No

Will you use an existing dataset such that a link exists that could allow the source of the data to be re-identified?

☐ Yes ☐ No

Will you use an existing dataset but a trusted agent has stripped the identifiers before providing it to the investigators?

☐ Yes ☐ No

Will your study be conducted in an educational setting, involving normal educational practices?

☐ Yes ☐ No

Does your study involve educational tests, surveys, interviews, focus groups, or observation of public behavior?

☐ Yes ☐ No

Does your study involve the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens?

☐ Yes ☐ No

Does your study involve a taste and food quality evaluation or consumer acceptance studies?

☐ Yes ☐ No

STUDY DESCRIPTION

1. **Number of Participants Required:** 40 participants are needed for this study to achieve statistical power. We would like to increase our recruitment to 50 people to account for attrition and missing data.

2. **Is there external funding?** ☐ **Yes** ☐ **No**

3. **Timeframe of Study: Ready to start in March 2016**

4. **Background:**

   Air Force Battlefield Airmen have to perform missions in diverse and challenging environments. An important role of the team leader is to make sure the team arrives at their waypoints on time and in good physical health to carry out their mission. Currently there is no way for them to monitor their team member's physiological health except looking at them to make a judgment or asking how they are feeling. This study will explore the ability to judge the capabilities of other people performing a ruck march with and without physiological monitoring devices to aid in the decision making of their physiological health.

5. **Objectives:**

1) Evaluate the effectiveness of judging the physiological health of team members performing a rucksack march.
2) Determine if physiological data such as heart rate aids in the accuracy of decision making regarding the runner's physiological health and endurance.

6. **Study Methods:**

The data will be collected on a standard Windows desktop computer with a 24" LCD monitor. This system uses a standard keyboard and mouse for responses. All stimuli of runners performing a rucksack march were recorded at the Air Force Research Laboratory's STRONG Lab, see Figure 1. Participants will watch 50 30sec clips of people running on a treadmill during various stages of their run. After each clip the participant will provide a rating of the Borg Perceived Exertion Scale which range from 6 (no exertion) to 20 (maximum exertion) for each running clip on the computer. Additionally, the participant will input on the computer their estimate for how much longer in minutes the running can go for. The clips will be randomized with half of them overlaid with the runner's heart rate.

Figure 1. Depiction of an Airmen performing a loaded rucksack march on a laboratory treadmill

Timeline:

Review and sign ICD	= 5 minutes
Instructions	= 5 minutes
Watch video clips and fill out questionnaire	= 17 minutes

7. **Subject Recruitment Methods:**

Human subjects with diminished autonomy, specifically cadets, will be recruited to participate. Participants will come from the DFBL participant pool made up mostly of BS 110 and 310 students. Furthermore, DFBL personnel will serve as principal investigator. To account for this, persons with direct authority and greater rank over potential subjects will not participate in recruitment as participants will sign up for these studies on the SONA recruitment software. Furthermore recruitment will emphasize voluntary participation and direct benefits of participation. Participants will receive instruction that voluntary withdrawal from the investigation cannot be the basis for any retribution brought against the subject. Finally, participants will be given reasonable time to reflect on his or her participation and to ask questions of the recruiter.

8. **Potential Risks/Inconveniences:**

There is no risk greater than that found using a computer. All equipment is standard office material. Total time to participate will not exceed 45 minutes. Participation will not impact participant's abilities to mobilize, perform their duties, and be available for duty.

9. **Direct and Indirect Benefits:**
   There are no direct benefits from participating in this study.
10. **Risk/Benefit Analysis:**
    Information from this study will be used to aid in the development of tools to provide dismounted team leaders with to monitor and judge the physiological health of their team. Standard computers will be used in this experiment thus presenting minimal risk to the participant.

11. **Compensation:**
    Participants will receive extra-credit points in their BS 110/310 course as it is stated in their course syllabus for participation in this study

12. **Confidentiality:**
    The identity of participants will be protected in the following manner. Participants will apply their name only to the informed consent document; no other document will contain participant names (participant's data will be identified with a number). The informed consent documents will be filed separately from the rest of the experiment materials in a locked drawer. Demographic data that could be used to identify a participant will not be collected.

Please obtain wet signatures, scan and email to usafa.irb@usafa.edu

Principal and Associate Investigators' Assurance Statement:

I read and understand the USAFA policies concerning study involving human subjects and I agree:

1. **to comply with all IRB policies, decisions, conditions, and requirements;**
2. **to accept responsibility for the scientific and ethical conduct of this study;**
3. **to obtain prior approval from the Institutional Review Board before amending or altering the study protocol;**
4. **that each individual listed as an investigator in this application has received the mandatory human study protections education;**
5. **to submit documentation of any publications or presentations that result from this study;**
6. **to transfer all full protocol study documents to a USAFA colleague prior to departing the Academy or close the protocol.**

Victor S. Finomore, Jr., Ph.D., DR-II, USAF
Distinguished Visiting Researcher
Department of Behavioral Sciences and Leadership
Principal Investigator

John Allen, C1C, USAF
Cadet
Department of Behavioral Sciences and Leadership
Associate Investigator

Austin Rohrer, C1C, USAF
Cadet
Department of Behavioral Sciences and Leadership
Associate Investigator

Johnathan Graham, C1C, USAF
Cadet
Department of Behavioral Sciences and Leadership
Associate Investigator

Christopher McClernon, LtCol, USAF
Associate Professor
Department of Behavioral Sciences and Leadership
Associate Investigator

Endorsement by the Department Research Director or an individual with similar responsibility and authority:

This is to certify that I have reviewed this protocol and determined that it is scientifically valid, emphasizes good experimental design, and minimizes the use of and risks to human subjects.

Christopher McClernon, Lieutenant Colonel, USAF
Associate Professor and Director of Research
Department of Behavioral Science and Leadership

Endorsement by the Department Chair or an individual with similar responsibility and authority (Note: If the Principal Investigator is also the Department Chair, the Vice Chairperson or equivalent should sign this section).

This is to certify that I have reviewed this study protocol and determined that it is scientifically valid, emphasizes good experimental design, and minimizes the use of and risks to human subjects. I will ensure that the study records and data for this protocol will be maintained for a minimum of 3 years.

Gary Packard, Colonel, USAF
Permanent Professor and Chair
Department of Behavioral Science and Leadership

Attachments:

Attachment A: Questionnaire scale
Attachment B: ICD
Attachment C: Human Subject Training

Attachment D: Primary Investigator CV
Attachment E: DFBL participant pool approval

Attachment A: Borg Perceived Exertion Scale

Rating	**Descriptor**
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

ATTACHMENT B.

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Estimation of Team Member's Running Exertion during Rucksack March.

1. WHO IS DOING THE STUDY?

Primary Investigator: Victor S. Finomore, Jr., Ph.D., DFBL, 719-333-9892
Associate Investigator: Christopher McClernon, LtCol, Ph.D., DFBL
Associate Investigator: John Allen, DFBL
Associate Investigator: Austin Rohrer, DFBL
Associate Investigator: Johnathan Graham, DFBL

2. WHAT IS THE PURPOSE OF THE STUDY?

This study is designed to explore the ability of team leaders to judge the physiological health of team members while they carry out a rucksack march. The results of this study will help inform the development of tools to aid team leaders to accurately monitor and judge the physiological health of their team.

3. WHAT WILL YOU BE ASKED TO DO?

1). The experimenter will explain how to use the computer interface that will display video clips of people running on a treadmill and the corresponding questionnaires for you to fill out in which you judge the runners' exertion levels and your estimation of how much longer they can run at their current pace.

There are two experimental conditions that you can be randomly placed in. This is a process similar to flipping a coin to determine the condition you will be assigned to. One condition consists of monitoring the runners on the treadmill while the other conditions will overlay their physiological data (i.e., heart rate) on the screen. If you volunteer to take part in this study, you will be one of about 50 people to do so.

4. WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

You will need to come to DFBL's Multimodal Research Laboratory for Innovation, Room 5L34, one time during the study. The visit will take about 30 minutes. The total amount of time you will be asked to volunteer for this study will not exceed 45 minutes.

5. WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

There is no risk greater than that found using a computer. All equipment is standard office material. Total time to participate will not exceed 45 minutes. Participation will not impact participatns' abilities to mobilize, perform their duties, and be available for duty.

6. WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

You will not receive any personal benefit from participating in this study.

7. DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. Your choice to participate will not affect your military or Air Force Academy career.

8. CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study. If you choose to withdraw from this study the extra-credit for participating will be reduced to be equal to the amount of time you participated for.

9. IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

Choosing not to participate is an alternative to participating in this study. Your course syllabus or instructor will have information on how to receive extra credit without taking part in a research study.

10. WILL YOU RECEIVE ANY REWARDS OR PAYMENT FOR TAKING PART IN THIS STUDY?

You will receive extra-credit points in your BS110/310 course as it is stated in your syllabus for taking part in this study.

11. WHO WILL SEE THE INFORMATION THAT YOU GIVE?

This study is anonymous. That means that no one, not even members of the research team, will know that the information you give came from you. You will be assigned a random number to help identify your questionnaire data. USAF Surgeon General's Research Oversight and Compliance Division (AFMSA/SGE-C) and other DoD personnel may inspect your study records.

12. WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Victor Finomore at 719-333-9892. If you have questions about your rights as a volunteer in this research or believe you were harmed as a result of participation, contact the USAFA IRB Administrator between the hours of 7:30 am and 3pm at 719.333.6593 or usafa.irb@usafa.edu. We will give you a signed copy of this consent form to take with you.

My signature below indicates my willingness to participate in this research study.

____

Participant printed name

______________________________ ____________

Participant signature Date

____

Advising Investigator printed name

_________________________________ ____________

Advising Investigator Signature Date

I witnessed the participant's signature to this document.

____

Witness printed name

______________________________ ______________

Witness Signature Date

ATTACHMENT C.

Human Subject Training (CITI) is on file with the IRB for

Primary Investigator: Victor S. Finomore, Jr.
Associate Investigator: John Allen
Associate Investigator: Austin Rohrer
Associate Investigator: Johnathan Graham
Associate Investigator: Christopher McClernon

ATTACHMENT D.
Victor Finomore's CV is on file with the IRB

ATTACHMENT E.

DEPARTMENT OF THE AIR FORCE
THE DEPARTMENT OF BEHAVIORAL SCIENCES AND LEADERSHIP
USAF ACADEMY, COLORADO

18 August 2014

MEMO FOR RECORD

SUBJECT: DFBL Participant Pool Approval Letter

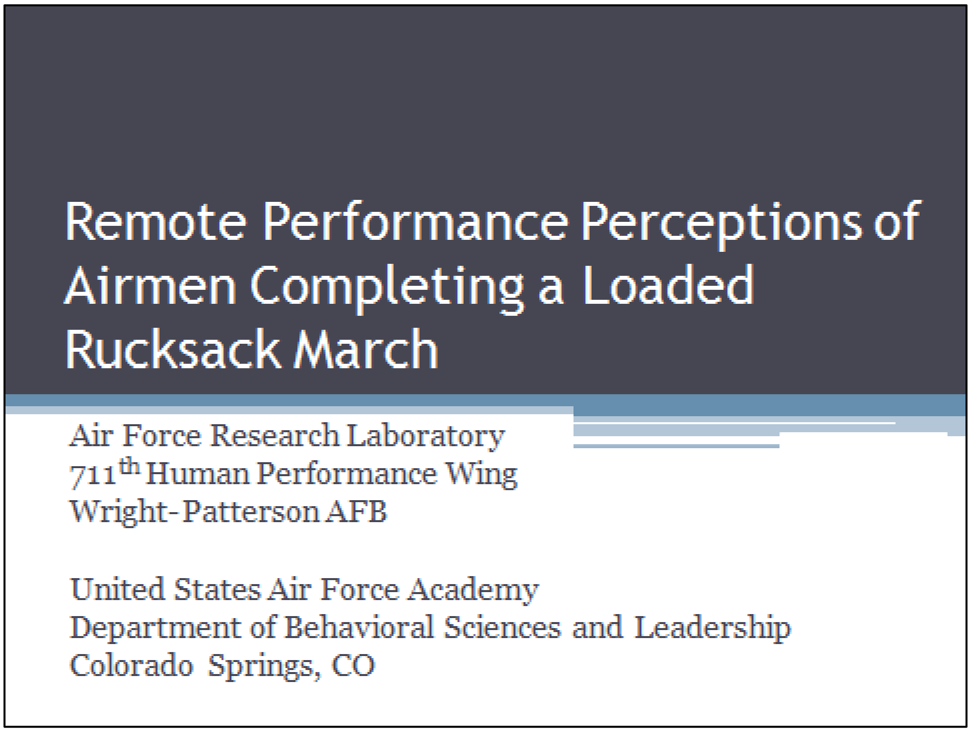
1. You have permission to use the Behavioral Science 110/310 participant pool for human subjects research.

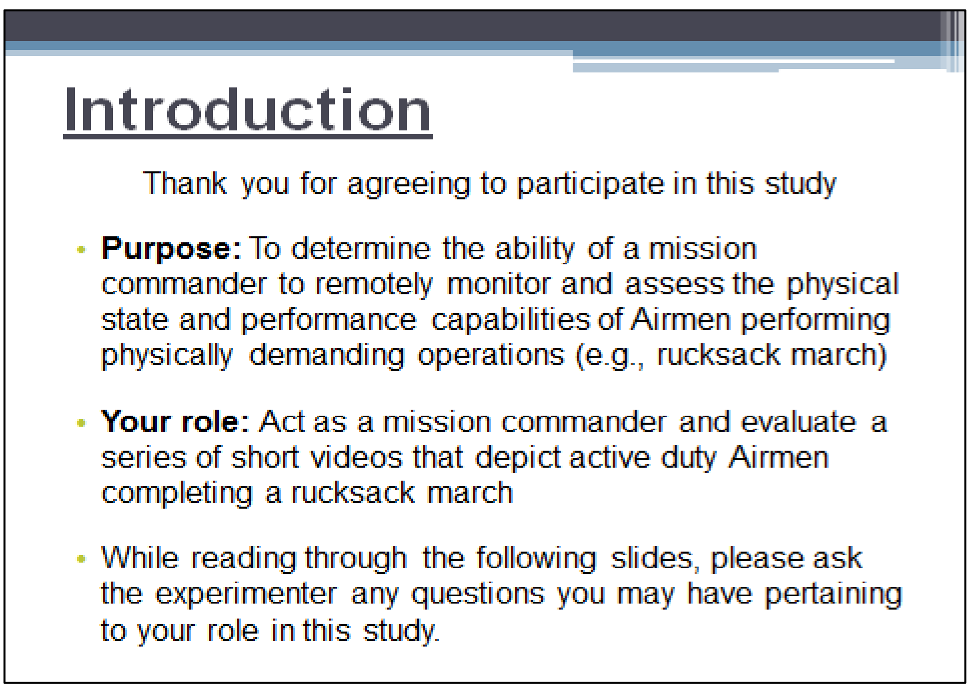
2. Once the U.S. Air Force Academy Institutional Review Board has approved your protocol, send it to me along with your approved Informed Consent Document. At that point I will create a researcher account for you in SONA which will permit you to post sign-up times to recruit volunteer participants. You are required to use your recruitment script as detailed in your protocol to recruit participants in SONA.

3. You are encouraged to contact me with any questions. I can be reached via email at: Brian.Johnson@usafa.edu and via cell phone at 806-559-6137.

BRIAN R. JOHNSON, LCDR, USN
DFBL SONA DIRECTOR

Appendix B: Video Instructions (No HRZ feedback)

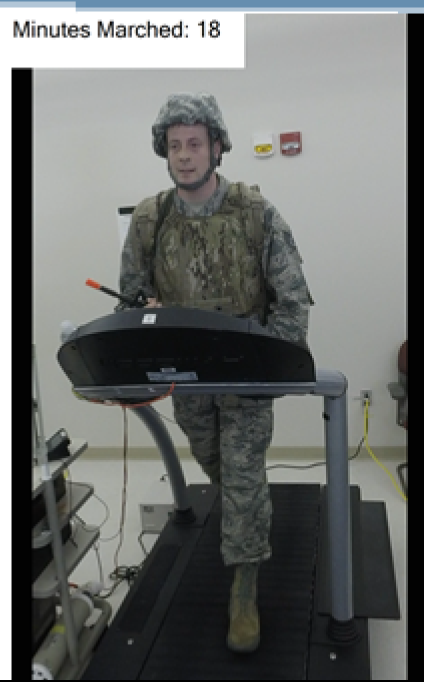




Instructions

- **STEP 1:** Observe a 15-second video clip of an Airman completing a rucksack march on a treadmill
  - Subjects in the videos are marching at a constant speed (3.0-3.5 mph) and grade (3-6%), and complete this activity for as long as possible, only stopping when completely exhausted
  - Total gear weight: approximately 50 lbs

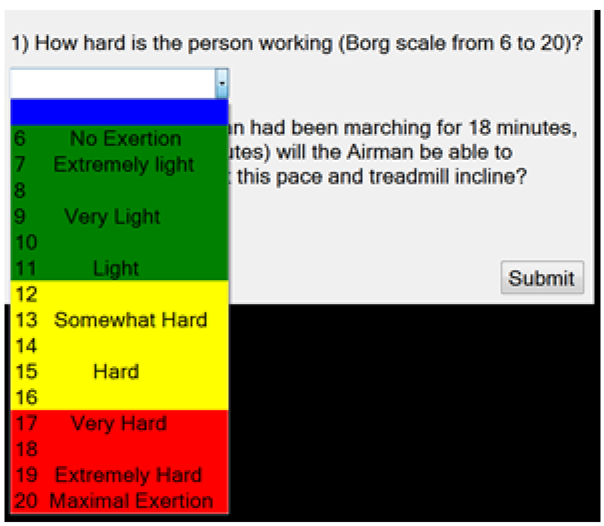
- At the start of each trials, a video clip will start playing automatically (it cannot be paused or replayed) that depicts each Airman marching
- The band at the top of the video indicates how long the Airman has been marching



Instructions

- **STEP 2:** Following each clip, answer two questions based on your perception and evaluation of the Airman's marching performance
  - **Questions:**
    1. *How hard is the person working (Borg scale from 6 to 20)?*
    2. *Given that the Airman had been marching for xxx minutes, how much longer (minutes) will the Airman be able to continue this activity at this pace and treadmill incline?*

- Answer **Question 1** utilizing the Borg Rating of Perceived Exertion (RPE) scale



RPE Scale	
6	*No Exertion*
7	Extremely light
8	
9	Very Light
10	
11	Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Extremely Hard
20	*Maximal Exertion*

- The Borg Rate of Perceived Exertion (RPE) scale is used to subjectively assess an individual's level of exertion
- Subject's perception may take into consideration feelings of effort, strain, discomfort, and/or fatigue

- Answer **Question 2** based on knowledge of how long the Airman has already marched and your visual observation of the Airman's performance

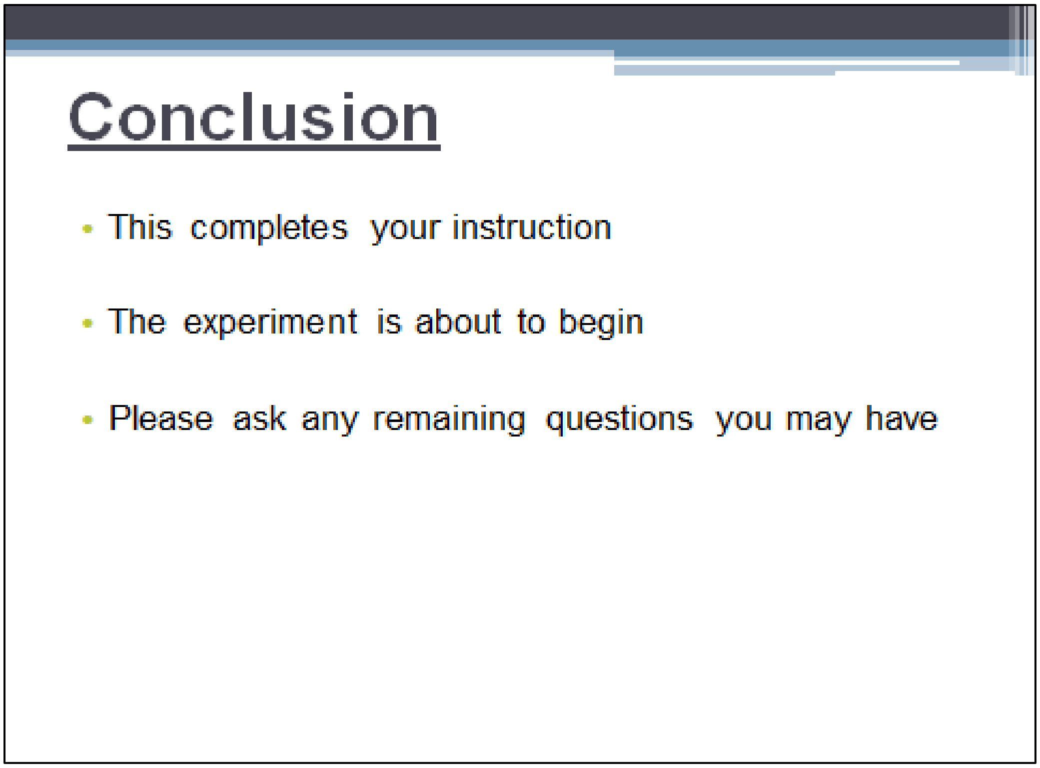
1) How hard is the person working (Borg scale from 6 to 20)?

2) Given that the Airman had been marching for 18 minutes, how much longer (minutes) will the Airman be able to continue this activity at this pace and treadmill incline?

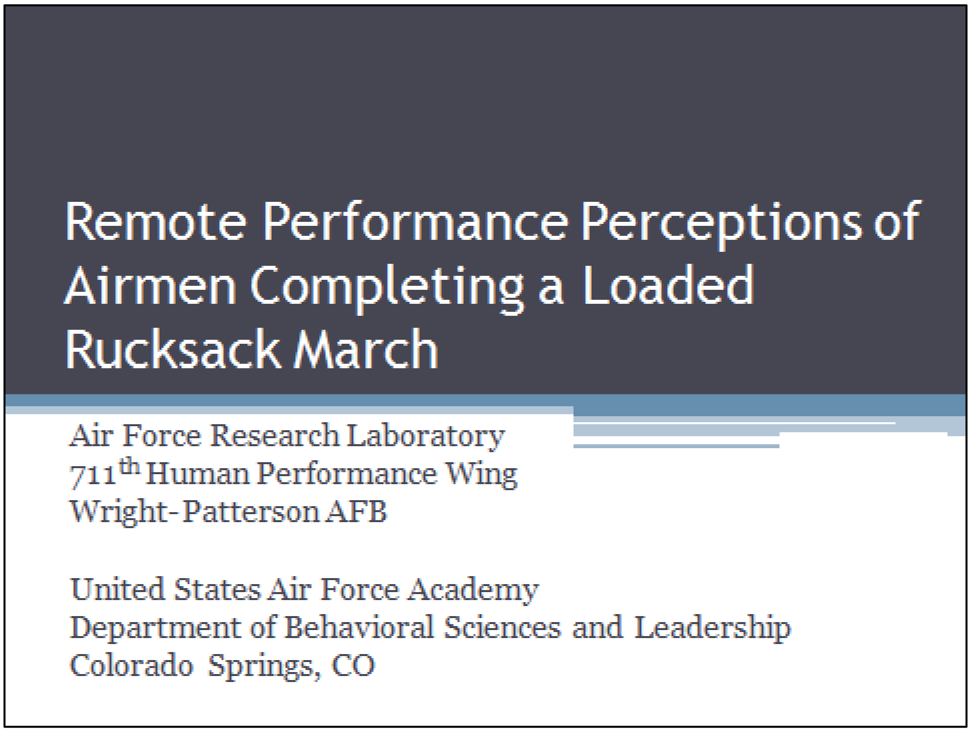
Minutes

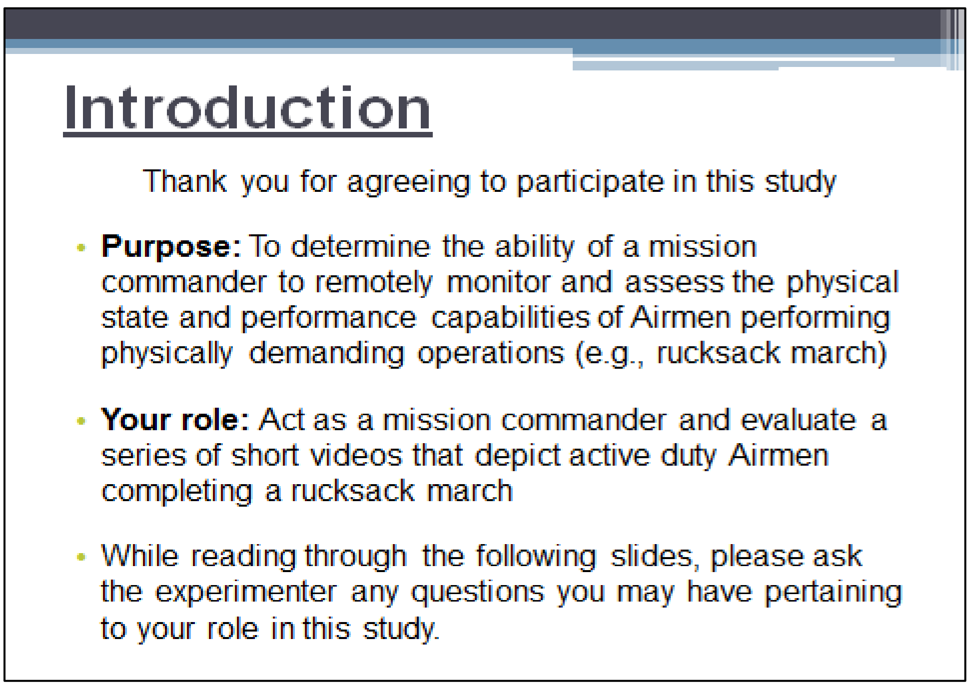
Submit

- Click **Submit** to move on to the next video


Conclusion
This completes your instruction
The experiment is about to begin
Please ask any remaining questions you may have

Appendix C: Video Instructions (HRZ feedback)





Instructions

- **STEP 1:** Observe a 15-second video clip of an Airman completing a rucksack march on a treadmill
  - Subjects in the videos are marching at a constant speed (3.0-3.5 mph) and grade (3-6%), and complete this activity for as long as possible, only stopping when completely exhausted
  - Total gear weight: approximately 50 lbs

- At the start of each trials, a video clip will start playing automatically (it cannot be paused or replayed) that depicts each Airman marching
- The band at the top of the video indicates how long the Airman has been marching and identifies the individual's real-time heart rate zone during the moments the video was taken

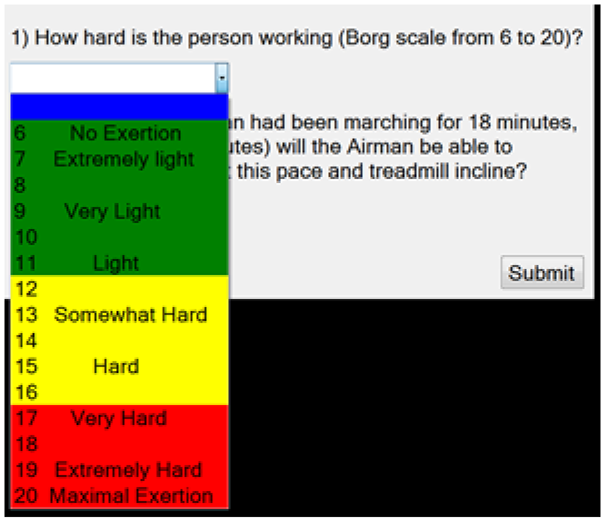
Instructions

- **STEP 2:** Following each clip, answer two questions based on your perception and evaluation of the Airman's marching performance
  - **Questions:**
    1. *How hard is the person working (Borg scale from 6 to 20)?*
    2. *Given that the Airman had been marching for xxx minutes, how much longer (minutes) will the Airman be able to continue this activity at this pace and treadmill incline?*

- Heart Rate zones (detailed below) correspond to different levels of cardiovascular and peripheral muscle stress that can cause different types of perceived comfort levels, which can potentially result in consequences for physical performance

Heart Rate Zones	
Zone 1	• Activity: recovery • Level of difficulty: easy • Places little stress on muscles, comfortable
Zone 2	• Activity: maintainable • Level of difficulty: moderate • Places moderate stress on muscles
Zone 3	• Activity: non-maintainable • Level of difficulty: hard • Rapidly increasing muscle discomfort

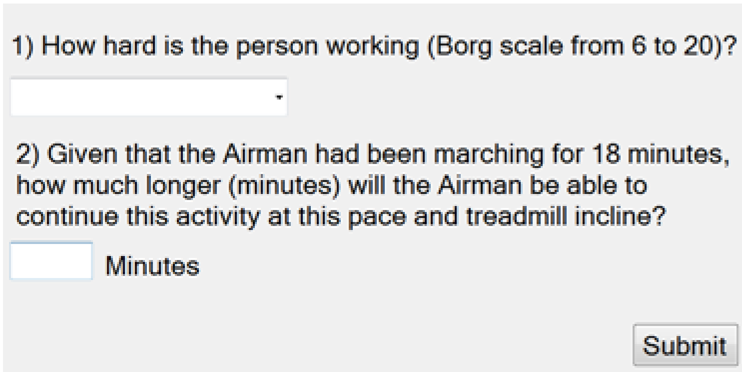
- Answer **Question 1** utilizing the Borg Rating of Perceived Exertion (RPE) scale



RPE Scale	
6	*No Exertion*
7	Extremely light
8	
9	Very Light
10	
11	Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Extremely Hard
20	*Maximal Exertion*

- The Borg Rate of Perceived Exertion (RPE) scale is used to subjectively assess an individual's level of exertion
- Subject's perception may take into consideration feelings of effort, strain, discomfort, and/or fatigue

- Answer **Question 2** based on knowledge of how long the Airman has already marched and your visual observation of the Airman's performance


1) How hard is the person working (Borg scale from 6 to 20)?

2) Given that the Airman had been marching for 18 minutes, how much longer (minutes) will the Airman be able to continue this activity at this pace and treadmill incline?

Minutes

Submit

- Click **Submit** to move on to the next video

Conclusion

- This completes your instruction
- The experiment is about to begin
- Please ask any remaining questions you may have

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
23-03-2017	Master's Thesis	October 2015 - March 2017

4. TITLE AND SUBTITLE	**5a. CONTRACT NUMBER**
Perception vs. Reality: Improving Mission Commander Decision-Making Capabilities by use of Heart Rate Zone Feedback in Training Environments	**5b. GRANT NUMBER**
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
Oviatt, Caitlin, M., Capt	**5e. TASK NUMBER**
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/ENC) 2950 Hobson Way Wright-Patterson AFB OH 45433-7765	AFIT-ENC-MS-17-M-152
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
711 HPW/RHCPA Dr. Adam Strang 2510 Fifth Street, Area B, Bldg 840 Wright-Patterson AFB, OH, 45433-7022 adam.strang.1@us.af.mil	711 HPW/RHCPA **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Statement A: Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

In the military environment, it is common for commanders to rely exclusively on perceptional information (e.g., visual observations) to make decisions on their personnel's physical capabilities. There is little evidence to support the idea that the information provided by physiological feedback technology, typically made available to the individual visually, could improve assessments and decision-making capabilities of outside observers (e.g., mission commander in a remote location). Through experimental examination this research shows that commanders who have Heart Rate Zone (HRZ) biofeedback information about their Airmen by use of physiological technology were able to more accurately predict the level of effort and how much longer their Airmen were able to continue an AF relevant endurance activity (e.g., rucksack march) than those commanders without the biofeedback information.

15. SUBJECT TERMS

Improving Decision-Making Capabilities; Heart Rate Zone (HRZ) Feedback

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Dr. Edward White, AFIT/ENC
U	U	U	UU	77	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636 x4540 edward.white@afit.edu

Reset