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Investigating The Effects Of Tactile Stress On A Military Touniquet Application Task

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INVESTIGATING THE EFFECTS OF TACTILE STRESS ON A MILITARY TOURNIQUET APPLICATION TASK

by

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ABSTRACT

In combat, soldiers encounter stress from multiple sources including loss of sleep, extremely high levels of physical and psychological discomfort, extended periods of increased vigilance, and intense danger. Therefore, it is imperative to train such personnel on how to cope with these stressors. One way to do this is to include stressors in different forms of training to acclimate soldiers to the subsequent stress of combat. Due to their advantages, tactile trainers are being investigated increasingly for the use of training Army medics in this context. The present work examines how vibrating tactile sensors, or tactors, can be used as surrogate sources of stress on an operator performing a simulated medical task. This work also examines how this "optimal" configuration interacts with other types of stress, such as noise and time pressure. The outcome findings support the hypotheses that configurations placed on sensitive body areas are more stressful than those placed on more benign body locations in terms of worse task performance on a tourniquet application task. In terms of application times, the same trends persist in terms of proper application, subjective stress and subjective workload, as well as a secondary monitoring task, in terms of response times, accuracy, and time estimation. Additionally, findings supported hypotheses that the stress responses experienced order tactile stress alone is compounded when other types of stress are employed, both on the primary and secondary tasks. These results have implications for training, such that if stressors are employed in training, performance decrements might be lessened during actual task performance; they can be generalized to not only combat medics, but other military specialties and civilian jobs that incur vibration, auditory stress, and time pressure while engaged in performance.

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CHAPTER ONE: INTRODUCTION

This work examines how tactile interfaces can be used as forms of stress and how their effects on performance combined with other sources of stress. This investigation focuses on tasks performed by United States Army medical personnel in combat. Consider, for example, a tank carrying U.S. Army soldiers driving down a street in Iraq when an improvised explosive device (IED) detonates, throwing all the soldiers from the vehicle. As the medic in the following vehicle runs to the scene, he looks in concern at a soldier who has lost his leg and is bleeding profusely. This being his fifth week of deployment, he has never applied a tourniquet. He knows that, especially with lower extremities, if the tourniquet is not applied tightly enough, the patient may well bleed to death very quickly. However, he has been qualified on a tactile trainer to properly administer this tourniquet. The tourniquet is applied correctly, and the medic can now confirm that his training has been invaluable in saving the soldier's life.

Currently, the Army combat medic, designated as "68 Whiskey" (68W), formerly "91 Whiskey" (91W), supplies the first line of treatment for wounded soldiers. The majority of all combat casualties result from penetrating trauma (Parsons, 2004). Additionally, ninety percent of all combat deaths result from an injury that could not be treated in time but would otherwise be survivable (Fowler, Smith, & Litteral, 2005). While lack of response time is certainly partially to blame, inadequate training that adds to treatment time can also affect survival rate. To prevent unnecessary death, prompt and accurate treatment prior to evacuation is necessary. However, according to one of the Army's leading medical trainers, civilian training is often not adequate for combat care because the two are not synonymous (Parsons, 2004). There are many areas that differentiate combat care and civilian care including the presence or absence of enemy fire, the variation in ambient environmental conditions, differences in medical equipment availability, differing evacuation time delays, and tactical considerations in combat care that are not present in civilian care, such as events or procedures that place the mission at a higher priority than patient treatment (Parsons, 2004). Due to these differences, many civilian training systems are inappropriate for training combat medics. Due to the need to incorporate such stresses into military medical training, tactile interfaces are being considered to supplement and augment current training regiments.

What are Haptic and Tactile Interfaces?

"Haptics" has been defined many ways, such as the science of touch, the modality of touch and the sensation for a virtual object, and the active touch of an object (Holland, Williams, Conatser, Howell, & Cade, 2004; McLaughlin, Rizzo, Jung, Peng, Yeh, Zhu, & the USC/UT Consortium for Interdisciplinary Research, 2005; E. Rinalducci, personal communication, January 20, 2004). "Tactile" has also been defined various ways, but will be referred to here to mean the passive gathering of information from touch (E. Rinalducci, personal communication, January 20, 2004). The main difference between "haptic" and "tactile" is that haptic refers to the active seeking of information, while tactile refers to the passive gathering of information. With respect to haptic and tactile interfaces, several issues need to be addressed. These are the types of devices, haptic/tactile processing, touch and other modalities, and touch in simulated environments.

There are various devices through which tactile information and haptics are delivered to the operator, such as pens, steering wheels, flight yokes, and surgical instruments. The main mechanism through which these devices provide feedback is vibration, though this feedback could be as simple as providing resistance when the operator interacts with a surface of the device (Holland, Williams, Conatser, Howell, & Cade, 2004).

Less is known about haptic/tactile processes than visual processes. In many instances, the haptic/tactile system can be used to identify an object but not locate it. Location information requires additional processing after an identification has been made (Purdy, Lederman, & Klatzky, 2004). There are differing opinions about the capacities of the haptic/tactile system. Some researchers suggest the full range of haptic/tactile system limitations remains to be identified (Purdy, Lederman, & Klatzky, 2004) while others suggest that when processing only location information, the haptic/tactile system has no limitations (Shiffrin, Craig, & Cohen, 1973). Additionally, the haptic/tactile system uses different processes to determine identity versus location (Purdy, Lederman, & Klatzky, 2004).

Haptic/tactile presentation can help in learning complex motor skills that are hard to explain verbally or visually (Feygin, Keehner, & Tendick, 2002). It may also aid learning when used with other modalities (Helmick-Rich, Burke, Oron-Gilad, & Hancock, 2004). According to Fitts and Posner (1967), learning occurs in several stages. In the cognitive stage of learning, haptic/tactile training can aid learning by letting the operator easily make a connection with the bodily movements and verbal/visual cues. In the associative stage, haptic/tactile training may aid by directly showing the operator how to perform the task. However, in the autonomous stage, haptic/tactile training may not be advantageous because reliance on haptic/tactile cues may prevent the operator from automating the task (Fitts & Posner, 1967). With haptic/tactile guidance, the operator is physically guided by the system to give a kinesthetic understanding of what is required (Feygin, Keehner, & Tendick, 2002).

Srinivasan (1995) defined “haptic interfaces” as all devices that allow manual interaction with simulated environments. It should be noted that simulated does not necessarily mean virtual environments as controlled by computers. A simulated environment might simply be a room rearranged to represent a different environment. He also categorized haptic/tactile interfaces in many ways, including distinguishing between 1) free motion, involving no contact with objects in the environment, 2) contact involving unbalanced resultant forces, such as choosing from a touch screen, and 3) contact involving self-equilibrating forces, such as squeezing an object. Free motion represents no haptic or tactile information while the other categories represent varying degrees of that information. Another distinction among haptic/tactile interfaces is whether they are manipulated directly with the body or by using a device. Both methods are currently used in haptic/tactile interfaces with differing degrees of success depending largely on the interface. Yet another distinction is ground-based devices, such as joysticks, versus body-based devices, such as wearable gloves, versus tactile displays.

The research here on the benefits of using haptic tasks and tactile devices encourages the use of these for this dissertation. Haptics were used with the tourniquet task, and tactile devices were used with the tactile vests. These were employed to leverage the benefits of these types of tasks in research.

Medical Haptic/Tactile Trainers

Recently, there has been an increase in the number of haptic/tactile interfaces used for medical training (Liu, Tendick, Cleary, & Kaufmann, 2003). This is likely due to the advantages that haptic/tactile interfaces render. Haptic/tactile simulators are especially helpful in the medical profession because they can provide many benefits that live practice can not. Medical practitioners develop critical skills through practice and traditionally they have developed these skills by practicing on animals, cadavers, and live patients. However, animal anatomy is different from human anatomy, which makes this medium less than ideal. Cadavers do not provide the same physiological responses as live patients on which professionals will be working, so this medium is not preferred either, and the risk to live patients is increased greatly when a professional is still acquiring skills (Liu, Tendick, Cleary, & Kaufmann, 2003). Given these factors, trainers that simulate live patients and the appropriate physiological responses to a procedure are ideal for medical training. The appropriate physiological responses include not only visual cues, but often haptic/tactile feedback as well. Medical professionals often palpate the area in question before beginning procedures; they cut tissue during procedures, and suture lacerations. Human tissue often gives feedback to the practitioner through cues such as providing more or less resistance depending on the area and condition of tissue, stretching when pulled, and giving way when punctured or cut (Dev, Montgomery, Senger, Heinrichs, Srivastava, & Waldron, 2002). Additionally, not only does human tissue provide feedback, but instruments do also. For example, when a medical professional is suturing a wound, the forceps and thread offer feedback as to how successful one is in tying a knot (Okamura, 2003). Thus, haptic/tactile interfaces can add a great deal of fidelity to a medical simulator and may offer increases in training transfer by making the simulation as realistic as possible. This could be because haptic/tactile simulation creates real-world simulation, which has been shown to have significant transfer to performance in actual conditions (Kozak, Hancock, Arthur, & Chrysler, 1993). However, there are many human factors issues associated with haptic/tactile interfaces.

Human Factors Issues

Haptic/tactile interfaces have been used for a variety of tasks from military applications to helping aging populations. However, these interfaces are not as well researched and understood as visual and auditory interfaces, although there has been promising research on how to best exploit them for training purposes. They have been employed with some success in dental procedures (http://www.uic.edu/classes/dadm/dadm396/ADSreserch/Contents.htm, 2006), laparoscopic procedures (Liu, Tendick, Cleary, & Kaufmann, 2003), and arthroscopic procedures (Okamura, 2003). As with any budding area of research, there are human factors issues to be considered when using haptic and tactile information in an interface. Some of these issues arise in the areas of Human-Computer Interaction (HCI), Ergonomics, and Sensation and Perception.

Human-Computer Interaction (HCI)

In the area of HCI, many issues could be addressed. However, three issues are of particular importance for haptic/tactile interfaces, which are refresh rates, the type of procedure(s) simulated, and the type of model used for the simulation. Refresh rates are extremely important. If an interface is not refreshed with sufficient frequency, the operator’s sensory capacity will perceive the delay. Thus, an interface refresh rate must exceed human perceptual capabilities. Long delays are quite common in older visual displays, which need a refresh rate of approximately 30Hz (Choi, Sun, & Heng, 2004). If the display is refreshed at a rate slower than this, the operator will see the refreshing of the screen, which usually appears as a series of flashes. However, this problem is also of concern in haptic/tactile interfaces, which typically need a refresh rate of approximately 1000Hz in order to seem realistic to the operator (Choi, Sun, & Heng, 2004). If the display is not refreshed at such rates, the haptic/tactile feedback given by the system will lag behind the action of the operator to such an extent that the operator will notice a time difference between his/her manipulation and a resulting force on the object. This is problematic in medical trainers because the less realistic the simulation is to the practitioner, the less transfer he/she will experience when performing live procedures. Tissue deformation is particularly susceptible to this technological constraint (Choi, Sun, & Heng, 2004). Luckily, this problem is addressed easily by ensuring refresh rates are high enough, which modern-day computerized systems are able to achieve.

However, another issue is in regard to open surgery versus laparoscopic procedures. With open surgery, the haptic/tactile interface design gets exponentially more complex with the addition of degrees of freedom of movement than with the relatively small movements in laparoscopic procedures. This problem is being investigated, but has not yet been solved (Cosman, Cregan, Martin, & Cartmill, 2002).

Equally important as the type of procedure is the type of model used. When creating a deformable tissue model, Choi, Sun, and Heng (2004) used a computational haptics loop to sustain high refresh rates. This is especially important in complex, multi-level systems with high bandwidth constraints. To achieve real-time deformation, this study used the Personal Haptic Interface Mechanism (PHANToM). The PHANToM is a small, desktop machine with a stylus grip and works similarly to a tactile mouse in 3-D. This system has been used in many studies to achieve the refresh rates required by haptic interfaces (Liu, Tendick, Cleary, & Kaufmann, 2003; Dev et al., 2002; Holland, Williams, Conatser, Howell, & Cade, 2004; McLaughlin et al., 2005). Though this system is relatively inexpensive compared to other haptic/tactile devices, it still costs approximately $20,000, which may be too expensive for small laboratories doing haptic/tactile research. However, the creators at the Massachusetts Institute for Technology

(MIT) claim that as haptic/tactile research becomes more prevalent, the cost associated with this device will most likely decrease. They are currently adding a thermal application so the stylus will match the temperature of the object it is touching in the simulated environment (http://web.mit.edu/newsoffice/1998/phantom.html, 1998). This would greatly benefit the medical community for whom temperature is a key component of diagnosis for many conditions.

Ergonomics

In the area of ergonomics, operator fit and force feedback must be accounted for in any interface, including haptic/tactile interfaces. With respect to haptic/tactile devices, theoretically, if the device is uncomfortable or binding, the haptic/tactile feedback can be compromised. Practically, if it is uncomfortable or binding, the device may well be neglected. Thus, ergonomic considerations must be taken into account when designing a haptic/tactile interface. This concerns both wearable haptic/tactile devices and those which simply require manipulation by the operator. This is a problem for medical simulations because often haptic and tactile information is employed in the instruments used for procedures. Typically these instruments are small hand tools, and adding sensors often makes them awkward to hold. Additionally, in order for these tools to provide the correct haptic/tactile feedback, the forces of a live patient must be recorded to use in the simulations. However, there are few sensors that can be sterilized well enough to be used in live procedures; thus, the information about forces in a live patient are often very difficult to obtain (Cosman, Cregan, Martin, & Cartmill, 2002).

While it is hard to attain forces for haptic/tactile feedback in surgical tools, it is not impossible. Dev, Montgomery, Senger, Heinrichs, Srivastava, and Waldron (2002) employed the PHANToM system in a force feedback stylus to give rotational and translational information for a simulated surgical grasper. However, the stylus used is thicker than many surgical tools, which may compromise transfer, and the diameter of the stylus can not be changed to simulate different instruments, which limits the use of the device.

The University of Illinois at Chicago uses haptic dental instruments to train their students to distinguish between healthy and abnormal oral tissue and teeth using force feedback (http://www.uic.edu/classes/dadm/dadm396/ADSreserch/Contents.htm, 2006). This tool may be more realistic than the PHANToM because it is very similar to actual dental tools in diameter, weight, and materials. However, the validity of the haptic information from these instruments is unclear, again because it is hard to approximate forces generated in live patients.

Another type of device used in medical training is the virtual haptic back (VHB) which was designed by Holland, Williams, Conaster, Howell, and Cade (2004) to train medical students how to correctly palpate. Using the PHANToM haptic interface, as users move their fingers to the correct location, the Cartesian locations are sent to a computer which calculates the force that should be felt at that location, and that information is conveyed to the user by forces felt through the PHAMToM stylus. Later iterations of the VHB will include modeling for the underlying structures, such as bone and muscle, to make it more realistic, but only portions of the spine that medical professionals would normally be able to feel. Also, the graphical cues will be disabled to assess how well a student can diagnose by feel alone (Holland, Williams, Conatser, Howell, & Cade, 2004).

Sensation and Perception

The area of sensation and perception includes receiving information from the environment through sensory channels and subjectively interpreting that information. When designing haptic/tactile interfaces, three sensation and perception topics should be taken into account – sensation and control of contact forces and joint angles, perception of contact conditions and object properties, and integration of local information with non-local perception of the environment (Srinivasan, 1995).

The first topic depends greatly upon a person's kinesthetic abilities. That is, the better a person can sense his/her own joint angles, limb motions, and their associated forces, the better he/she should perform with haptic/tactile interfaces. While human kinesthetic abilities have been researched for years, they may still not be well-defined and understood which can hinder the progress in haptic/tactile interfaces (Srinivasan, 1995). However, in haptic/tactile guidance, the system physically guides the operator to demonstrate the appropriate movements for the task to give a kinesthetic understanding of what is required. There is evidence that suggests this type of guidance aids in training (Feygin, Keehner, & Tendick, 2002). However, there is also evidenced that too much guidance in a motor task is detrimental to that task, termed the guidance hypothesis (Salmoni, Schmidt, & Walter, 1984). As research continues in this area, and human capabilities and limitations are investigated more thoroughly, haptic/tactile interfaces should greatly improve.

The second and third topics deal largely with the perception side of sensation and perception. Interpretation of sensory information is critical to any type of interface, particularly in haptic/tactile interfaces. An interesting example of misinterpretation has been shown in an experiment by Weber in the late nineteenth century in which participants reported that cold objects felt heavier than warm objects of equal weight (Srinivasan, 1995). However, in haptic/tactile interfaces, the connection between sensory stimuli and interpretation is a little harder to quantify. Limb position and net forces give sensory feedback to the user. Two main issues which arise in this area are the strength and location of stimuli required to invoke the desired response. Stimuli must be presented at a strength that is adequate for the operator to sense but not so strong that performance is hindered, or the operator is startled. Similarly, stimuli must be presented at locations that make sense intuitively to the operator and convey information about the state of the system. These issues are currently being researched in the areas of human factors and sensation and perception (Terrence, Brill, & Gilson, 2005). The solutions to these issues vary among different haptic/tactile interfaces, but in all interfaces they should be considered during design.

Even with all the human factors issues that must be considered when designing haptic/tactile interfaces, they are extremely beneficial in certain areas, such as those in which prompt and accurate training is required and visual and auditory interfaces are not available or are not the desired approach. The military, particularly combat medical treatment, is one such area.

CHAPTER TWO: LITERATURE REVIEW

Combat Medical Personnel

There are many types of medical personnel in the US Army. Training varies depending on the type of medic, as do familiarization to simulation, experience, and the types of injuries treated. The first line of care is the 68W. This refers to personnel qualified in basic emergency medical treatment (EMT) at the National Registry Level providing combat medical care independent of a hospital setting. Slightly above a 68W, but still providing immediate care are the Special Operations Combat Medics and the Special Forces Medics, who have more than one year of training at Fort Bragg and EMT certification at the paramedic level and six months' additional training, respectively. The next level of care is the Forward Medical Unit. It consists of physician assistants, who have training in Advanced Trauma Life Support with further training in resuscitation and stabilization, junior doctors, or "battalion surgeons," who put in chest tubes for pneumothorax, start IVs, and stabilize fractures for transport. The next level of care is the Medical Company, which does not deal with combat injuries – they are specialized for issues such as dentistry, radiology, etc. The Forward Surgical Team, the next level of care, has one or two general surgeons, one orthopedic surgeon, one nurse anesthetist, and some junior and senior non-commissioned officers. This team can quickly exceed capacity since there are only two surgeons if they can not co-locate with a Medical Company and evacuate patients to the rear. The next level of care is the Critical Care Aeromedical Transport Teams, essentially ICUs in the air, are used for far forward evacuation after a patient has been treated. The Combat Support Hospital is the final stage of combat care and has about 200 beds and capabilities for CT scans, but not MRI, and most surgical specialties except neurosurgery and cardiothoracic surgery.

Though there are many types of combat medics, the most common type is the 68W. The 68Ws are the first responders to most combat wounds, and, because they are exposed to a wide variety of injuries, they must be trained on a wide variety of tasks (Barclay, 2006).

Initial training of the 68W is at the Army Medical Department Center and School at Fort Sam Houston, TX. The course is 16 weeks, consisting of 6 weeks of the National Registry Emergency Medical Technician (NREMT) basic course, for which the medic must pass the NREMT-B test and become certified, and 10 weeks of training for more advanced trauma and field exercises. The 68W must learn and master combat medic skills including measuring a patient's pulse oxygen saturation, control bleeding, obtain an electrocardiogram, administer oxygen, perform needle chest decompression, insert a combi tube, treat a casualty with an open chest wound, treat burns of the eyes, administer morphine, intubate a patient, and insert a chest tube. However, training challenges occur because medics do not have adequate access to patients, even when working in an emergency room, riding along with an emergency medical service, or working in a trauma clinic. Additionally, the types of wounds sustained in combat, such as gunshot wounds, severe burns, multiple penetration injuries, and nuclear, chemical and biological casualties, are not often found in civilian medicine. Thus, many medics get their practice in the field. As this is highly undesirable for the efficiency and efficacy of the combat medic, simulators are being incorporated into training. Model-driven simulators (MDSs) are the highest fidelity simulators for medics and use mannequins or mannequin parts to simulate patients. MDSs often have physiological reactions to the treatment of the medic. Instructor-driven simulators have intermediate fidelity. While these simulators use mannequins and associated parts like MDSs, responses to treatment are often initiated by the instructor. Virtual reality simulators use computer simulations to immerse the medic in a realistic patient environment and because they use computers, data collection is fairly simple with these simulators. The largest benefit of using simulators to the combat medic is that the worst thing that will happen if he/she mistreats a patient is that the scenario can be restarted and different tactics can be employed. There is no risk of loss of life or further damage to a live patient. Simulators are increasingly used in combat medic training at the Medical Company Training Site in Pennsylvania. The largest push for simulators in this facility came when medics were unable to obtain a NREMT-B certification because they could not meet the requirement of treating at least five patients. With the use of approved simulators this is no longer a problem. Even with the current technology, portability for deployed medics remains an issue. However, the main disadvantage reported by instructors and students of these simulators is that they do not like integrating technology into a standard course. For instructors, the main complaint was the time it took to write scenarios, familiarize themselves with the simulators, set up the simulators, clean up and maintain the simulators, and familiarize the students with the simulators. This has since been remedied in later classes of medics (Fowler, Norfleet, & Basebore, 2003).

The current battlefield in the Middle East has not changed with respect to the types of wounds that soldiers sustain since World War I (Parsons, 2004). The leading cause of death is injury due to explosions, and this accounts for 57% of deaths. At 27%, gunshot wounds are second, followed by aircraft accidents at 11%. However, with all these causes of death, only 18% of deaths on the battlefield are preventable. Of these, almost half of the injuries are to the extremities, and 81% of preventable death is caused by hemorrhage. The leading cause of preventable death on the battlefield is exanguination from extremities. The second and third causes of preventable death are tension pneumothorax and airway obstruction, respectively (Parsons, 2004). Thus, if hemorrhage control can be better learned, the majority of preventable battlefield death will be averted (Parsons, 2004). A big problem in the Army medical community is that many 68Ws are around 18 years old, have never been deployed, and have not been in the Army very long. They typically have never held another military occupational specialty (MOS) before. Thus, not only do the 68Ws not know the medical tasks very well, they often are not equipped to handle the stresses of combat, especially on their first tours of duty (Parsons, 2004).

Stress Effects on Performance Capacity

To understand stress on the battlefield, one must take into account empirical research conducted on stress in both the civilian world and the military world. Stress has been defined many ways, such as an event that poses a threat to physical or emotional well-being, a force that decreases performance ability, and the product of a person and his/her responses and the environment when the environment is threatening to the person's well-being (Bollini, Walker, Hamaan, & Kestler, 2004; Hancock, Conway, Szalma, Ross, & Saxton, 2006; Hancock & Warm, 1989). Stress is typically thought of as a function of the environment, although the coping mechanism of the individual and physiological adaptability are other ways to viably assess stress (Hancock & Warm, 1989). Also, stressors are independent of the individual, but stress itself is not (Hancock, Conway, Szalma, Ross & Saxton, 2006). Important things to consider when investigating stress are the main theories and models, how stress affects task performance and the operator, including the soldier, reactions to stress, and types of stress.

One of the most well-known theories of stress and arousal is the Yerkes-Dodson model, or the inverted-U model. However, there are several problems with this model (Hancock & Ganey, 2003). The original Yerkes-Dodson report described the relationship between discrimination learning and aversive reinforcement. The experiments used dancing mice, not humans, and the focus was not on stress, but on rates of learning. The original studies were conducted to investigate learning under varying condition of black/white discrimination with a shock stimulus. The criterion for success was to correctly complete 10 trials one day and three consecutive days afterward. “Learning” was measured by how many days it took the mouse to reach this criterion. Three experiments were conducted. The first and third experiments found that for a “medium” level of shock, learning was best facilitated. However, the second experiment revealed that the strongest stimulus resulted in the most rapid learning. This was contradictory to the first results, which spurred the authors to conduct the third experiment. Additionally, the law named after Yerkes and Dodson should not have been extrapolated by these experiments. Perhaps the largest reason is that the authors themselves did not link their observations to stress and performance, which are the parameters to which the law refers (Hancock & Ganey, 2003). This law gained support through Hebb’s work on drive and other studies (Hebb, 1955). This model has a great deal of face validity, which has perpetuated it for many years. However, another basic problem of this model is that it can not produce strong hypotheses (Hancock et al., 2001). Additionally, according to the Yerkes-Dodson law, the optimal level of stress is a function of task difficulty, so that difficult tasks require lower levels of arousal to attain peak ability, but this does not always hold true (Hancock, Conway, Szalma, Ross, & Saxton, 2006).

A model developed by Hancock and Warm (1989) better approximates the human condition. This model suggests that stress can be thought of in three components – input, adaptation, and output. Input stress refers to a description of the physical features of the environment. It is deterministic and the same for all individuals. It is referred to as a stress signature because of the components that are accounted for by this factor. Adaptive processes can also be thought of as compensatory processes and are those which involve internal physiological processes that respond to external influences. These characteristics are similar among all individuals, but not identical, and thus are thought of as nomothetic rather than deterministic. Lastly, output processes are largely affected by the individual's goals and state at the time of stress, and are idiographic or person-specific. This represents goal-directed behavior. This model is very similar to the model created by Lazarus and Folkman which suggested that stress can be thought of as input, adaptation, and output, but also includes a feedback loop between output and input such that one's appraisal of his/her performance might become a stressor in itself (Lazarus & Folkman, 1984).

The Hancock and Warm model shows dynamic stability, dynamic instability which progresses toward ultimate collapse, and a shift between the two. A view of stress and performance must take into account that the task itself is often the primary source of stress. Control seems to be an important factor to the perception of stress because the most stressful conditions are those in which the individual has little perceived control with high demand (Bollini, Walker, Hamann, & Kestler, 2004). Input stress that affects only psychological processes are transmitted throughout the physiological system. The amount of input stress that can be coped with before output is affected is called maximal adaptability. In the Hancock and Warm model (1989), the boundaries of the zones of maximal adaptability for physiological and psychological processes may be continuous or may represent discontinuities. "Stereotypical" behavior will not be seen with mild levels of stress because there are many options through which one might achieve the desired result. However, at extreme levels of stress, options are limited, and common behavior is often seen.

The culmination of this continuum is a point at which only one option is available for survival. The model is most useful for continuous exposure to simple stress. The Hancock and Warm model, or the extended-U model, has three focal points of stress, which are the environment itself, the interaction between the environment and the exposed operators, and the output from the operator. The last focal point could be the best way to estimate stress effects. Realistically, when an individual experiences stress, it is rarely caused by a single source. Often, the person is operating in undesirable conditions, perhaps with time pressure. This reasoning is why the task itself must be included in stress models (Hancock et al., 2001).

When comparing the inverted-U model to the extended-U model, one can see that both models show degraded performance at stress extremes. However, the extended-U model shows adaptation for the mid-range of stress in which attentional narrowing is adaptive. The main difference between the two models is the continual, steady decrease in performance in the inverted-U model and the sharp decrease in performance at failure in the extended-U model. This facet of the extended-U model is supported by a strong response capacity until the time of failure, at which point performance very rapidly decreases. This is seen in anecdotal soldier evidence which shows little variation in performance over prolonged periods of activity except the occasional complete failure often requiring evacuation and medical attention (Hancock, Ganey, & Szalma, 2003).

The Hancock and Warm model is best used to understand and describe an operator's successive failures under stress. Currently, the most widely accepted notion of explaining stress effects on performance is through arousal. However, the arousal theory's main disadvantage is that it is difficult to make a priori predictions (Hancock, & Warm, 1989). Sanders created a model of attention linked to arousal, which postulated that arousal and attention are positively correlated, but it is limited to choice reaction time (Sanders, 1983). Additionally, physiological models of stress, such as arousal, are not well linked to complex human behavior. However, in Hancock, Chingell, and Vercruyssen (1990) created a model which is comprised of zones bordering a normative zone. This model takes into account physiological and behavioral reactions to stress. The task itself is considered a major source of stress in addition to general disorder.

Another model addressing attention, which was linked to decision making, was developed by Smith and Hancock (1992). The creation of this model was initiated by the growing focus on automation. When human operators control automated systems, it is often to perform some system intervention. Thus, operators are increasingly performing in incomplete, unusual and uncertain situations, which can cause immense stress. Their paper outlines a model of decision making under stress. In the model, decision making is broken down into three components - attention, assessment, and intervention. Operators use attention to scan the environment and choose the area(s) to further assess. Environmental risks, risks associated with interacting with the environment, and risk ambiguity are all assessed using different processes. Lastly, intervention is decided upon using a set of rules that match the risk assessment. When automating processes, the only of these that can not be automated is assessing environmental risks because it often relies on expert knowledge. However, attention to displays, matching heuristics, and assessing uncertainty can be automated to a system that supports decision making. When used in dynamic settings, these systems alert the operator to parameters that require assessment and interventions are recommended by the system. This type of support can lower operator stress.

Another study investigated the effects of stress and anxiety on task efficiency. The Process Efficiency Theory (PET) was created to explain how task performance is influenced by anxiety (Burke, Szalma, Oron-Gilad, Duley, & Hancock, 2005). Often, task performance can be sustained while under stress, though the operator must exert more effort. Thus, performance is effective but is no longer efficient. This study attempted to identify changes in that efficiency while under various amounts of stress. While participants performed two simultaneous tasks, performance on both tasks changed, indicating one task was not directing the other. In the most demanding condition, when both tasks required high working memory, performance on the primary task was better when the secondary task was present, but secondary task performance decreased. These results could be a function of combined practice and fatigue effects. Since performance on the secondary task was significantly poorer in this condition, participants may have been ignoring the secondary task and focusing only on the primary task (Burke, Szalma, Oron-Gilad, Duley, & Hancock, 2005).

Stress has been known to compromise physiological well-being, particularly with respect to the immune system. A study conducted by Hale, Weigent, Gauthier, Hiramoto, and Ghanta (2002) showed that different types of stress have different effects on the immune system. This is supported by anecdotal evidence with people who report different feelings of illness depending on the amount and type of stress they are experiencing at the time. Additionally, a study by Bollini, Walker, Hamann and Kestler (2004) found that when people perceive they have control over the amount of stress they are experiencing, adverse health effects can be reduced.

Stressors soldiers experience in combat are loss of sleep, extremely high levels of physical and psychological discomfort, extended periods of increased vigilance, and intense danger (Hancock & Hoffman, 1997). Performance decrements have been inferred by the lack of weapon fire in combat and impaired performance in simulated battle conditions. These decrements are predicted because combat decisions involve a wide variety of information-processing elements, and stress inhibits these at different information-processing stages (Hancock, 1986; Wickens, 1996).

Intuitively, one might realize that stress affects different people in different ways. When under severe stress, some people experience distortions in time. Individuals cope with spatial stress by narrowing their attention to specific spatial cues in the environment (Easterbrook, 1959). The temporal domain is stress-sensitive in a similar manner to the spatial domain and comparable narrowing occurs, resulting in distortions of perceived time (Hancock & Weaver, 2005). Stress drains attentional resources, but it also prevents the production of these resources. Thus, the resources that remain are used for task-relevant activities, and attention to time-based cues is minimized, causing a distortion for the current passage of time and for time recollection. There is much anecdotal and experimental evidence to support this phenomenon (Hancock & Weaver, 2005). Time estimation is affected by the stress and mental effort that operators experience. If stress conditions are sufficiently high, such conditions will induce time distortion (Block, Zakay, & Hancock, 1999). Time estimation can be categorized into the prospective paradigm, in which an individual is aware during a task that he/she needs to estimate time, and the retrospective paradigm, in which an individual is unaware that he/she must estimate time until after the task has been completed. The former requires divided attention during a task and is associated with working memory, whereas the latter relies primarily on short-term memory. When the task requires high attentional demands, prospective judgments become similar to retrospective judgments. Additionally, when time estimation is delayed after the termination of the task, prospective judgments become similar to retrospective judgments (Zakay & Block, 2004). Time distortion may well prove dangerous for a combat medic who believes he/she started an IV drip on a casualty ten minutes before and is not concerned the casualty does not show signs of improvement when it was really thirty minutes before. This misperception could quickly result in loss of life.

There are many things that influence one's reaction to stress. One of these is time exposed to the stress. Harris, Hancock and Harris (2005) found that prolonged (one week) exposure to stress caused decreased cognitive performance and increased discomfort. Immediately after the exposure, participants were able to maintain their normal level of performance, but for a shorter period than before the exposure. For stress assessment, simple reaction time is a reliable measure for stress-induced deterioration. Participants had difficulty concentrating in later sessions, which is consistent with information processing impairments. They were able to maintain temporary levels of high performance, but these levels could not be sustained after chronic stress. This study adds the finding of cognitive deterioration that other studies may have missed because of inappropriate assessment and data analyses that were not sensitive to complex cognitive processes (Harris, Hancock, & Harris, 2005).

Research has also shown that when under extreme stress, a person's cognitive abilities and response time may be compromised. Harris, Hancock, and Morgan (2005) conducted an experiment in which participants were put through one week of Survival, Evasion, Resistance, and Escape (SERE) School training, after which cognitive performance showed an increased response time with little change in accuracy. As the task was self-paced, participants chose to take longer on the task to maintain accuracy. Memory was most sensitive to stress. After one night of sleep, cognitive performance returned to normal. When combined, chronic psychological and physical stress influence cognitive performance are significantly different than the effects of physical stress alone. While most combat simulations include extreme physical stress, psychological stress is often hard to simulate. However, the SERE training was able to incorporate a great deal of psychological stress. Decision making involves attaining applicable information, processing spatial and logical information, and formulating a response strategy. Cognitive changes vary from not being influenced by stress at initial exposure to the eventual complete collapse of cognitive functioning. This change has been seen in many real-world catastrophes. Additionally, the combined effects of stress duration and intensity are multiplicative, not additive (Conway, Szalma, & Hancock, 2007).

Still another factor that determines how a person will react to stress is how immersed he/she is in the work prior to the stress. Operator stress is of particular concern when it occurs suddenly after periods of inactivity. This is comparable to being attacked at night while deployed. The medic might now have gone from sleeping or resting quietly to a confused state in which he/she has many casualties to treat simultaneously. The attentional narrowing that occurs in these types of situations is often thought of as an intentional strategy by the brain, but is usually under little voluntary control by the operator. In order to cope, people often engage in task shedding. In team settings, this often involves assigning to tasks to others. Thus, a medic might elicit help from other soldiers for tasks that can be easily performed by those with little medical training (Hancock & Szalma, 2003).

Also, the number of tasks a person is doing can affect how he/she is influenced by stress. In the military today, soldiers' jobs often involve multiple tasks which must be performed under stress. Research has shown that secondary task performance decreases when performed simultaneously with a primary task under stress (Wickens, 2002). Thus, understanding the behaviors performed during this time is crucial to help remedy this deficit. Behavior can be classified into skill-based, rule-based, and knowledge-based (Rasmussen, 1983). Skill-based behaviors are those which are automatic and do not require conscious cognitive processes. Rule-based behaviors are those which are directed by a set of rules. Knowledge-based behaviors are those for which known rules do not apply, and new rules must be formulated. It is only by investigating the relationship between primary task performance and secondary task performance under stress that behavior can be understood and stress effects can be mediated (Weaver, Bradley, Hancock, Szalma, & Helmick, 2003).

Some research even suggests that mood and emotion may play a part in the effects of stress on an operator when performing a task. For example, Ross, Szalma, and Hancock (2004) found that task performance is affected by spatial characteristics and temporal characteristics, and stress often influences performance by distorting these two dimensions. Research has suggested that the stress a person feels is affected by that person’s optimism and pessimism. However, it must be noted these effects are dependent on the spatial and temporal aspects of the task being performed. It was found that pessimism and optimism mostly affect performance by influencing the person’s affective state before the task is performed. Optimism effects were found to be very task-dependent (Ross, Szalma, & Hancock, 2004).

Despite the causes and contributors to stress and the mechanisms through which stress manifests itself, operators are still able to maintain performance at times. Using Hockey’s Compensatory Control Model (CCM), one can see that operators are able to maintain performance under stress by compensating at the cost of other processes (Hockey, 1970). Thus, research must attempt to uncover the underlying processes to effectively establish when an operator is at risk. This can be done by measuring lower-priority tasks, less resource-intensive strategies, subjective levels of effort, and fatigue after-effects. Additionally, training a participant could minimize the masking of stress effects (Conway, Szalma, & Hancock, 2007).

An important facet of stress is that because it is a multidimensional construct, measurement is difficult. Neurological indices must be sensitive to this multidimensional quality, which can be quite hard to accomplish. However, performance and subjective indices are often not adequate to measure this construct either, so neurological indices are often a good measure where performance and subjective measures are not possible or practical (Hancock & Szalma, 2003). While there are many causes and effects of stress, there are many types of stress also. In addition to research conducted in general stress, research has been conducted in types of stress, including visual, fatigue, hunger, vibration, temperature and noise. This review will focus on two environmental stressors – vibration and noise.

Vibration Stress

Vibration stress is caused by motion somewhere in the body. Vibration is a mechanical wave that transfers energy but not matter. Most often, vibration is felt when a surface is vibrating and a person is in contact with that surface. When the surface stops vibrating, the immediate effects are not felt anymore, but after-effects can still be felt for some time. Vibration can also be thought of as a function of the environment. With respect to human processing and the Hancock and Warm model, vibration affects output responses (Conway, Szalma, & Hancock, 2007). Four main topics have emerged in the vibration literature. These are situations in which vibration is experienced, moderating factors of vibration, how vibration acts as a stressor, and vibration characteristics.

Vibration is encountered in many environments including construction workers, aviation, sailing and driving. While there can be specific areas of the body that are vibrated, the majority of vibration is whole-body vibration (WBV). Overall, vibration has negative effects on task performance (Conway, Szalma, & Hancock, 2007). One study found that when people who experienced WBV were tracked longitudinally, they were at more of a risk for musculoskeletal and nervous system disorders than those not exposed to WBV (Seidel & Heide, 1986). While there is not much data concerning chronic effects of WBV, there is a plethora of subjective responses (Kittusamy & Buchholz, 2004). In one survey, construction workers who used equipment which produced vibration reported significantly more spinal discomfort and more spinal disorders than those with similar jobs without vibration (Dupuis & Zerlett, 1987). A review of 45 studies in which people experiencing WBV were compared to people not experiencing WBV yielded several conclusions, including that cumulative exposure to WBV can contribute to injury and disorder of the spine and that a model of the relationship between stress exposure and response can not be determined with the present amount of information (Wikstrom, Kjellberg, & Landstrom, 1994).

Two things that moderate the vibration felt are characteristics of the vibration, such as waveform (random, intermittent, or continuous), magnitude, frequency, and exposure duration, as well as the characteristics of the task being performed. Since vibration is measured in three axes, the effects of vibration on performance are often dependent on the task such that vibration has different effects on different tasks. However, the largest effects have been seen in perceptual tasks, possibly because these tasks require a physical response. A modest effect can be seen for cognitive performance. In general, tasks requiring accuracy are affected more than those requiring speed. With respect to the vibration itself, larger performance decrements are seen with higher frequencies and intensities of vibration. In fact, vibrations ranging from 1-2 Hz degrade performance more than any other frequency range in the x and y axes, while vibrations ranging from 4-8 Hz degrade performance more than any other frequency range in the z axis. However, the mechanisms by which different frequencies disrupt performance are still not explicitly known. Also, it is thought that vibrations of greater magnitudes degrade performance more than those of lesser magnitudes. It appears that the longer a person is exposed to vibration, the more his/her performance is disrupted (Conway, Szalma, & Hancock, 2007).

With respect to the Hancock and Warm model, the way vibration acts as a stressor is through adaptation. Using this model, one can stipulate that the defense against this vibration is to adapt, which occurs at several levels, including the physiological, behavioral, and subjective. However, using this model, one must recognize that the stress caused by vibration extends beyond the environment to the task itself. The position that the task itself is the most proximal source of stress has always been advocated by Hancock and Warm. If this theory is true, exposure to a stressor always involves at least two forms of stress, one being the task and one being the stressor itself (Conway, Szalma, & Hancock, 2007).

As this model supports representing WBV as a vector encompassing environmental and task characteristics, varying the vibration characteristics may yield varying results across tasks. However, to get effects from experimentation, one must ensure that the methods used are sensitive enough to capture performance differences since the mechanisms by which WBV affects performance are not known. However, it is important to know that any fatigue after-effects that are seen during a task that employs WBV are not due to the vibration itself, but to compensatory processes by the operator (Conway, Szalma, & Hancock, 2007). Many stressors act to mitigate one another when experienced together. However, there is little to no research documenting the effects of vibration on performance when combined with other stressors.

Auditory Stress

Auditory stress, or noise stress, is caused by an auditory stimulus that is perceived and/or actually harmful to a person. Sound is typically measured on the decibel (dB) scale, which is logarithmic. However, because the human ear does not have equivalent sensitivity for all frequencies and pressures, the dB scale does not adequately measure what the human ear identifies. Thus, the dBa scale was created to adjust for the sensitivities of the human ear (ITU-R 468 Noise Weighting, 2007; Hancock, Conway, Szalma, Ross & Saxton, 2006). The facets of auditory stress that are prevalent in literature are the mechanics of noise, types of noise, noise as a stressor, how noise affects human performance, how noise affects operators differently, and environments in which auditory stress is likely to occur (Cohen, 1977).

Noise, like all sound, results from vibration through a medium, and as particles collide, a sound wave is created (Hancock, Conway, Szalma, Ross, & Saxton, 2006). Noise has been defined many ways, such as any unwanted sound and all disturbing, annoying and hazardous sounds which influence the human body (Enmarker & Boman, 2004; Hancock, Conway, Szalma, Ross, & Saxton, 2006). Several types of noise have been used for research, including chatter, white noise, screams, babies crying, and unintelligible sentences (Bollini, Walker, Hamann, & Kestler, 2003; Enmarker & Boman, 2004; Nayeem, Oron-Gilad, & Hancock, 2005). While the effects of noise stress are not fully understood, research indicates it can be used as a reliable stressor. Noise is one of the most widespread stressors in living environments (Marjut & Wallenius, 2004).

Noise can be classified as intermittent or continuous. One type of continuous noise is white noise, which has equivalent pressure across all frequencies. Using the Hancock and Warm (1989) model, noise affects performance through input and output, specifically through information processing, attention, and memory (Hancock, Conway, Szalma, Ross, & Saxton, 2006). As a stressor, continuous noise of 80-100 dB serves to increases alertness, increases selectivity, has no effect on speed, decreases accuracy, decreases short-term memory, and decreases working memory. It is thought that the way noise affects working memory is through the distraction of attention from the task being performed. However, another possibility is that noise increases mental workload. Either way, operators must still increase effort to maintain performance under noise. Additionally, different types of noise have different characteristics, and therefore have effects on task performance (Hancock, Conway, Szalma, Ross, & Saxton, 2006).

Noise can have very specific effects on human performance processes, such as cognitive and physical functions. Like many other stressors, noise often causes attentional narrowing in operators, and reading and writing can be degraded as noise stress increases (Hockey, 1970). Additionally, noise inhibits information selection many ways. It can mask incoming physical messages, interfere with other sensory information, reduce capacities to process information, and interfere with memory. While physical functions are often compromised, the majority of noise effects are cognitive. This could be due to the lack of studies specifically studying whether noise affects perceptual-motor tasks. Like other types of stressors, operators are able to cope with noise stress to maintain performance at the cost of other processes. Operators often increase effort to maintain performance. However, it is impossible to compensate for very extreme levels of noise. Performance on secondary tasks often decreases, strategies change, and fatigue and negative feelings increase (Hancock, Conway, Szalma, Ross, & Saxton, 2006).

Adverse noise effects are more closely related to personal reactions to noise than to noise itself. Thus, noise is not only stressful in and of itself, but can be a stressor as a result of disturbing daily activities as well. Surveys administered to adult inhabitants living in noisy and non-noisy environments indicated an interaction between noise stress and personal project stress, or somatic self-report symptoms, when dealing with multiple stressors. When faced with multiple stressors, one often has a diminished capacity for coping with another (Marjut & Wallenius, 2004).

However, to elicit enough stress to see a decrement in task performance, operators must receive a tremendous amount of noise. One study showed that after ten minutes of white noise at 85 dBA, participants did not show a decrease in primary task performance (Nayeem, Oron-Gilad, & Hancock, 2005). Thus, it is suggested that for noise to be used a stressor, it should administered either at higher levels for longer durations or be combined with other stressors.

Various factors may affect a person’s ability to deal with noise stress. Research suggests that one of these factors may be serotonin. Since tryptophan depletion decreases serotonin levels, Richell, Deakin, and Anderson (2004) conducted a study in which they gave some participants a tryptophan supplement and some participants a tryptophan-depleting substance. The participants were otherwise healthy. The participants who received the tryptophan-depleting substance reported more negative affect to noise than those who received a tryptophan supplement, among other findings. Thus, tryptophan, and thereby serotonin, might help individuals subjected to noise stress better cope with it.

Occupational noise is often a distraction and nuisance and can cause workplace stress. In a study by Leather, Beale and Sullivan (2002), the interaction of noise and job stress was investigated. No direct effects of noise on job satisfaction, well-being, or organizational commitment were seen. However, lower noise levels lessened negative feelings toward job stress. Additionally, the effects of acute noise exposure were increased when multiple tasks were being performed, particularly cognitive tasks. There may also be differences between adults and children in coping abilities. Enmarker and Boman (2004) compared teachers' responses to disturbing and distracting noises to those of students ages 13 and 14. They found that teachers rated the noise significantly more disturbing than did the students.

Noise may interact with other types of stress to create varying performance effects. When noise and heat are experienced together, noise alleviates some of the stress effects produced by heat. This relationship is also seen between noise and sleep deprivation (Hancock, Conway, Szalma, Ross, & Saxton, 2006).

In many environments, such as combat, noise is extremely invasive and is both acute and chronic. In combat, soldiers are over-loaded with visual information so more information is being conveyed aurally (Hancock, Conway, Szalma, Ross, & Saxton, 2006). Because the stress of combat can exceed any type of stress soldiers may have faced prior to being in combat, they receive a great deal of training for their particular MOS. There are many types and facets of training employed for soldiers, including combat medics. Some of the most relevant training will now be reviewed.

Training and Military Personnel

In the United States military, training is an essential component of combat readiness (http://www4.army.mil/ocpa/read.php?story_id_key=9586; Fowler, Norfleet, & Basebore, 2003; Parsons, 2004). Different aspects of training can be studied, including ways to train, tasks to train, and simulation. Immersion is often thought of the best way to train military personnel.

However, there can be a great deal of variability among individuals with respect to performance. This variability is largely due to individual differences in responding to the environment, not the fidelity of the environment. In the future, soldiers may be screened for adaptability to novel situations when little information about the situation is given to assess potential ability (Morris, Ganey, Ross, & Hancock, 2002).

One line of training research aims at making the tasks performed relevant to the tasks performed in combat. Experiments by Morris, Hancock, and Shirkey (2004) showed that context-relevant stress can cause an increase in “mission success.” Questionnaires assessed stress, mood and arousal. Participants watched a movie relevant to their task prior to training. To induce stress, half of the participants were shown a graphically intense movie, while the non-stress participants were shown a documentary. Performance was best when participants were exposed to stress that caused higher motivational or positive stress in game-based training. Individuals’ ability to produce this stress on their own varies widely in the population. Motivation was inferred because scores on “mission success” improved for the experimental group, but scores on the training content did not vary between groups. Training retention was found in individuals who experienced relevant stress and reacted with positive arousal.

As technology progresses, training increasingly uses simulators rather than live exercises due to the low cost, high availability, and low risks to military personnel. Today’s military is replete with simulators for various purposes ranging from flight training to maintaining proficiency in driving a tank. Training medics to treat combat trauma is one area in which simulation is being developed. In most training exercises today, patients are live actors or delicate mannequins that provide limited realism to the simulation (Fowler, Smith, & Litteral, 2005). Thus, more realistic simulations are still needed despite the current rates of improvement.

One system that attempts to provide realism for the combat medic is the Combat Trauma Patient Simulation (CTPS) commissioned by the Department of Defense and the Army. The CTPS can simulate bloodloss, pneumothorax, or anaphylactic shock, and it uses several components to simulate the combat trauma treatment process. The process by which the CTPS simulates these conditions is as follows: a patient and the scenario information are created using one component; the patient is transferred to another component to determine initial patient state after which yet another component simulates the patient physiology. The patient is then transferred to the component with which the medic interacts, and the information is sent back to the system to evaluate the procedures taken by the medic who receives feedback on the treatment employed (Rajput & Petty, 1999).

Another simulator is the Tactical Combat Casualty Care (TC3) prototype trainer developed by the Army. Because 68Ws only treat combat injuries and are not equipped for detailed surgery, tests and evaluations, proper treatment prior to evacuation is crucial. This game-based simulator trains the 68W to treat a variety of injuries, and scenarios include initial contact with the patient, assessment, scene security, triage, initial treatment, and evacuation of the patient. The TC3 simulation presents the student with a problem, gives the tools and resources necessary for treatment, and offers suggestions based on the situation. When the student offers a solution, he/she can see the consequences of their solution and is provided with suggested areas for review if the solution was incorrect. This allows the student to learn certain areas better before the next session. The goal of this simulation is to increase the student’s ability to correctly assess and prioritize injuries and select the appropriate treatments (Fowler, Smith, & Litteral, 2005).

A disadvantage of sophisticated simulators is that as technology advances, and simulators become more complex, the amount of information an operator receives often increases. This increase in information can lead to an overload of sensory channels if the information presented in a particular channel exceeds the capacity of that channel (Brooks, 1968). Thus, performance on a task can increase when multiple modalities are employed because this effectually spreads information across sensory channels (Feygin, Keehner, & Tendick, 2002; Fientuch, Rand, Kizony, & Weiss, 2004). Many simulators employ the use of visual and auditory cues to give feedback to the operator, which has resulted in some systems being at capacity for this type of information. Examples of this are many aircraft cockpits which have a plethora of visual and auditory cues and feedback. Additionally, tasks that are learned or performed in stressful conditions are greatly affected by the modality through which information is presented. However, modality is of much more importance when task demand is high, since when task demand is low operators are able to compensate. Attentional capacity is larger when information is presented across multiple modalities than a single modality (Helmick-Rich, Burke, Oron-Gilad, & Hancock, 2004).

As noted by Wickens (2002), there are practical and theoretical implications of theories that advocate employing multiple modalities. Practically, the theory speaks to an operator's ability to perform multiple tasks. Theoretically, the theory speaks to the ability to predict dual task interference. However, in both contexts, the difference between "multiple" and "resources" must be distinguished. "Multiple" implies parallel, separate, or independent processes, while "resources" implies that the referred to entity is both limited and allocatable (Wickens, 2002). Shifting attention in one modality causes a shift in attention in other modalities, and knowledge in one modality improves performance when employed in another modality. Multi-modal displays can be used for many types of tasks, such as those that have embedded texture perception (Venkatraman & Drury, 1999). Because the visual system only has two types of receptors, and the haptic/tactile system has approximately ten, haptic and tactile information may be a better way to encode information. It could be argued that more options are available for this sense than for vision (van Erp, 2006). Also, haptic/tactile feedback may improve learning at an early phase (Feintuch, Rand, Kizony, & Weiss, 2004). This has led to the investigation of using haptic/tactile interfaces in simulators, particularly for training.

Haptic and Tactile Information: The Body's System, Research, and Technological Creations

"Haptic and tactile information" includes kinesthetic feedback found in position and force receptors in muscles, tendons, and joints (Liu, Tendick, Cleary, & Kaufmann, 2003). Haptic and tactile information can be a very complicated area of research, so it is imperative that researchers are aware of some key issues of haptic/tactile interfaces. Some of these issues are how haptic/tactile interfaces work with the body physiologically, the use of tactile interfaces, properties of the haptic/tactile system, touch versus other modalities, training, special populations, and haptic/tactile simulation.

To fully understand how to best employ haptic/tactile interfaces, one must understand the body's system of touch. At about eight weeks following conception, touch is the sense to develop earliest in embryos. There are several types of receptors in hairless skin used for touch. Meisner corpuscles respond to light touch and low frequency vibrations. Pacinian corpuscles respond to gross pressure changes and high frequency vibrations. Ruffini endings are responsible for pressure perception, and Merkel disks are responsible for tactile form, the perception of roughness, and differentiating among forms of indentations, and are used for high resolution discrimination. Unspecialized free nerve endings react to stretch, pressure, and other mechanical stimulation. There are also muscle and skeletal receptors used for balance and movement, such as muscle spindles, Golgi tendon organs, and joint capsule mechanoreceptors. Feedback from touch is a crucial part of everyday life and has been honed quite nicely. For example, one can usually very easily find a light switch in the dark (Carter & van Erp, 2006).

Kontarinis and Howe (1995) outline the use of tactile interfaces and give guidelines for the implementation of tactile interfaces. Tactile refers to passive feedback sensed by mechanoreceptors. Tactile simulation is not currently employed a great deal in medical simulation because of lack of good hardware (Liu, Tendick, Cleary, & Kaufmann, 2003). Tactile displays are complex because of the number of receptors in the skin they must stimulate. Certain physiological issues should be further investigated, such as sensing and controlling forces and joint angles, perception of conditions and properties of objects and the environment, integrating local contact information with nonlocal perception of the environment, performance with time delays, distortions and noise, and information flow (Srinvinivasan, 1995). Besides the PHANToM, another popular haptic device is the Laparoscopic Impulse Engine from Immersion Corp, which allows surgical tools to be tracked and manipulated in 3-D (Liu, Tendick, Cleary, & Kaufmann, 2003).

Unlike the rest of the human sensory systems, the haptic/tactile system can both sense and act on the environment. The performance on a haptic/tactile interface is constrained by human limitations because the human is controlling the interface. Haptic/tactile interfaces can be categorized as 1) free motion, involving no contact with objects in the environment, 2) contact involving unbalanced resultant forces, such as choosing from a touch screen, and 3) contact involving self-equilibrating forces, such as squeezing an object. Another distinction among haptic/tactile interfaces is whether they are manipulated directly with the body or using a device. Yet another distinction is ground-based devices versus body-based devices versus tactile displays. Simple haptic/tactile interfaces include computer keyboards and mice, which do not give force feedback, and joysticks and steering wheels, which often do give force feedback (Srinvinivasan, 1995).

A common question when discussing touch is determining its added value to other modalities. Compared to no cuing, visual, spatial-audio, and haptic/tactile cuing augmented acquisition performance on a target acquisition task, and are often used in aviation-related target acquisition tasks. In an unmanned aerial vehicle (UAV) study by Gunn, Warm, Nelson, Bolia, Schumsky, and Corcoran (2005), visual cues, spatial-audio cues, and haptic cues were compared since there is little evidence supporting one over another. Recent vigilance research has suggested that the vigilance decrement occurs because of the high demand on information processing, not an inability to maintain alertness as previously thought. This has been supported by NASA-TLX scores which show workload in the mid to upper range of the scale (Gunn, Warm, Nelson, Bolia, Schumsky, and Corcoran, 2005). Because the UAV environment is dominated by visual input, visual cuing is better than spatial-audio or haptic.

Haptic/tactile interaction is often accompanied by visual feedback, but is not required. Some virtual musical instruments can be played by only auditory feedback. Haptic/tactile interaction can be broken down into three steps – indicating the object of interest, executing commands and control on the object, and providing feedback to the user. Interaction techniques include moving a pointer relative to the object, moving the object itself, possessing the object, and interacting independently. For users with normal vision, haptic/visual/audio, haptic/visual, and haptic/audio interfaces are recommended. For users with impaired vision, haptic/visual/audio, haptic/visual, and haptic/audio interfaces are recommended. For users with no vision, haptic/audio interfaces are recommended. For users with no vision or hearing, haptic interfaces are recommended (Andrew & Fourney, 2006).

With respect to training transfer, Feygin, Keehner, and Tendick (2002) found that haptic guidance can facilitate performance, particularly temporal aspects. Thus, haptic guidance could aid in training transfer since timing is an important aspect of transfer. Haptic/tactile interfaces can be extremely important for people with certain impairments, such as those with visual or auditory impairments. One set of guidelines used for the design of haptic/tactile interfaces are the Guidelines on Tactile and Haptic Interactions (GOTHI). The GOTHI model has six elements. “Applicability of tactile and haptic interactions” currently focuses on creating interfaces for visually impaired operators, such as Braille. “Tactile/haptic inputs and outputs” postulates that tactile/haptic interactions should use both inputs and outputs, where output is initiating sensory observations of the environment, and input is information received from the environment. “Attributes for tactile/haptic encoding of information” entails selection of tactile/haptic characteristics to be used and how that information is encoded. Encoding may be done in a spatial, temporal or sensory tactile/haptic space. Successful encoding requires knowledge of the user’s perception of that encoding, such as knowing that two forces must have a 7% difference to be distinguished between. “Layout of tactile/haptic objects” refers to the spatial representation through which these interactions take place, which is typically in three-dimensions. Haptic structures are represented similarly to visual structures, which are on a spatial map; conversely, auditory structures are represented on a pitch-based organization. “Interaction tasks” can be classified as either navigation tasks, selection tasks, or manipulation tasks. “Interaction techniques” involve the user’s actions required to accomplish a task and can be classified as moving relative to an object, moving an object, possessing an object, touching an object, and gesturing (Nesbitt & Carter, 2006).

Medical haptic/tactile simulation is used in training and planning. Procedures used to date employ delicate maneuvers in small spaces, good hand-eye coordination, hand dexterity, and a good kinesthetic sense. For things such as injury detection, swelling and bone fractures need to be simulated. Types of validity that need to be demonstrated in haptic/tactile interfaces are face validity, content validity, construct validity, concurrent validity, and predictive validity. Reliability can be established through inter-rater measures or test-retest measures. When designing systems, sensors should be placed correctly and be biocompatible and robust (Okamura, 2003).

While haptic/tactile interfaces have much promise, they must be used carefully and with strict supervision, as some people have had adverse reactions using them. Some people may have motion illusions from the interaction of displays with motion and movement forces. One person interacted with a virtual haptic/tactile environment of cyclonic wind forces for 10 minutes and immediately after experienced postural instability for a few minutes. Hours after, vertigo with head turns started and grew worse before subsiding. Nausea was also present with head turns and lasted 3 days. When one eye was covered, symptoms could be reduced. There was no other significant pathology (Viirre & Ellisman, 2003).

The Current Studies

While there is much known about combat medics, and much research has been done in tactile information, there is a lack of knowledge in how tactile information can be used to train combat medics, particularly with respect to acclimation to stress. Additionally, since there is a lack of research in how vibration degrades performance, more research should be done in vibration and how it interacts with other stressors (Conway, Szalma, & Hancock, 2007; Hancock & Szalma, 2007). Thus, the present research was conducted to investigate the effects of placement of vibration stimuli on bone versus soft tissue and time pressure on performance, workload, and stress on a combat medic-related task. Additionally, this research investigated the interactive effects of vibration and auditory stress on performance, workload, and stress.

CHAPTER THREE: METHODOLOGY

This research involved one pilot study and two experiments. The pilot study was conducted to determine the final configuration of the vests, to investigate gender differences, and the tactor periods. The first experiment was conducted to investigate tactor configurations on task performance, and the second experiment was conducted to compare vibration and auditory stress, as well as to investigate a possible interaction between the two.

Pilot Study

A pilot study was conducted with five females and five males to determine the best configurations for the tactors, to examine whether or not there would be gender effects, and to determine the rest period between tactor vibration. The final configuration for the vest in configuration one was changed slightly for the two main experiments, as participants reported that the tactors could be concentrated more on bony areas. Additionally, no differences were seen between genders for either task performance or for subjective ratings. Lastly, the rest period between tactor vibration was changed from 100 ms to 250 ms, as participants reported the shorter duration between vibration periods did not elicit as much stress as the longer duration. This was likely due to the fact that in the shorter durations, the motor did not have time to fully stop before starting again as it did in the longer durations.

Experiment One

Experimental Hypotheses

As outlined above, vibration stress can be extremely detrimental to task performance. Thus, the first experiment investigated the effects of vibration on performance on a tourniquet application task with a secondary monitoring task. To induce this stress, tactile vests were created. Vibration stress was operationalized by vibrating tactors put into the vests. Since the vests used vibration as a stressor, the potential stress effects from vibration were considered when forming the hypotheses for this experiment. The amount of stimulation was not manipulated in this experiment because existing research suggests the more vibration people are exposed to, in terms of cumulative effects, the worse their performance will be (Conway, Szalma, & Hancock, 2007). Rather, little to no research exists on the effects of vibration on different body locations. Additionally, this experiment focused on core-body vibration, as opposed to whole-body or limb vibration, as extensive research has been done in these areas (Conway, Szalma, & Hancock, 2007). Thus, eight hypotheses were developed to this end.

Hypothesis 1. Participants in the condition receiving vibration stress on bone from configuration 1 (see Figure 1) were expected to perform worse on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress than participants in the control group and in the group receiving stress on soft tissue from configuration 2 (see Figure 2).

Hypothesis 2. Participants in the condition receiving vibration stress from configuration 2 were expected to perform worse on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress than participants in the control group.

Hypothesis 3. Participants in all conditions were expected to perform worse on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress in the time pressure conditions relative to the baseline condition.

Hypothesis 4.While all participants were expected to perform worse with time pressure, an interaction was expected between time pressure and vibration such that participants in all conditions were expected to perform worse on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress when vibration stress was combined with time pressure than in the baseline condition.

Hypothesis 5. Participants in the condition receiving vibration stress from configuration 1 were expected to perform worse on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks than participants in the control group and participants in the group receiving stress from configuration 2 because as workload increases, secondary task performance often decreases when the tasks share resources, which the tasks did.

Hypothesis 6. Participants in the condition receiving vibration stress from configuration 2 were expected to perform worse on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks than participants in the control group because as workload increases, secondary task performance often decreases when the tasks share resources, which the tasks did.

Hypothesis 7. Participants in all conditions were expected to perform worse on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks in the time pressure conditions than in the baseline condition.

Hypothesis 8. While all participants were expected to perform worse with time pressure, an interaction was expected between time pressure and vibration such that participants in all conditions were expected to perform worse on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks when stress was combined with time pressure than in the baseline condition. A summary of the hypotheses can be seen in Table 1.

Table 1. Experiment one hypotheses summary.

	Hypothesis Number							
Dependent Measure	1	2	3	4	5	6	7	8
Tourniquet Application Time	$V_1>[V_2,C]$	$V_2>C$	$T>C$	$V_1*T>C$ $V_2*T>C$				
Tourniquet Score	$V_1<[V_2,C]$	$V_2<C$	$T<C$	$V_1*T<C$ $V_2*T<C$				
Subjective Stress	$V_1>[V_2,C]$	$V_2>C$	$T>C$	$V_1*T>C$ $V_2*T>C$				
Subjective Workload	$V_1>[V_2,C]$	$V_2>C$	$T>C$	$V_1*T>C$ $V_2*T>C$				
Secondary Task Accuracy					$V_1<[V_2,C]$	$V_2<C$	$T<C$	$V_1*T<C$ $V_2*T<C$
Secondary Task Response Time					$V_1>[V_2,C]$	$V_2>C$	$T>C$	$V_1*T>C$ $V_2*T>C$
Time Estimation					$V_1<[V_2,C]$	$V_2<C$	$T<C$	$V_1*T<C$ $V_2*T<C$

*C = Control, V_1 = Vest in Configuration 1 (Bony), V_2 = Vest in Configuration 2 (Fleshy), T = Time Pressure
V*T = Vest by Time Interaction

Experimental Design

To test the foregoing propositions, the experiment investigated the effects of tactile stimulation location (3) and time pressure (2) on task performance for a tourniquet application task. A 3 (vibration location) by 2 (time pressure) design with repeated measures on both factors was used. With respect to the second within-subjects factor, a pre-post design was employed, with the effect of time pressure evaluated for participants using their own baseline scores. The hypotheses were tested using the following three-group, within-subjects design. The first manipulated variable was tactile stimulation with the following levels - no vibration, vibration on bony areas (Configuration 1, see Figure 1), and vibration on soft tissue areas (Configuration 2, see Figure 2). The second manipulated variable was time pressure with no pressure being the pre- measure, and pressure being the post- measure. The full experimental design is articulated in Table 2. A within-subjects design was used to minimize the impact of inter-individual differences. Conditions were counterbalanced to avoid any order effects. Forty participants were used. This number was chosen because at this *n* value, an effect of .3 and greater, which is a medium effect, is found with power at .82 (Cohen, 1977).

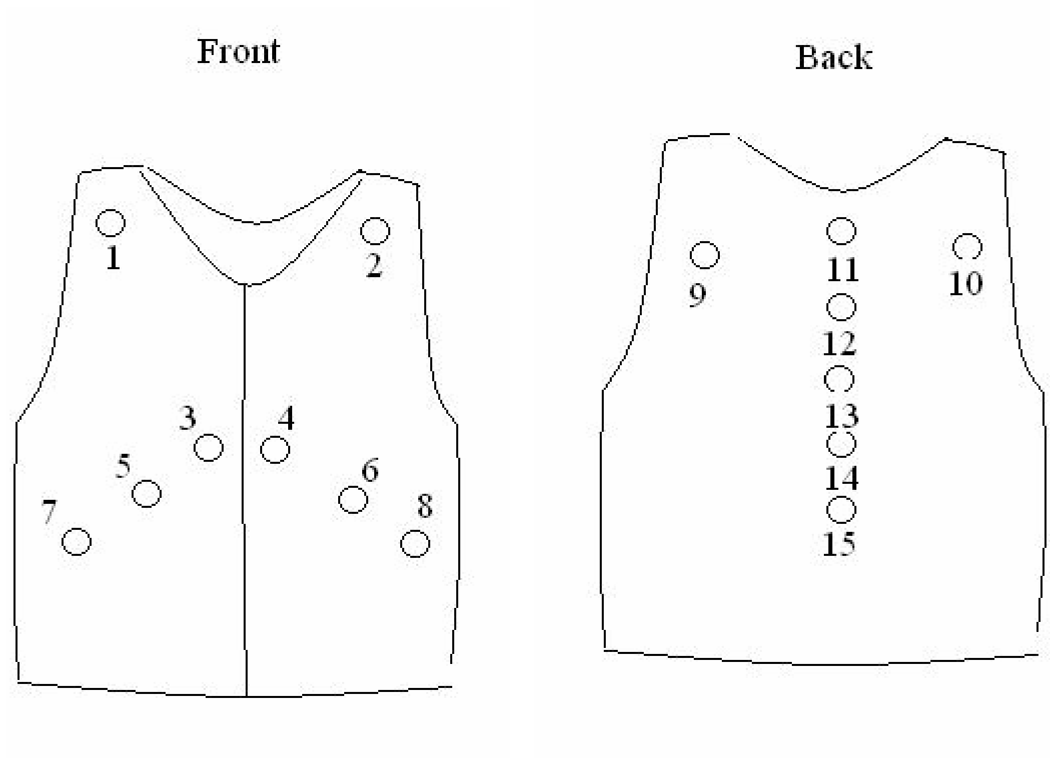


Figure 1. Front and Back of Tactile Vest in Configuration 1.

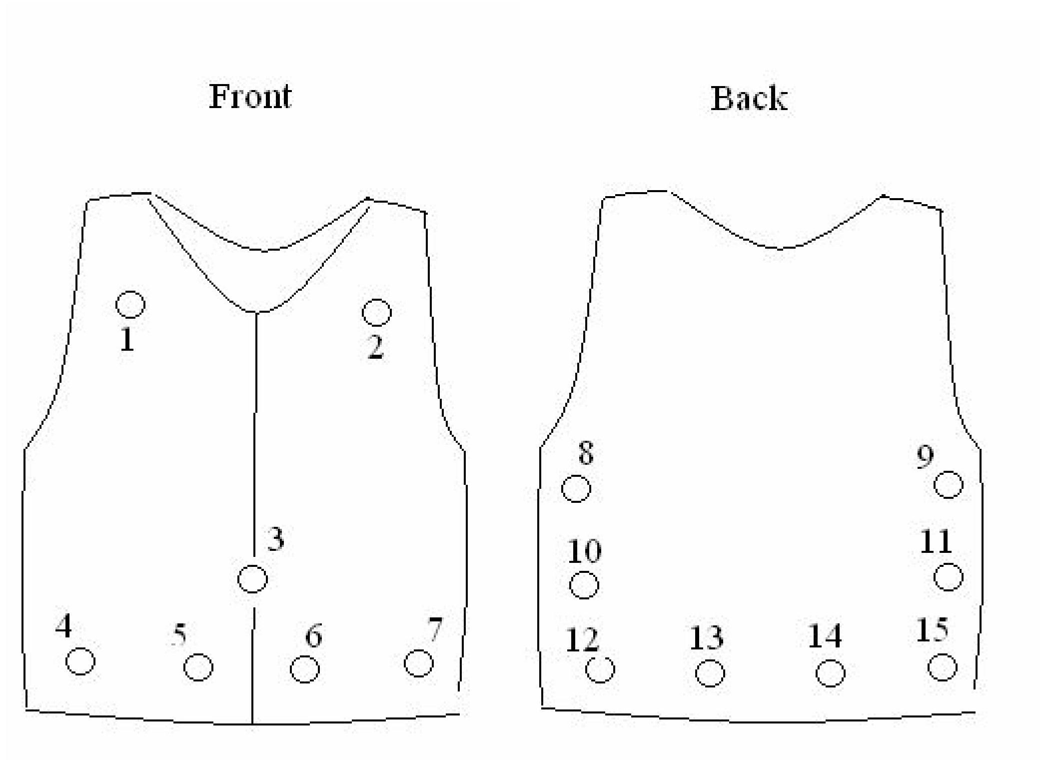


Figure 2. Front and Back of Tactile Vest in Configuration 2.

Table 2. Experimental Design for Experiment One.

Time Pressure Condition	**Vibration Condition**		
Time Pressure	Baseline (Vest worn but not on)	Vest with Configuration 1	Vest with Configuration 2
No Time Pressure	Baseline (Vest worn but not on)	Vest with Configuration 1	Vest with Configuration 2

Experimental Participants

The participants for this experiment were students from the University of Central Florida (UCF). Participants were recruited using the University's online experiment system, Sona. Compensation given was extra credit for a course of the student's choice, assigned through Sona. There were forty participants for this study – twenty-seven females and thirteen males.

Experimental Apparatus

This experiment used a tactile vest with vibrating tactors in different locations obtained from the Institute of Simulation and Training (IST) at UCF. Both configurations had 15 cell phone vibrators (tactors) place in various locations. The number of tactors was chosen because previous research in tactile displays used similar numbers in vests and obtained significant results (van Erp, 2005). Placement for tactors in configuration 1 was identified through pilot testing to be particularly noxious due to the placement over bone (see Figure 1). Placement for tactors in configuration 2 was identified through pilot testing to be particularly benign due to the placement over flesh (see Figure 2). Tactors vibrated at 168 Hz for the duration of the trials, and there was a rest period of 250 ms between vibrations. The two vests were configured to operationalize the delivery of high and low vibratory stress. Configuration 1 was anticipated to be more stressful than configuration 2 due to the placement of the tactors on bone versus flesh. The actual vest is shown in Figure 3.

Figure 3. Tactile Vest.

The tourniquet application task used a mannequin obtained from the U.S. Army Research, Development, and Engineering Command. Additionally, a video camera and an improvised tourniquet were used. The improvised tourniquet was comprised of a bandana and a metal stick approximately four inches long. The subjective measures were administered via a Dell laptop, model Latitude D600.

Experimental Tasks

A primary-secondary task paradigm was chosen because the primary task was simple, as reported by combat medics, and the secondary task was used to add to the difficulty of the tasks. Additionally, in combat, medics perform multiple tasks. The primary and secondary tasks were performed simultaneously. The primary task was properly applying the improvised tourniquet. There was one baseline condition and two experimental conditions. Feedback on the tightness of the tourniquet was delivered via a computer graphic controlled by the experimenter. Feedback was a vertical column presented on a computer screen that showed the required pressure, and the current pressure was indicated by color in the column; as the tourniquet was tightened, the column filled with color, terminating when the tourniquet was sufficiently tight and the column was completely filled with color. The secondary task was differentiating between friendly and enemy forces and responding as quickly as possible by pressing the left mouse button for friendly forces and the right mouse button for enemy forces (see Appendix A). Images were shown were for three seconds, or until a response was given by the participant, whichever came first. Inter-stimulus images were shown for five seconds after every image. On average, participants saw 3.4 images per trial. Participants were shown the images at the beginning of the experiment and were given a chance to familiarize themselves with them. However, during the experiment, the test images were not available to the participants for reference since the participants were required to make absolute judgments rather than comparative judgments. Friendly images differed from foe images in color of soldier uniform and type of weapon. This task was chosen because it is a task that combat medics currently perform while applying tourniquets. In combat, it is imperative that all personnel, medics included, be able to differentiate between friendly and enemy forces and react accordingly (Fowler, Smith, & Litteral, 2005). Additionally, the task was a loading task, which is one that stimulates demands absent from the laboratory environment but are expected in the actual conditions (O'Donnell & Eggemeier, 1986).

To derive a baseline for workload and stress, a card sorting task was used. Participants had three sorting tasks. The first task was simply turning the cards face-up, which represents 0 bits of analyzed information. The second task was sorting the cards into black and red cards, which represents 1 bit of analyzed information, namely color. The third task was sorting the cards into four suits, which represents 2 bits of analyzed information, namely suit. This task was chosen because it is relatively simple and has been shown to provide good baseline information for subjective workload and stress prior to task performance.

Performance Measures

Primary Task. Performance measures were task completion time and the proper application of the tourniquet, determined by a 68W instructor, which was assessed on a point system (Kearneyn, 2006). Participants received one point for each step performed correctly and in the correct order (Parsons, 2004; see Appendix B). This type of assessment is employed in special operations and medic training. The experiment was recorded so multiple raters could assess performance after the completion of the experiment.

Secondary Task. The discrimination task was assessed for accuracy and response time. Accuracy was the percent correct and response time was in milliseconds.

Card Sorting Task. The card sorting task was not assessed for performance.

Time Pressure. During the experimental trials, completion time was measured as a pre-post measure.

Subjective Measures. Workload was measured via the Borg Rate of Perceived Exertion (RPE; see Appendix C; Borg, 1998). This measure was chosen because it has been shown to accurately measure psychomotor tasks and was short enough to administer between trials as dictated by the experimental design. Stress was measured via the Subjective Stress Scale (SSS; see Appendix D; Bollini, Walker, Hamann, & Kestler, 2004). This measure was chosen because it has been shown to accurately measure subjective stress during task performance and was short enough to administer between trials as dictated by the experimental design. Additionally, participants provided a prospective time estimation, which is often also used as a measure of workload (Zakay, Block, & Tsai, 1999). The actual time estimation was not used, as it is of little value. Rather, the estimates were translated into duration judgment ratios (DJR; Block, Zakay, & Hancock, 1999), which is calculated by dividing the estimated time by the actual time and multiplying this by 100. By using this estimate, analyses can be conducted on how accurate or inaccurate the time estimations were, as well as whether they were overestimations or underestimations by comparing them to 100 as a base, or perfect score. Scores that were negative indicate an overestimation, and scores that were positive indicate an underestimation.

Experimental Procedure

Participants first read and signed an informed consent (see Appendix E) indicating they willingly participated in the experiment and could stop at any point without incurring any consequences. Additionally, participants completed a demographic questionnaire (see Appendix F) listing any previous medical training. Participants then completed the card sorting task and completed an RPE and SSS that served as baselines. Participants then received a brief explanation and description of the tasks and were able to hold the improvised tourniquet and practice the task until they were comfortable with it, and the experimenter saw that they could properly apply it per the grading standards. Additionally, they were shown samples of friendly and enemy forces and given a chance to familiarize themselves with them (see Appendix G – Experiment One).

The room lights were dimmed to increase difficulty and simulate application during dawn/dusk. Participants were told the experiment would begin in 5 seconds, the vest was turned on, and then participants were instructed to begin applying the improvised tourniquet. Each participant completed six baseline trials, three with time pressure and three with no time pressure, six trials wearing the vest with configuration 1, three with time pressure and three with no time pressure, and six trials wearing the vest with configuration 2, three with time pressure and three with no time pressure. Experimental conditions were counterbalanced to avoid any confounding order effects (Poulton, 1982). Participants were told before beginning each experimental trial that they would need to estimate the amount of time they were performing the task after task completion. Participants had a one-minute rest period between each trial. The task performance for each trial was timed, and at the completion of each trial, the improvised tourniquet was taken off the limb and put back in the starting position. After each trial, participants provided a time estimate and completed the RPE and SSS. Once all trials were completed, participants took off the tactile vest, provided a time estimate, and completed the RPE, SSS, and a usability questionnaire (see Appendix H). Participants were then debriefed and compensated for their time. All trials were video-taped to aid in performance assessment at the completion of the experiment.

Experimental Results

All analyses were performed using SPSS 11.5, and the alpha level was pre-set at .05. However, due to the large number of comparisons, a Bonferroni correction was applied, such that the alpha level for each test was .008. The inter-rater reliability for all scores was at least .95.

Primary Task

Primary task performance scores for all conditions were averaged across participants. A series of paired-samples t-tests was performed for vest condition, time condition, and possible interaction effects for each dependent variable. T-tests were chosen in lieu of ANOVAs because the hypotheses were written to a degree of specificity that lent the data to be analyzed by pre-planned comparisons, and t-tests were the appropriate choice given the a priori comparisons outlined by the hypotheses.

Tourniquet Application Time. For tourniquet application time, t-tests compared configurations 1 and 2 with the baseline as well as each other. The analyses showed that configuration 1 (M = 55.04, SD = 2.48) caused significantly longer application times than the baseline (M = 20.28, SD = 1.81) and configuration 2 (M = 35.54, SD = 1.58), $t(39) = -66.988$, $p < .0001$, $d = 16.01$, and $t(39) = 50.305$, $p < .0001$, $d = 9.38$, respectively. Additionally, the analyses showed that configuration 2 caused significantly longer application times than the baseline, *t*(39) = -38.078, *p* < .0001, *d* = 8.98, (see Figure 4).

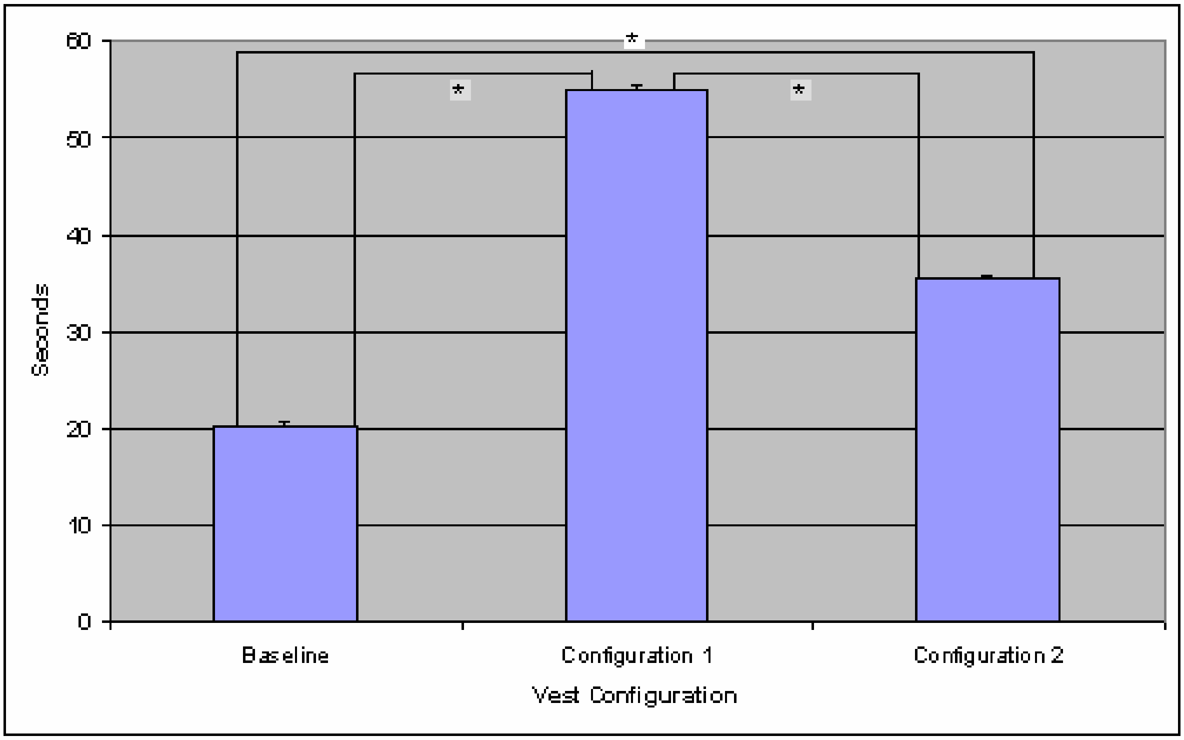


Figure 4. Tourniquet application times across vest configurations.

For the time condition, a t-test compared the time pressure condition (M = 48.54, SD = 2.35) to the baseline (M = 20.28, SD = 1.81) for application time. The analysis showed that the time pressure condition caused longer application times than the baseline, *t*(39) = -57.941, *p* < .0001, *d* = 13.47 (see Figure 5).

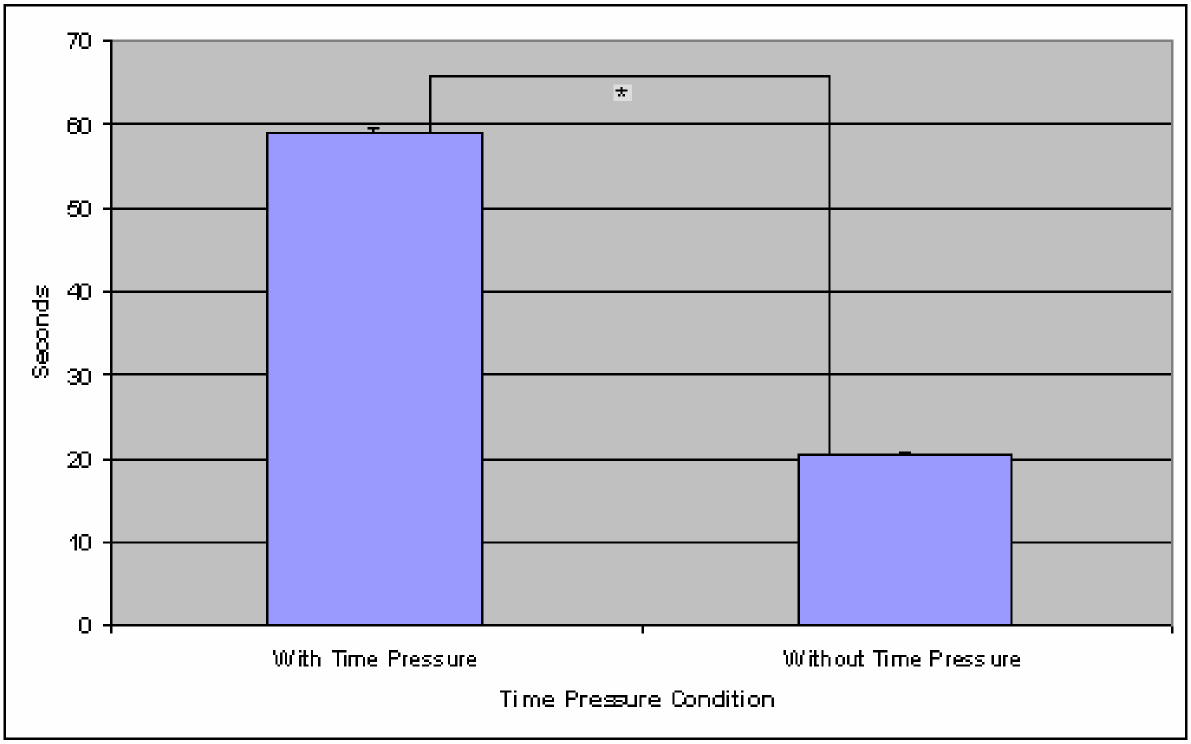


Figure 5. Tourniquet application time across time conditions.

For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 59.21, SD = 3.44) to the baseline (M = 20.28, SD = 1.81), and configuration 2 with time pressure (M = 37.88, SD = 2.29) to the baseline (M = 20.28, SD = 1.81), on application time. The analyses showed that configuration 1 with time pressure and configuration 2 with time pressure both caused significantly longer application times than the baseline, $t(39) = -59.840$, $p < .0001$, $d = 14.16$, and $t(39) = -38.875$, $p < .0001$, $d = 8.53$ (see Figure 6).

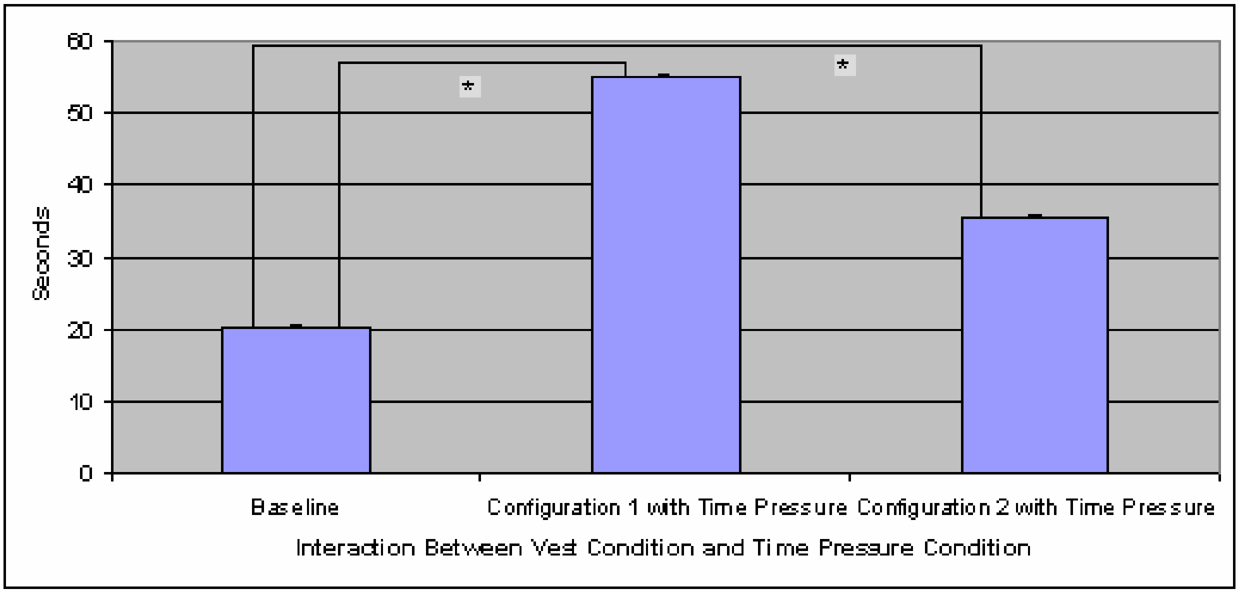


Figure 6. Tourniquet application time for interaction between vest conditions and time conditions.

Proper Tourniquet Application. For proper tourniquet application, t-tests compared configurations 1 and 2 with the baseline, as well as each other. The analyses showed that configuration 1 (M = 5.81, SD = .69) caused significantly more application errors than the baseline (M = 6.05, SD = .59), $t(39) = 2.912$, $p = .006$, $d = 0.37$. However, there were no significant differences in configuration 2 (M = 5.87, SD = .75) and the baseline, or between configuration 1 and configuration 2, $t(39) = 2.14$, $p = .039$, $d = 0.27$, and $t(39) = -.671$, $p = .506$, $d = 0.008$ respectively (see Figure 7).

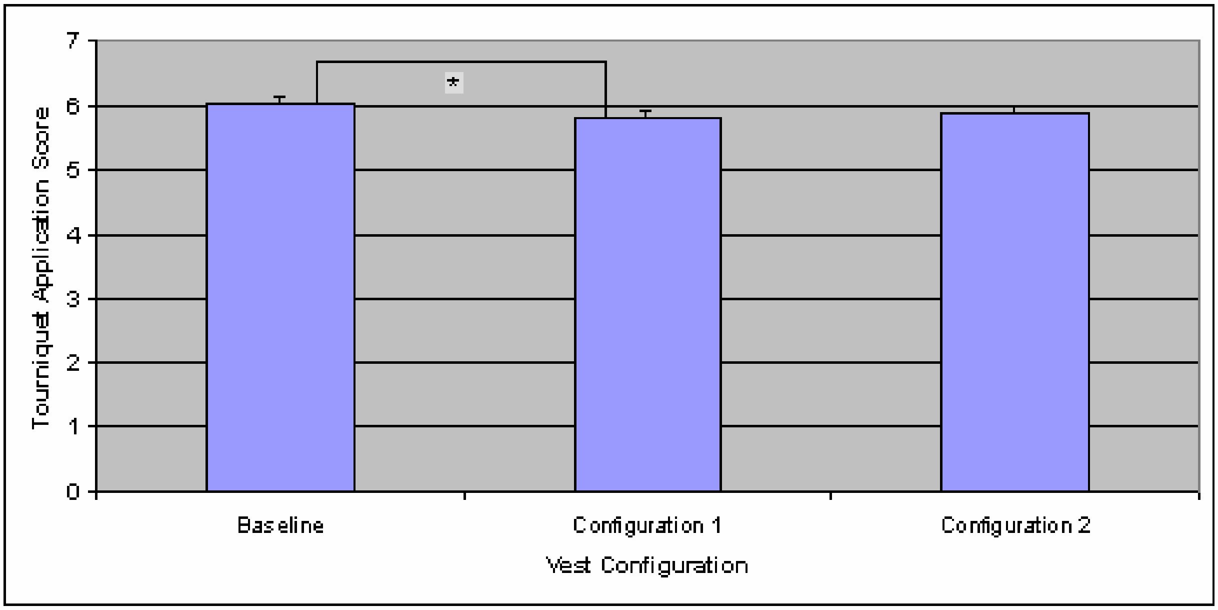


Figure 7. Proper tourniquet application across vest configurations.

For the time condition, a t-test compared the time pressure condition (M = 5.77, SD = .7) to the baseline (M = 6.05, SD = .59) for proper application. The analysis showed that the time pressure condition caused significantly more application errors than the baseline, $t(39) = 3.559$, $p = .001$, $d = 0.41$ (see Figure 8).

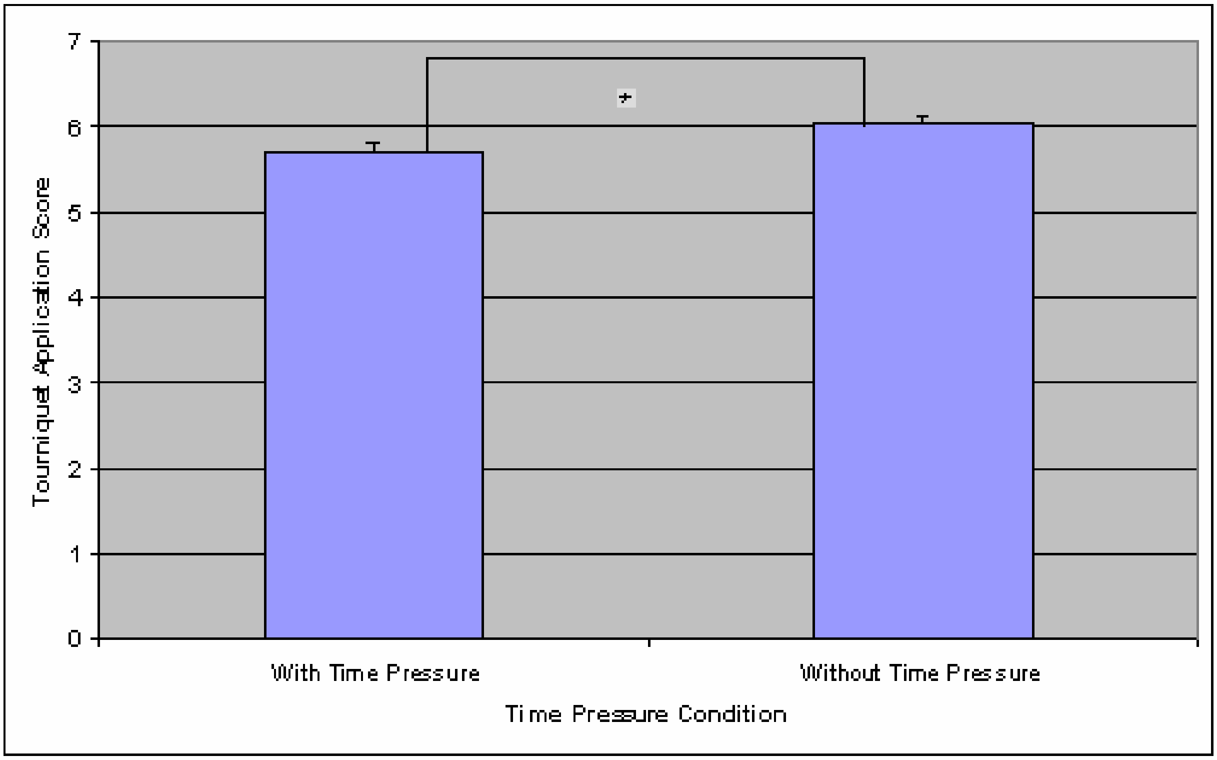


Figure 8. Proper tourniquet application across time conditions.

For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 5.7, SD = .8) to the baseline (M = 6.05, SD = .59), and configuration 2 with time pressure (M = 5.84, SD = .82) to the baseline (M = 6.05, SD = .59), on proper application. The analyses showed that configuration 1 with time pressure caused significantly more errors than the baseline, $t(39) = 3.411$, $p = .002$, $d = 0.5$. However, there was no significant difference between configuration 2 with time pressure and the baseline, $t(39) = 2.159$, $p = .037$, $d = 0.29$ (see Figure 9).

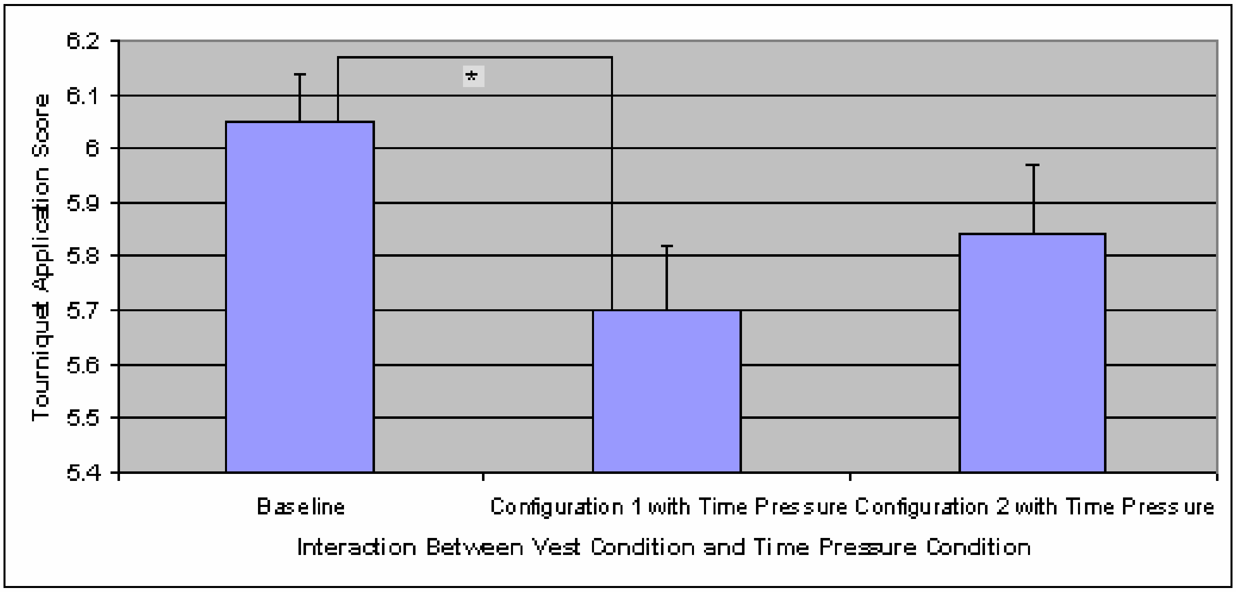


Figure 9. Proper tourniquet application for interaction between vest conditions and time conditions.

Subjective Stress. For subjective stress, t-tests compared configurations 1 and 2 with the baseline, as well as each other. The analyses showed that configuration 1 (M = 4.55, SD = 2.11) caused significantly more subjective stress than the baseline (M = 3.81, SD = 1.8), $t(39) = -3.098$, $p = .004$, $d = 0.38$. However, there were no significant differences in configuration 2 (M = 4.44, SD = 2.34) and the baseline, or between configuration 1 and configuration 2, $t(39) = -2.742$, $p = .009$, $d = 0.3$, and $t(39) = .768$, $p = .447$, $d = 0.05$, respectively (see Figure 10).

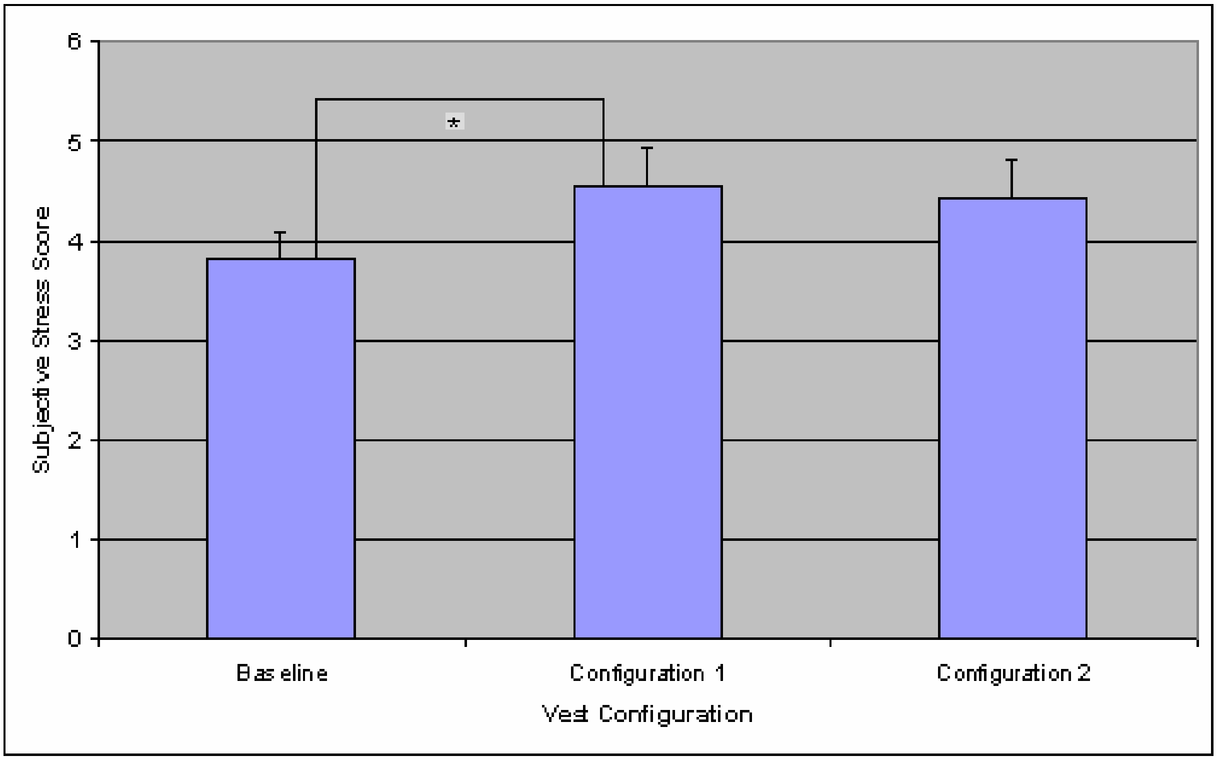


Figure 10. Subjective stress across vest configurations.

For the time condition, a t-test compared the time pressure condition (M = 4.65, SD = 2.38) to the baseline (M = 3.81, SD = 1.8) for subjective stress. The analysis showed that the time pressure condition caused significantly more subjective stress than the baseline, $t(39) = -3.408$, $p = .002$, $d = 0.4$ (see Figure 11).

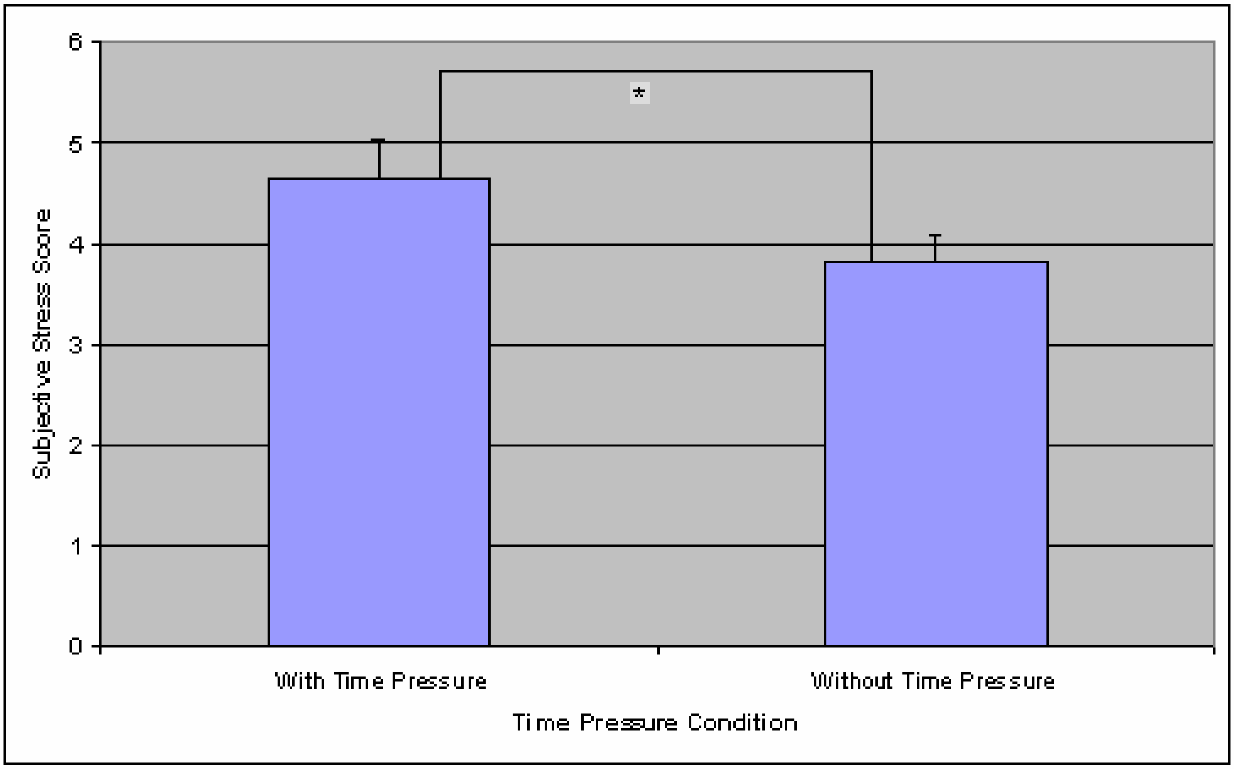


Figure 11. Subjective stress across time conditions.

For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 5.7, SD = .8) to the baseline (M = 3.81, SD = 1.8), and configuration 2 with time pressure (M = 5.84, SD = .82) to the baseline (M = 3.81, SD = 1.8), on subjective stress. The analyses showed that configuration 1 with time pressure caused significantly more subjective stress than the baseline, and configuration 2 with time pressure caused significantly more subjective stress than the baseline, $t(39) = -3.624$, $p = .001$, $d = 1.36$, and $t(39) = -2.901$, $p = .006$, $d = 1.45$, respectively (see Figure 12).

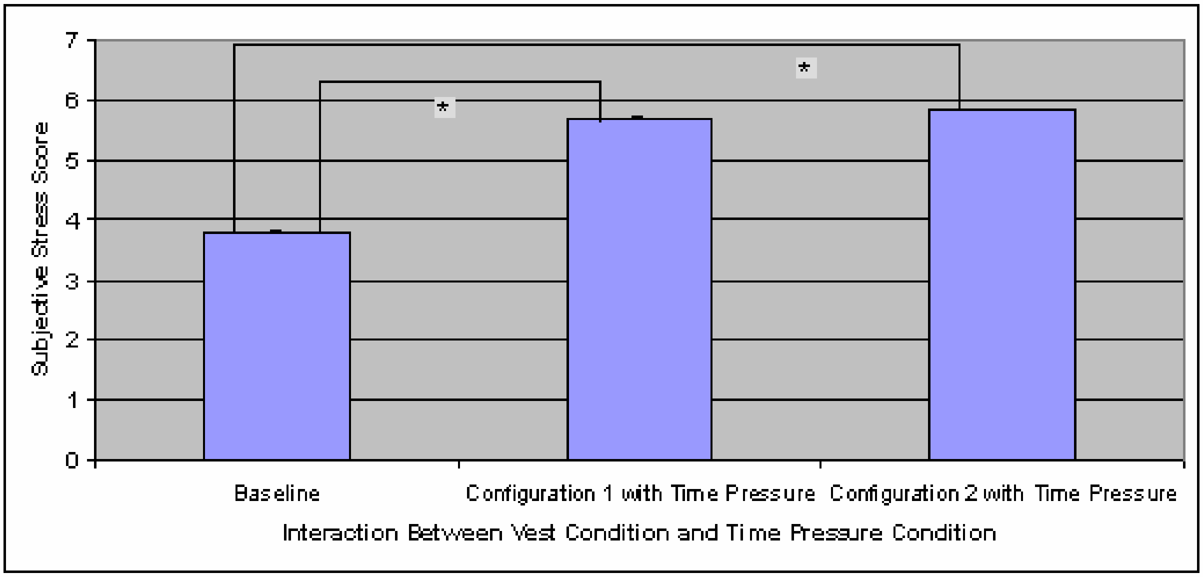


Figure 12. Subjective stress for interaction between vest conditions and time conditions.

Subjective Workload. For subjective workload, t-tests compared configurations 1 and 2 with the baseline, as well as each other. The analyses showed that there were no significant differences between configuration 1 (M = 4.71, SD = 1.97) and the baseline (M = 4.28, SD = 2.0), between configuration 2 (M = 4.76, SD = 2.44) and the baseline, or between configuration 1 and configuration 2, $t(39) = -2.34$, $p = .024$, $d = 0.22$, $t(39) = -2.192$, $p = .034$, $d = 0.22$, and $t(39) = -.312$, $p = .757$, $d = 0.02$, respectively. For the time condition, a t-test compared the time pressure condition to the baseline for subjective workload. The analysis showed that there was no significant difference between the time pressure condition (M = 4.84, SD = 2.37) and the baseline (M = 4.28, SD = 2.0), $t(39) = -2.546$, $p = .015$, $d = 0.26$. For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 4.82, SD = 2.21) to the baseline (M = 4.28, SD = 2.0), and configuration 2 with time pressure (M = 4.86, SD = 2.62) to the baseline (M = 4.28, SD = 2.0), on subjective workload. The analyses showed that there were no significant differences between configuration 1 with time pressure and the baseline, or between configuration 2 with time pressure and the baseline, $t(39) = -2.552$, $p = .015$, $d = 0.26$, and $t(39) = -2.28$, $p = .028$, $d = 0.25$, respectively.

Secondary Task Performance

Secondary task performance scores for all conditions were averaged across participants. A series of paired-samples t-tests was performed for vest condition, time condition, and possible interaction effects for each dependent variable.

Secondary Task Accuracy. For secondary task accuracy, t-tests compared configurations 1 and 2 with the baseline as well as each other. The analyses showed that the baseline (M = .81, SD = .11) resulted in significantly greater accuracy than configuration 1 (M = .15, SD = .04), and also significantly greater accuracy than configuration 2 (M = .47, SD = .09), $t(39) = 41.444$, $p < .0001$, $d = 7.97$, and $t(39) = 21.839$, $p < .0001$, $d = 3.38$, respectively. Additionally, the analyses showed that configuration 2 caused significantly greater accuracy than configuration 1, $t(39) = -28.695$, $p < .0001$, $d = 4.59$ (see Figure 13).

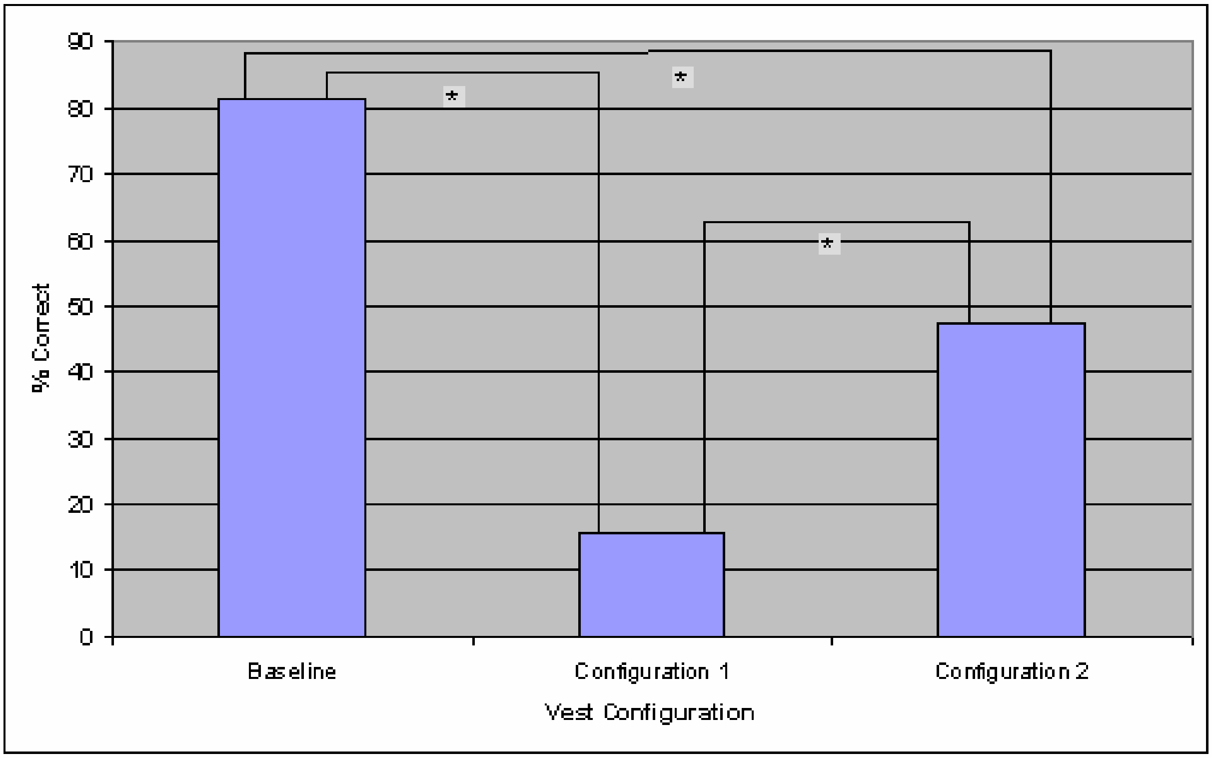


Figure 13. Secondary task accuracy across vest configurations.

For the time condition, a t-test compared the time pressure condition to the baseline for secondary task accuracy. The analysis showed that the baseline condition (M = .81, SD = .11) caused significantly greater accuracy than the time pressure condition (M = .26, SD = .07) caused, $t(39) = 31.902$, $p < .0001$, $d = 5.97$ (see Figure 14).

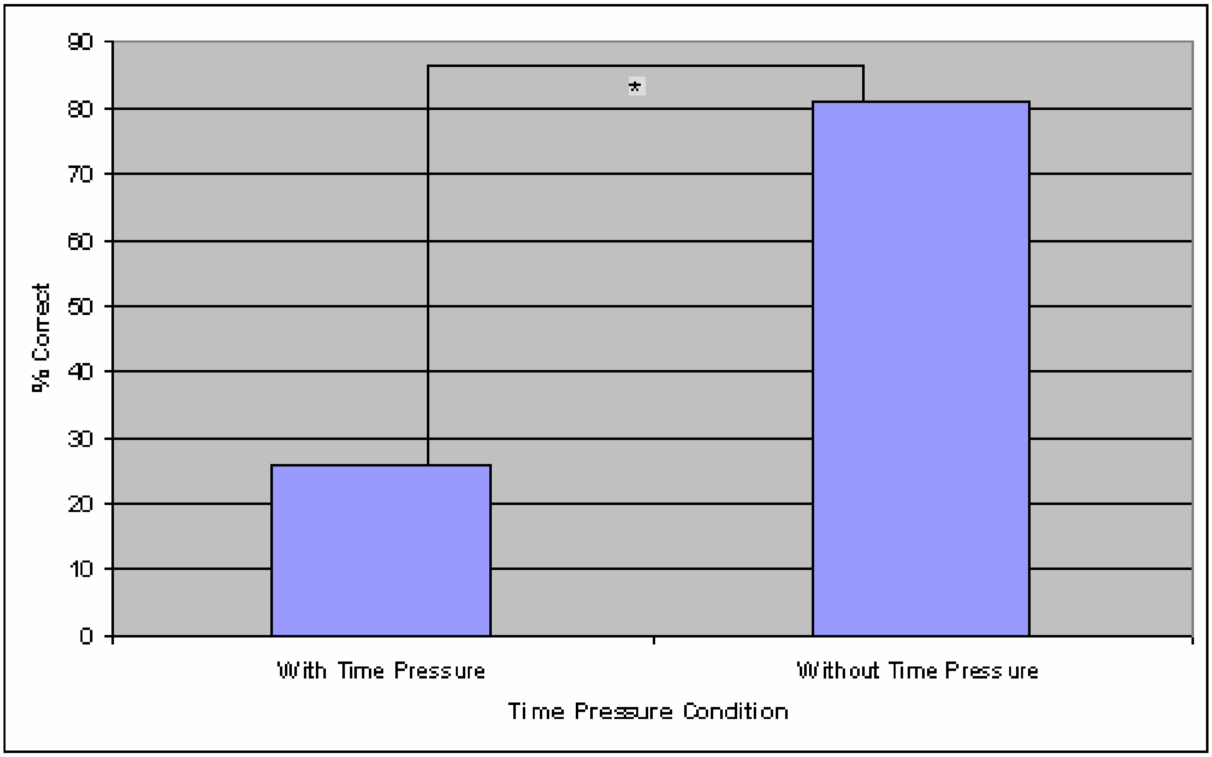


Figure 14. Secondary task accuracy across time conditions.

For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = .1, SD = .06) to the baseline (M = .81, SD = .11), and configuration 2 with time pressure (M = .42, SD = .11) to the baseline (M = .81, SD = .11), on secondary task accuracy. The analyses showed that the baseline condition caused significantly greater accuracy than both configuration 1 with time pressure and configuration 2 with time pressure, $t(39) = 40.057$, $p < .0001$, $d = 8.01$, and $t(39) = 19.824$, $p < .0001$, $d = 3.55$, respectively (see Figure 15).

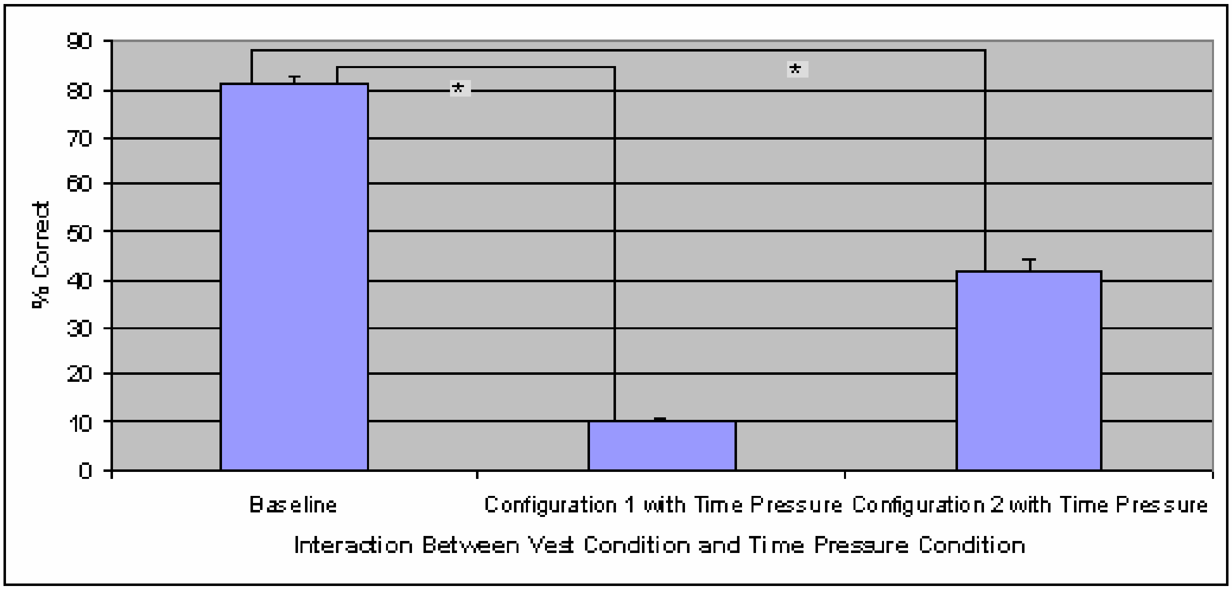


Figure 15. Secondary task accuracy for interaction between vest conditions and time conditions.

Secondary Task Response Times. For secondary task reaction times, t-tests compared configurations 1 and 2 with the baseline, as well as each other. The analyses showed that there were no significant differences between configuration 1 (M = 1880.49, SD = 627.57) and the baseline (M = 2055.97, SD = 434.07), between configuration 2 (M = 1933.75, SD = 412.66) and the baseline, or between configuration 1 and configuration 2, $t(39) = 2.175$, $p = .036$, $d = 0.33$, $t(39) = 2.340$, $p = .024$, $d = 0.29$, and $t(39) = .393$, $p = .696$, $d = 0.1$, respectively. For the time condition, a t-test compared the time pressure condition to the baseline for secondary task response times. The analysis showed that there was no significant difference between the time pressure condition (M = 1884.66, SD = 537.21) and the baseline (M = 2055.97, SD = 434.07), $t(39) = 2.435$, $p = .020$, $d = 0.35$. For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 1880.49, SD = 627.57) to the baseline (M = 2055.97, SD = 434.07), and configuration 2 with time pressure (M = 1888.84, SD = 512.63) to the baseline (M = 2055.97, SD = 434.07), on secondary task response time. The analyses showed that there were no significant differences between configuration 1 with time pressure and the baseline, or between configuration 2 with time pressure and the baseline, $t(39) = 2.133$, $p = .039$, $d = 0.33$, and $t(39) = 2.337$, $p = .025$, $d = 0.35$, respectively.

Time Estimation. For time estimation, t-tests compared configurations 1 and 2 with the baseline as well as each other. The analyses showed that the baseline (M = 34.64, SD = 23.0) caused significantly greater time estimations than configuration 1 (M = 30.39, SD = 22.58), and the baseline caused significantly greater time estimations than configuration 2 (M = 29.67, SD = 22.94), $t(39) = 3.109$, $p = .004$, $d = 0.19$, and $t(39) = 3.071$, $p = .004$, $d = 0.22$, respectively. However, there was no significant difference between configuration 1 and configuration 2, $t(39) = .689$, $p = .495$, $d = 0.03$ (see Figure 16).

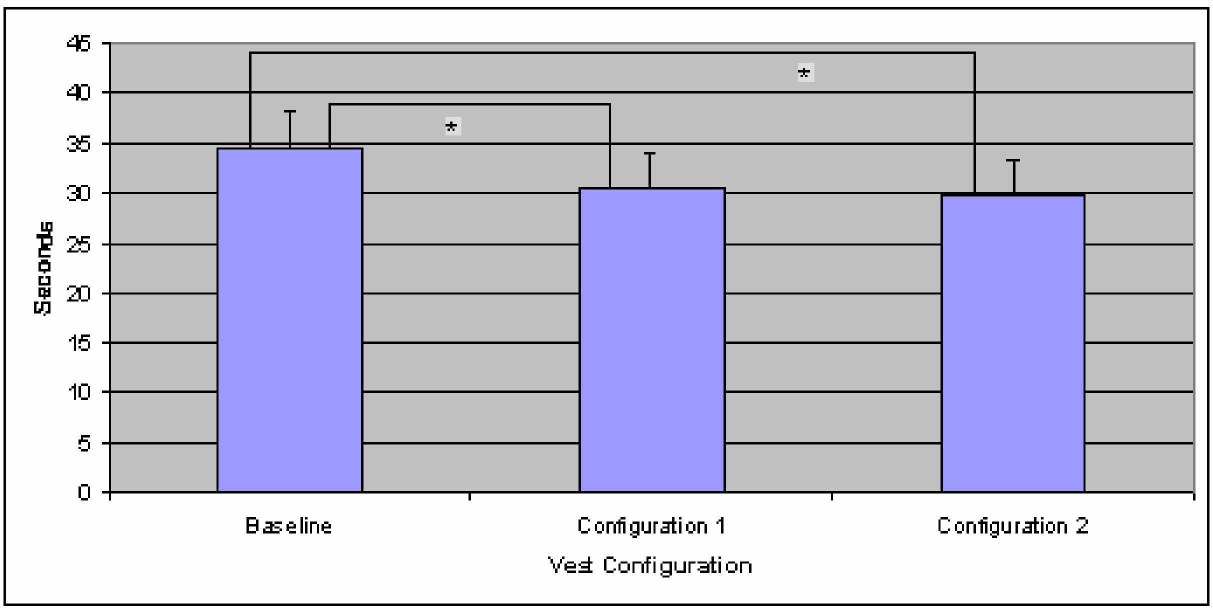


Figure 16. Time estimations across vest configurations.

For the time condition, a t-test compared the time pressure condition to the baseline for time estimation. The analysis showed that the baseline condition (M = 34.64, SD = 23.0) caused significantly greater time estimations than the time pressure condition (M = 29.35, SD = 23.33), $t(39) = 2.785$, $p = .008$, $d = 0.23$ (see Figure 17).

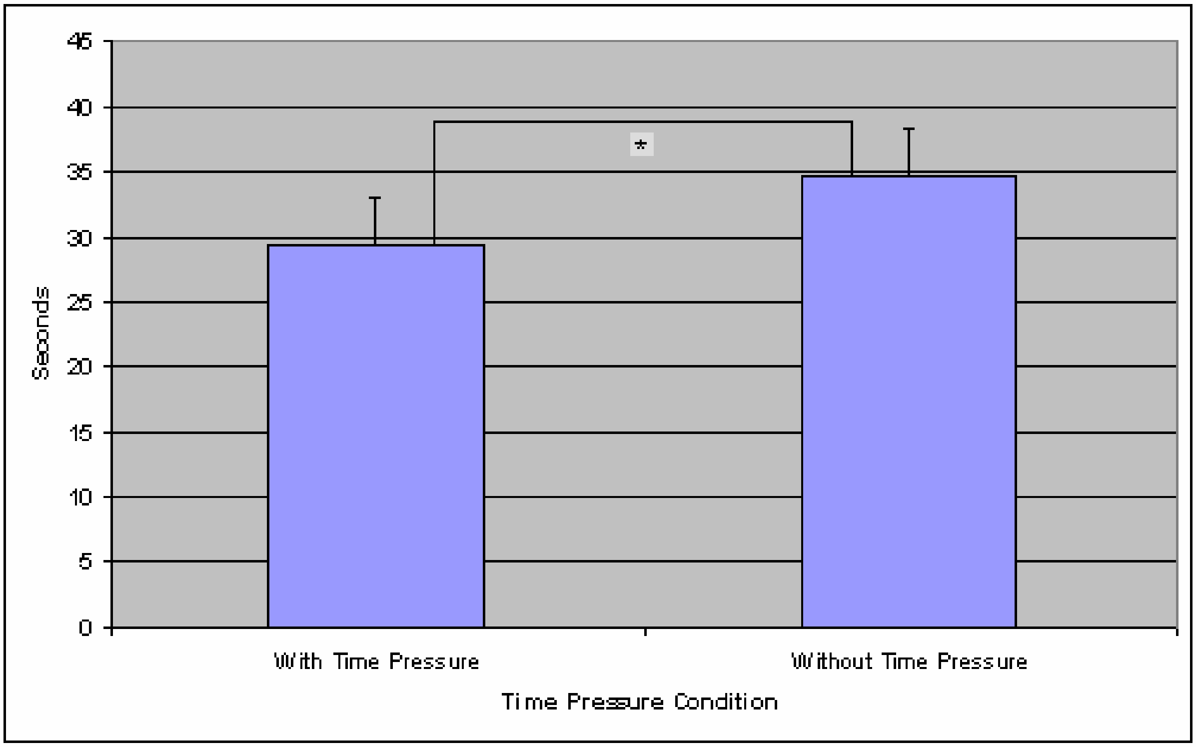


Figure 17. Time estimations across time conditions.

For the interaction, paired-samples t-tests were conducted for the interaction to compare configuration 1 with time pressure (M = 29.24, SD = 22.32) to the baseline (M = 34.64, SD = 23.0), and configuration 2 with time pressure (M = 29.47, SD = 25.48) to the baseline (M = 34.64, SD = 23.0), on time estimation. The analyses showed that the baseline condition caused significantly greater time estimations than configuration 1 with time pressure, $t(39) = 2.997$, $p = .005$, $d = 0.24$. However, there was not a significant difference between the baseline and configuration 2 with time pressure, $t(39) = 2.22$, $p = .032$, $d = 0.21$ (see Figure 18).

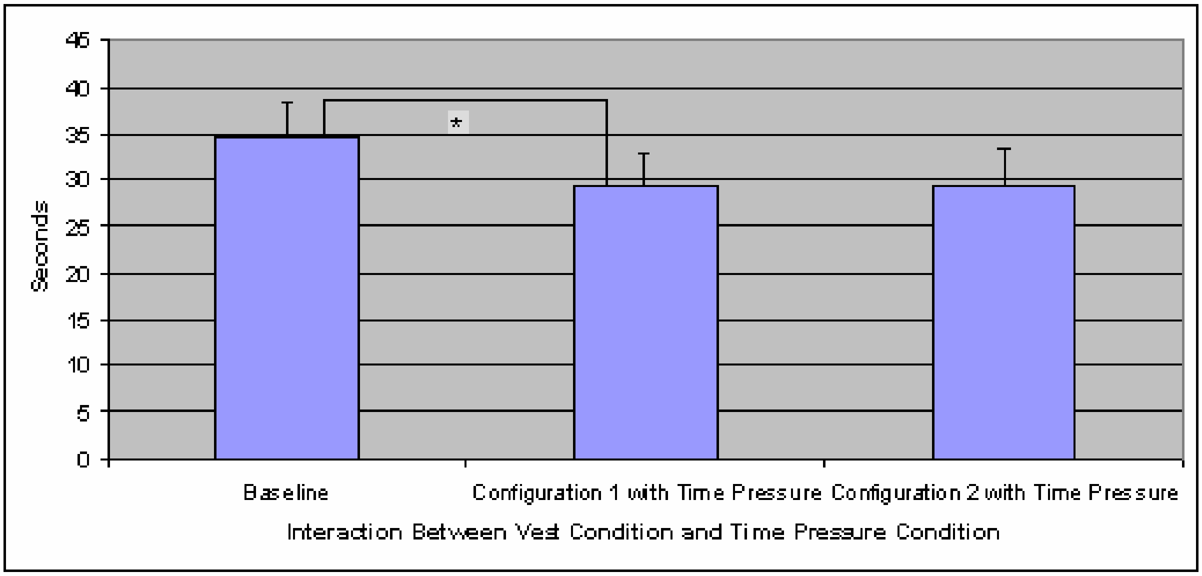


Figure 18. Time estimations for interaction between vest conditions and time conditions.

Summary of Results

The results from experiment one show that the vest in configuration 1 caused poorer task performance than the vest in configuration 2, which in turn caused poorer task performance than the baseline condition. Because of these results, the vest in configuration 1 was deemed the more stressful vest. This was true on both the primary and secondary tasks, as well as on objective and subjective measures. Additionally, the time pressure condition caused poorer task performance than the baseline condition. There was a significant interaction between vest configuration and time pressure, such that combining both created poorer performance than either condition alone. Furthermore, the greatest time distortion occurred in conditions that induced the most stress. This study shows that vibration stress does not affect the body uniformly, and different parts of the body are subject to different stress effects. Also, time pressure causes poorer task performance than no time pressure, and time distortion occurs when operators are under stress. Nearly each hypothesis proposed for experiment one was supported (see Table 3). Means and standard deviations for the variables can be seen in Table 4, and the complete data set for experiment one can be seen in Appendix I.

Table 3. Experiment one hypotheses/results summary.

	Hypothesis Number							
Dependent Measure	1	2	3	4	5	6	7	8
Tourniquet Application Time	**$V_1>[V_2,C]$**	**$V_2>C$**	**T>C**	**V_1*T>C** **V_2*T>C**				
Tourniquet Score	**$V_1<$**[V_2,**C**]	$V_2<C$	**T<C**	**V_1*T<C** V_2*T<C				
Subjective Stress	**$V_1>$**[V_2,**C**]	$V_2>C$	**T>C**	**V_1*T>C** **V_2*T>C**				
Subjective Workload	$V_1>[V_2,C]$	$V_2>C$	T>C	V_1*T>C V_2*T>C				
Secondary Task Accuracy					**$V_1<[V_2,C]$**	**$V_2<C$**	**T<C**	**V_1*T<C** **V_2*T<C**
Secondary Task Response Time					$V_1>[V_2,C]$	$V_2>C$	T>C	V_1*T>C V_2*T>C
Time Estimation					**$V_1<$**[V_2,**C]**	**$V_2<C$**	**T<C**	**V_1*T<C** V_2*T<C

*C = Control, V_1 = Vest in Configuration 1 (Bony), V_2 = Vest in Configuration 2 (Fleshy), T = Time Pressure
V*T = Vest by Time Interaction
Hypotheses in bold and underlined were supported by the results. Hypotheses with plain text were not supported.

Table 4. Experiment one means and standard deviations.

	Condition			
Dependent Measure	Baseline Condition	Configuration 1	Configuration 2	Time Pressure Condition
Tourniquet Application Time	M = 20.27 SD = 1.81	M = 55.04 SD = 2.48	M = 35.54 SD = 1.58	M = 48.54 SD = 2.35
Tourniquet Score	M = 6.05 SD = 0.59	M = 5.81 SD = 0.69	M = 5.87 SD = 0.75	M = 5.77 SD = 0.70
Subjective Stress	M = 3.81 SD = 1.80	M = 4.55 SD = 2.11	M = 4.44 SD = 2.35	M = 4.65 SD = 2.37
Subjective Workload	M = 4.28 SD = 2.00	M = 4.71 SD = 1.97	M = 4.76 SD = 2.44	M = 4.84 SD = 2.37
Secondary Task Accuracy	M = 81% SD = 11%	M = 15% SD = 4%	M = 47% SD = 9%	M = 26% SD = 7%
Secondary Task Response Time	M = 2055.97 SD = 434.07	M = 1946.93 SD = 462.26	M = 1933.75 SD = 412.66	M = 1884.66 SD = 537.21
Time Estimation	M = 34.64 SD = 23.01	M = 30.39 SD = 22.58	M = 29.67 SD = 22.94	M = 29.35 SD = 23.33

Experiment Two

Experimental Hypotheses

The results of the first experiment indicate that placing vibration on bony areas of the body produces greater performance decrements than placing it on fleshy areas of the body. Thus, the vest configured with tactors on bony was considered the more stressful vest, so it was used in experiment two. With respect to vibration stress, various interactions between it and other types of stress have been investigated. However, a clear gap in the research of stress interaction is that of noise and vibration (Hancock, Conway, Szalma, Ross, & Saxton, 2006; Hancock & Szalma, 2007). Therefore, the second experiment investigated how vibration stress interacts with auditory stress. This experiment used the vest with vibration on bony areas combined with auditory stress at an accepted “high” intensity (OSHA, 2006). Eight hypotheses were generated.

Hypothesis 1. When participants were in the combined stress (vibration and auditory) condition, they were expected to have worse performance on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress and subjective workload than when in single-stress and control conditions. It was expected that the interaction between vibration and noise would act in a protagonistic manner.

Hypothesis 2. When participants were in the vibration-only condition, they were expected to have worse performance on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress and subjective workload than when in the control condition. This was anticipated because of the added stress.

Hypothesis 3. When participants were in the auditory-only condition, they were expected to have worse performance on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress and subjective workload than when in the control condition. This was anticipated because of the added stress.

Hypothesis 4. Participants in all conditions were expected to perform worse on the primary task, in terms of longer application times and more failures for proper application, and report more subjective stress and subjective workload when vibration, auditory and combined stress was combined with time pressure than in the baseline condition. Specifically, they were expected to have longer application time, have more failures for proper application, and report more subjective stress.

Hypothesis 5. When participants were in the combined stress (vibration and auditory) condition, they were expected to have worse performance on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks than when in the single-stress and control conditions because as workload increases, secondary task performance often decreases when the tasks share resources, which the tasks did. It was expected that the interaction between vibration and noise would act in a protagonistic manner. Additionally, this was anticipated because of the added stress.

Hypothesis 6. When participants were in the vibration-only condition, they were expected to have worse performance on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks than when in the control condition because as workload increases, secondary task performance often decreases when the tasks share resources, which the tasks did.

Hypothesis 7. When participants were in the auditory-only condition, they were expected to have worse performance on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks than when in the control condition because as workload increases, secondary task performance often decreases when the tasks share resources, which the tasks did.

Hypothesis 8. Participants in all conditions were expected to perform worse on the secondary task, in terms of being less accurate, having longer response times, and underestimating the duration of the tasks when vibration, auditory and combined stress was mixed with time pressure than in the baseline condition.

A summary of the hypotheses for experiment can be seen in Table 5.

Table 5. Experiment two hypotheses summary.

	Hypothesis Number							
Dependent Measure	1	2	3	4	5	6	7	8
Tourniquet Application Time	AV>[A,V,C]	V>C	A>C	ST>C				
Tourniquet Score	AV<[A,V,C]	V<C	A<C	ST<C				
Subjective Stress	AV>[A,V,C]	V>C	A>C	ST>C				
Subjective Workload	AV>[A,V,C]	V>C	A>C	ST>C				
Secondary Task Accuracy					AV<[A,V,C]	V<C	A<C	ST<C
Secondary Task Response Time					AV>[A,V,C]	V>C	A>C	ST>C
Time Estimation					AV<[A,V,C]	V<C	A<C	ST<C

*C = Control, A = Auditory-only, V = Vibration-only, AV = Auditory + Vibration (combined stress), ST = Stress + Time Pressure

Experimental Design

This experiment investigated the combined effects of vibration (2), noise (2), and time pressure (2) on task performance for a tourniquet application task. The hypotheses were tested using the following within-subjects design. The first manipulated variable was vibration with the following levels – vibration and no vibration. The second manipulated variable was noise with the following levels – noise and no noise. The third manipulated variable was time pressure with the following levels – time pressure and no time pressure. The design consisted of one control condition, which did not receive any stress, and which participants completed before and after the experimental conditions, and three experimental conditions, one of which received tactile stress alone, one of which received auditory stress alone, and one of which received both tactile and auditory stress. Each participant achieved a baseline for performance determined by the experimenter as well as the participant feeling comfortable with the system. Participants were allowed to take as much time as necessary during the baseline trial(s). All participants completed each condition. The experimental design can be seen in Table 6. Conditions were counterbalanced using a latin square (Kirk, 1995) to reduce the likelihood of practice and fatigue effects (Poulton, 1982). Additionally, there were an equal number of participants in each condition order. The condition order can be seen in Table 7. A within-subjects design was used to minimize individual effetcs. Fourty-five participants were used. This number was chosen because an effect of .3 and greater, which is a medium effect, will be found at a power of .82 (Cohen, 1977).

Table 6. Experimental Design for Experiment Two.

	Type of Stress			
Baseline Trial (No Time Pressure)	**Tactile (Time Pressure)**	**Auditory (Time Pressure)**	**Tactile + Auditory Stress (Time Pressure)**	**Baseline Trial (No Time Pressure)**
X	**A**	**B**	**C**	**X**

Table 7. Condition Order for Experiment Two.

B	**A**	**C**
A	**C**	**B**
C	**B**	**A**

Experimental Participants

The participants for this experiment were students from the UCF. Participants were recruited using posted flyers on the main Orlando campus and through the university's online experiment system, Experimentrak. Compensation was extra credit for a course of the student's choice, assigned through Experimentrak, or $20 for the study. There were thirty-three males and twelve females. There were fourty-five participants in this study, which is sufficient to find an effect of .3 or greater at a power of .82 (Cohen, 1977).

Experimental Apparatus

This experiment used the tactile vest in configuration 1 because it was deemed "most stressful" by the performance measures in the previous experiment (see Figures 1). Tactors vibrated at 168 Hz.

The tasks used a mannequin limb obtained from IST at UCF. To support multiple application trials, the thickness of the mannequin limb was modified by adding/removing a layer to the existing limb. Additionally, an audio voice recorder, a video camera, and an improvised tourniquet were used.

The subjective measures and secondary task were administered via a Dell laptop, model # PPM, Inspiron 5000.

White noise was administered through Sennheiser headphones, model #HD201, worn by the participants. The noise was administered at 90 dBA measured with a Sper Scientific sound level meter, model # 840029. This noise level was chosen because in pilot testing it was found to be extremely unpleasant to the listener but does not violate any Occupational Safety and Health Administration regulations (OSHA, 2006).

Experimental Tasks

A primary-secondary task paradigm was chosen because the primary task was simple, as reported by combat medics, and the secondary task was used to add to the difficulty of the tasks. Additionally, in combat, medics perform multiple tasks. The primary and secondary tasks were performed simultaneously. The primary task was properly applying the improvised tourniquet. There was one control condition and three experimental conditions. All participants completed all conditions. Feedback on the tightness of the tourniquet was delivered via a computer graphic controlled by the experimenter. Feedback was a vertical column presented on a computer screen that shows the required pressure and the current pressure will be indicated by color in the column.

The secondary task was differentiating between friendly and enemy forces and responding as quickly as possible by pressing the left mouse button for friendly and the right mouse button for enemy (see Appendix A). Images were shown were for three seconds, or until a response was given by the participant, whichever came first. Inter-stimulus images were shown for five seconds after every image. On average, participants saw 4.1 images per trial. Participants were shown the images at the beginning of the experiment and were given a chance to familiarize themselves with them. However, during the experiment, the images were not available to the participants for reference since the participants were to make absolute judgments rather than comparative judgments. Friendly images differed from foe images in color of soldier uniform and type of weapon. This task was chosen because it is a task that combat medics currently perform while applying tourniquets. In combat, it is imperative that all personnel, medics included, be able to differentiate between friendly and enemy forces and react accordingly (Fowler, Smith, & Litteral, 2005). Additionally, the task was a loading task, which is one that stimulates demands absent from the laboratory environment but are expected in the actual conditions (O'Donnell & Eggemeier, 1986).

Additionally, to get a baseline for workload and stress, a card sorting task was used. Participants had three sorting tasks. The first task was simply turning the cards face-up, which represents 0 bits of analyzed information. The second task was sorting the cards into black and red cards, which represents 1 bit of analyzed information, namely color. The third task was sorting the cards into four suits, which represents 2 bits of analyzed information, namely color and suit. This task was chosen because it is relatively simple and has been shown to provide good baseline information for subjective workload and stress prior to task performance.

Performance Measures

Primary Task. Performance measures were task completion time and the proper application of the tourniquet, determined by a 68W instructor, which was assessed on a point system (Kearneyn, 2006). Participants received one point for each step performed correctly and in the correct order (Parsons, 2004; see Appendix B). This type of assessment is employed in special operations and medic training. The experiment was recorded so multiple raters can assess performance after the completion of the experiment.

Secondary Task. The addition task was assessed for accuracy and response time. Accuracy was the percent correct which was assessed after the experiment using the recorded data. Response time was in milliseconds.

Card Sorting Task. The card sorting task was not assessed for performance.

Time Pressure. During the experimental trials, completion time will be measured as a pre-post measure.

Subjective Measures. Workload was measured via the Borg Rate of Perceived Exertion (RPE; see Appendix C; Borg, 1998), and stress was measured via the Subjective Stress Scale (SSS; see Appendix D; Bollini, Walker, Hamann, & Kestler, 2004). Additionally, participants provided a prospective time estimation, which is often also used as a measure of workload (Zakay, Block, & Tsai, 1999). The actual time estimation was not used, as it is of little value. Rather, the estimates were translated into duration judgment ratios (DJR; Block, Zakay, & Hancock, 1999), which is calculated by dividing the estimated time by the actual time and multiplying this by 100. By using this estimate, analyses can be conducted on how accurate or inaccurate the time estimations were, as well as whether they were overestimations or underestimations by comparing them to 100 as a base, or perfect score. Scores that were negative indicate an overestimation, and scores that were positive indicate an underestimation.

Experimental Procedure

Participants read and signed an informed consent (see Appendix E) indicating they willingly participated in the experiment and could stop at any point without incurring any consequences. Additionally, participants completed a demographic questionnaire (see Appendix F) listing any previous medical training. Participants then completed the card sorting task and completed an RPE and SSS that served as baselines. Participants then received a brief explanation and description of the task and were able to hold the improvised tourniquet and practice the task until they were comfortable with it and the experimenter saw that they could properly apply it per the grading standards. Additionally, they were shown samples of friendly and enemy forces and were able to familiarize themselves with the images (see Appendix G – Experiment One).

After this, participants were fitted in the tactile vest and had an opportunity to feel the tactors when they were vibrating. The mannequin limb was then placed on the work station and the room lights were dimmed to increase difficulty and simulate application during dawn/dusk because anecdotal evidence suggest this may be a particularly challenging time for tourniquet application (Parsons, 2004). Participants were informed they would begin the experiment in 5 seconds, the stressors were turned on, and then participants were instructed to begin applying the improvised tourniquet. Participants were told before beginning each experimental trial that they would need to estimate the amount of time they were performing the task after task completion. Participants had a one-minute rest period between each trial. Trials were counter-balanced to avoid any order effects (Poulton, 1982). The task was timed, and at the completion of the task, the improvised tourniquet was taken off the limb and put back in the starting position. After each trial, participants provided a time estimate and completed the RPE and SSS. Once all trials were completed, participants took off all equipment, provided a time estimate, and completed the RPE, SSS, and a usability questionnaire (see Appendix H). Participants were then debriefed and compensated for their time. All trials were video-taped to aid in performance assessment at the completion of the experiment.

Experimental Results

All analyses were performed using SPSS 11.5, and the alpha level was pre-set at .05. However, due to the large number of comparisons, a Bonferroni correction was applied, such that the alpha level for each test was .008. The inter-rater reliability for all scores was at least .95.

Primary Task Performance

Primary task performance scores for all conditions were averaged across participants. A series of paired-samples t-tests was performed for stress condition for each dependent variable.

Tourniquet Application Time. For tourniquet application time, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition on application time. The analyses showed that the combined stress condition (M = 59.27, SD = 6.7) caused significantly longer application times than the auditory-only condition (M = 32.11, SD = 6.58), the vibration-only condition (M = 32.46, SD = 5.86), and the baseline condition (M = 21.67, SD = 2.58), $t(44) = -21.19$, $p < .0001$, $d = 4.09$, $t(44) = -18.021$, $p < .0001$, $d = 4.26$, and $t(44) = 35.536$, $p < .0001$, $d = 7.41$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition on application time. The analyses showed that the auditory-only condition caused longer application times than the baseline, and the vibration-only condition caused longer application times than the baseline, $t(44) = 9.68$, $p < .0001$, $d = 2.09$, and $t(44) = 10.762$, $p < .0001$, $d = 2.38$, respectively (see Figure 19).

Figure 19. Tourniquet application time across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials on application time. The analyses showed that the time pressure with stress conditions (M = 41.28, SD = 4.06) caused longer application times than the baseline (M = 21.67, SD = 2.58), $t(44) = -25.843$, $p < .0001$, $d = 5.77$ (see Figure 20).

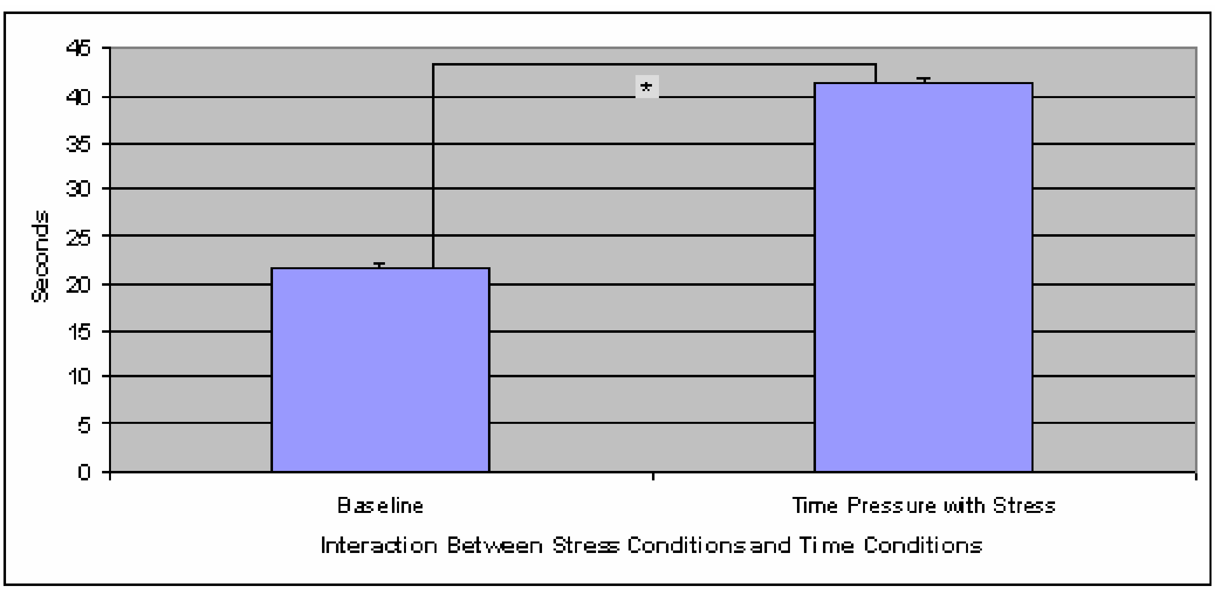


Figure 20. Tourniquet application time for interaction between stress conditions and time conditions.

Proper Tourniquet Application. For proper tourniquet application, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition on proper application. The analyses showed that the baseline condition (M = 6.43, SD = .29), the auditory-only condition (M = 4.83, SD = .63) and the vibration-only condition (M = 4.78, SD = .7) caused significantly higher application scores than the combined stress condition (M = 3.73, SD = .56), $t(44) = -29.544$, $p < .0001$, $d = 6.05$, $t(44) = 9.422$, $p < .0001$, $d = 1.85$, and $t(44) = 9.048$, $p < .0001$, $d = 1.66$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition on proper application. The analyses showed that the baseline condition caused significantly higher application scores than the auditory-only condition and the vibration-only condition, $t(44) = 9.68$, $p < .0001$, $d = 3.26$, and $t(44) = 10.762$, $p < .0001$, $d = 3.08$, respectively (see Figure 21).

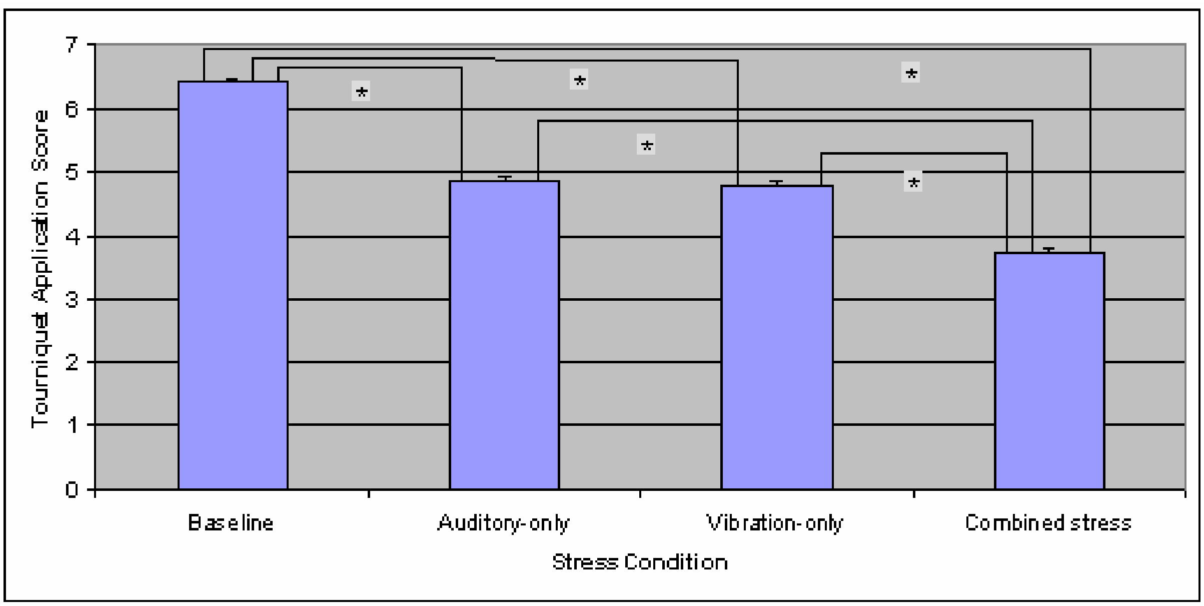


Figure 21. Proper tourniquet application across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials on proper application. The analyses showed that the baseline condition (M = 6.43, SD = .29) had significantly higher scores on proper application than the time pressure condition (M = 4.45, SD = .46), $t(44) = 24.897$, $p < .0001$, $d = 5.15$ (see Figure 22).

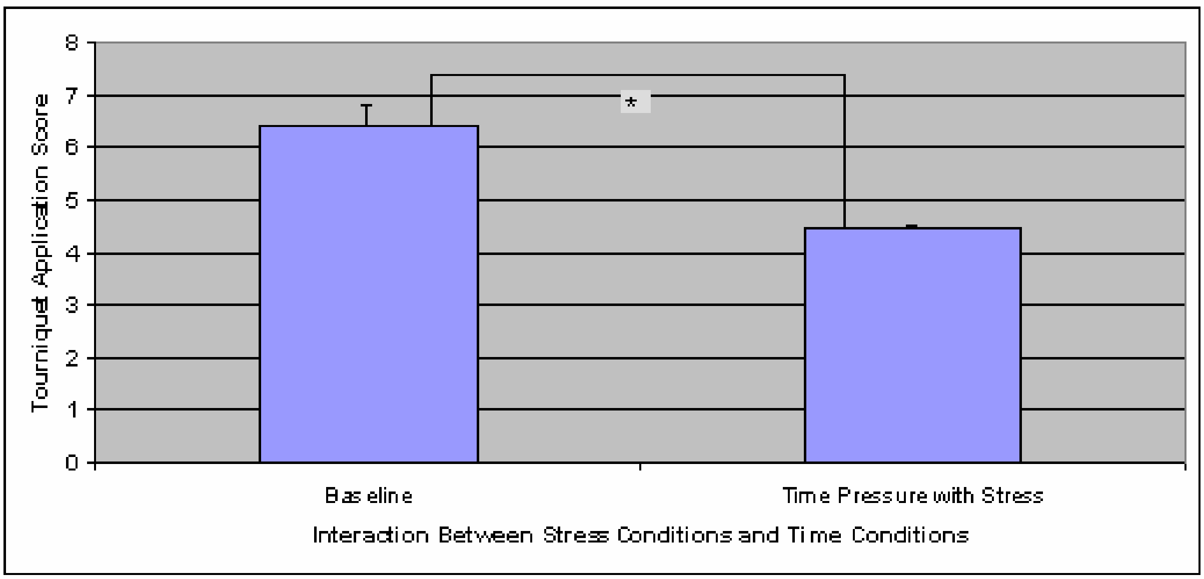


Figure 22. Proper tourniquet application for interaction between stress conditions and time conditions.

Subjective Stress. For subjective stress, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition on subjective stress. The analyses showed that the combined stress condition (M = 8.1, SD = .85) caused significantly more subjective stress than the auditory-only condition (M = 5.03, SD = .75), the vibration-only condition (M = 4.89, SD = .63), and the baseline condition (M = 1.99, SD = .8), $t(44) = -18.798$, $p < .0001$, $d = 3.92$, $t(44) = -20.026$, $p < .0001$, $d = 4.29$, and $t(44) = 32.201$, $p < .0001$, $d = 7.4$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition on subjective stress. The analyses showed that the auditory-only condition caused longer application times than the baseline, and the vibration-only condition caused more subjective stress than the baseline, $t(44) = 19.581$, $p < .0001$, $d = 3.92$, and $t(44) = 21.087$, $p < .0001$, $d = 4.03$, respectively (see Figure 23).

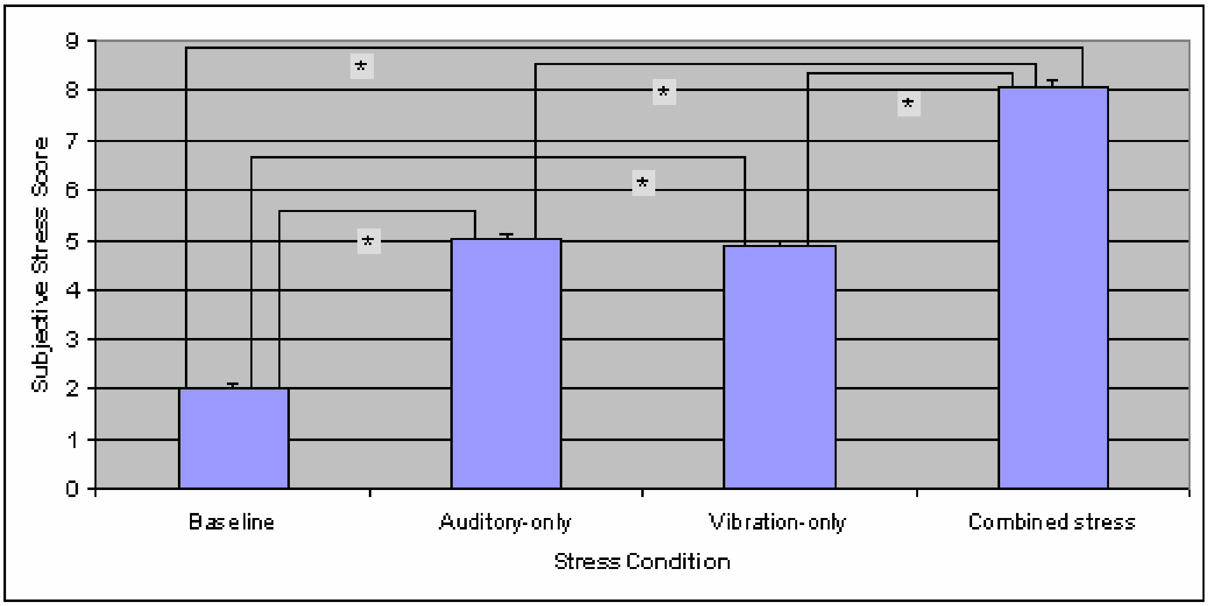


Figure 23. Subjective stress across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials on subjective stress. The analyses showed that the time pressure with stress conditions (M = 6.0, SD = .45) caused more subjective stress than the baseline (M = 1.99, SD = .8), $t(44) = -29.613$, $p < .0001$, $d = 6.18$ (see Figure 24).

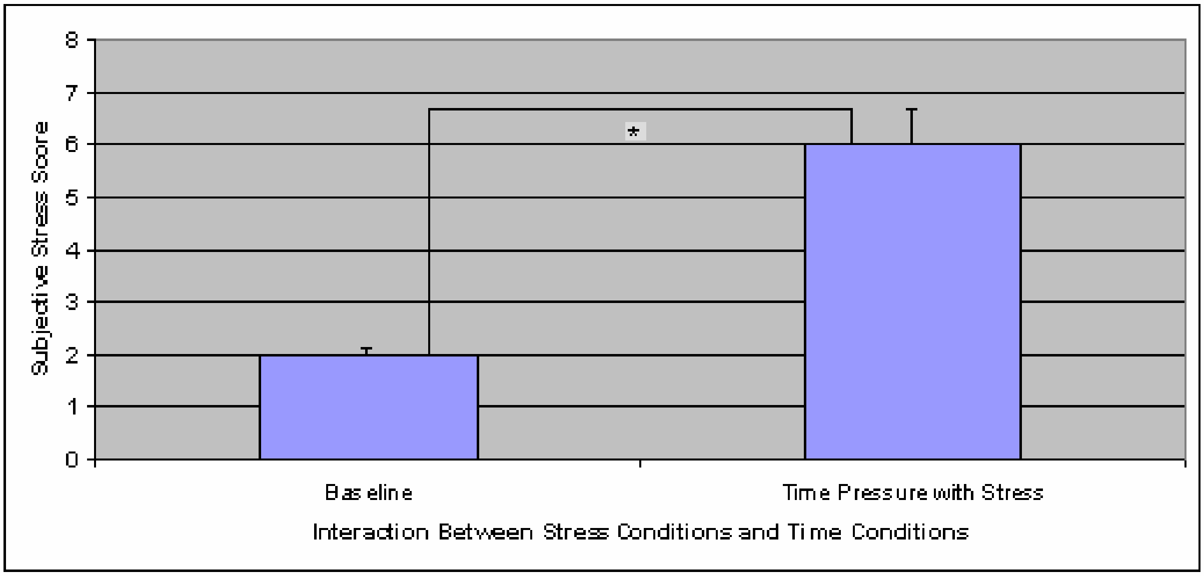


Figure 24. Subjective stress for interaction between stress conditions and time conditions.

Subjective Workload. For subjective workload, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition on subjective workload. The analyses showed that the combined stress condition (M = 4.89, SD = 2.33) caused significantly more subjective workload than the baseline condition (M = 3.97, SD = 2.31), $t(44) = 7.243$, $p < .0001$, $d = 0.4$. However, there were no significant differences between the combined stress condition and the auditory-only condition (M = 4.55, SD = 2.38) or the combined stress condition and the vibration-only condition (M = 4.66, SD = 2.37), $t(44) = -2.017$, $p = .05$, $d = 0.14$, and $t(44) = -1.761$, $p = .085$, $d = 0.1$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition on subjective workload. The analyses showed that the auditory-only condition caused more subjective workload than the baseline, and the vibration-only condition caused more subjective workload than the baseline, $t(44) = 3.864$, $p < .0001$, $d = 0.25$, and $t(44) = 5.301$, $p < .0001$, $d = 0.29$, respectively (see Figure 25).

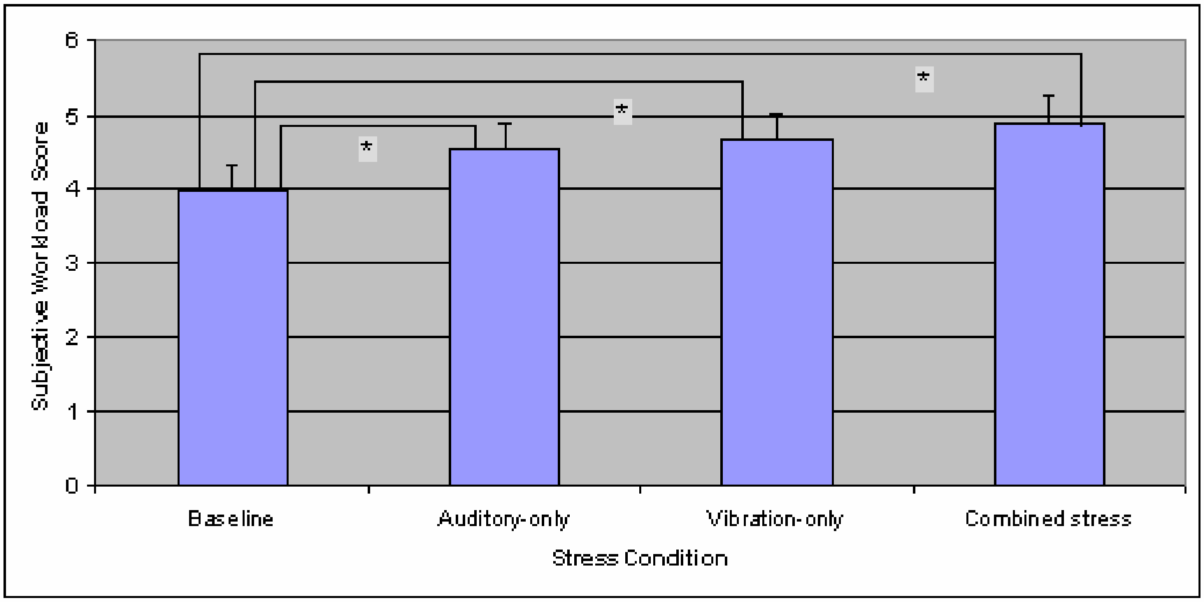


Figure 25. Subjective workload across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials on subjective workload. The analyses showed that the time pressure with stress conditions (M = 4.7, SD = 2.28) caused more subjective workload than the baseline (M = 3.97, SD = 2.31), $t(44) = -7.028$, $p < .0001$, $d = 0.32$ (see Figure 26).

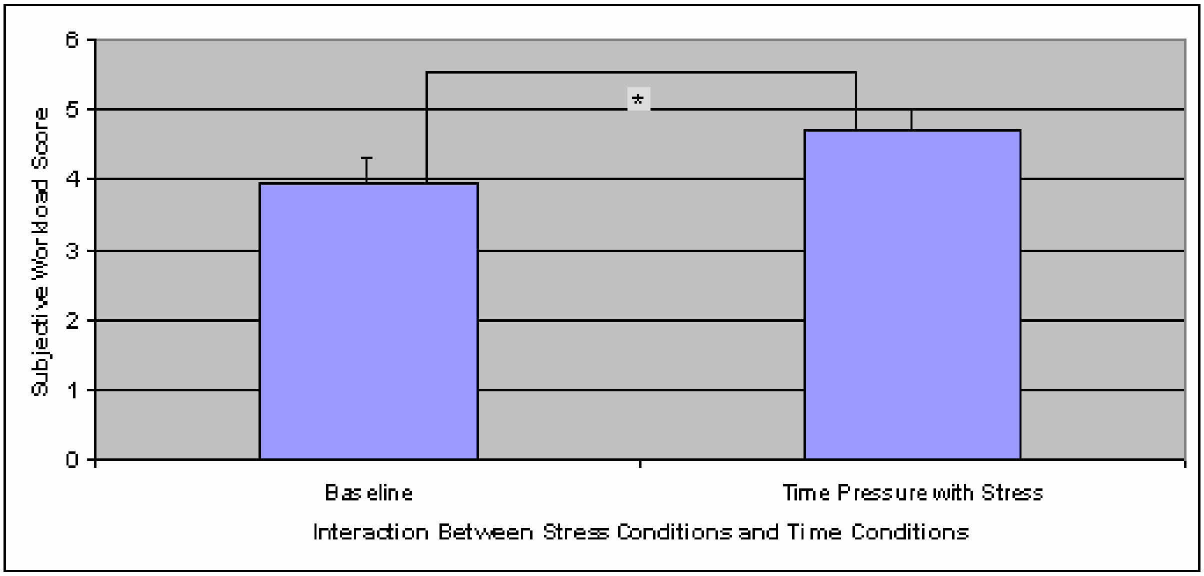


Figure 26. Subjective workload for interaction between stress conditions and time conditions.

Subjective Task Performance

Secondary task performance scores for all conditions were averaged across participants. A series of paired-samples t-tests was performed for stress condition for each dependent variable.

Secondary Task Accuracy. For secondary task accuracy, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition for secondary task accuracy. The analyses showed that the baseline condition (M = .79, SD = .11), the auditory-only condition (M = .52, SD = .14) and the vibration-only condition (M = .55, SD = .14) caused significantly greater accuracy than the combined stress condition (M = .21, SD = .06), $t(44) = -27.953$, $p < .0001$, $d = 6.55$, $t(44) = 15.121$, $p < .0001$, $d = 2.88$, and $t(44) = 16.507$, $p < .0001$, $d = 3.16$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition for secondary task accuracy. The analyses showed that the baseline condition caused significantly greater accuracy than the auditory-only condition and the vibration-only condition, *t*(44) = -9.901, *p* < .0001, *d* = 2.14, and *t*(44) = -9.516, *p* < .0001, *d* = 1.91, respectively (see Figure 27).

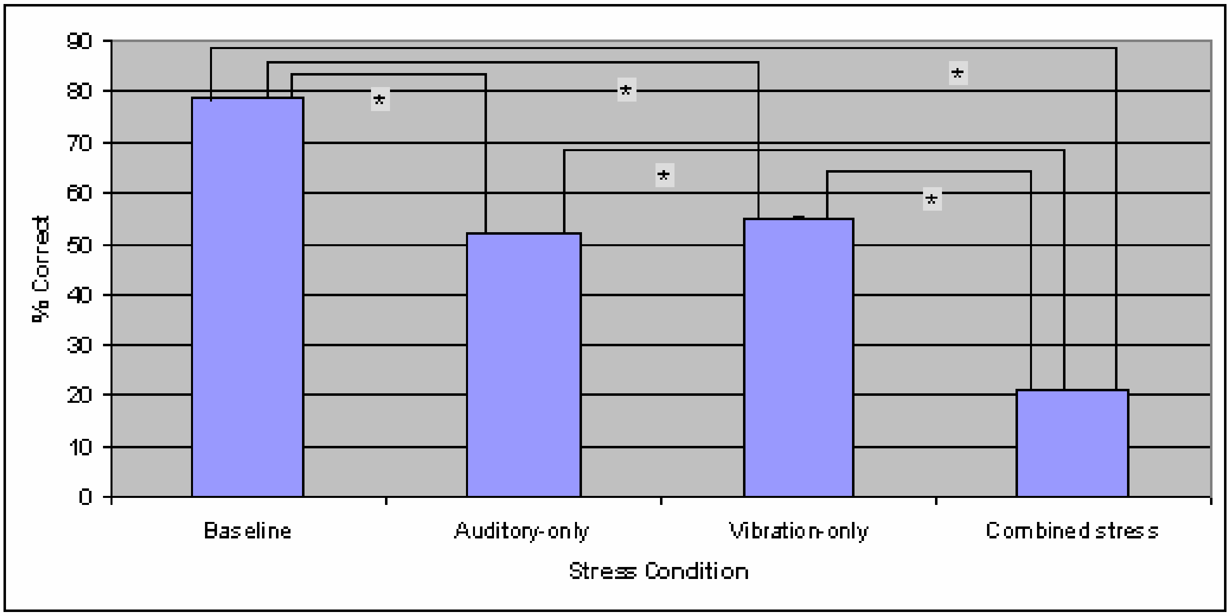


Figure 27. Secondary task accuracy across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials for secondary task accuracy. The analyses showed that the baseline condition (M = .79, SD = .11) had significantly greater accuracy than the time pressure with stress trials (M = .43, SD = .08), *t*(44) = 17.259, *p* < .0001, *d* = 3.74 (see Figure 28).

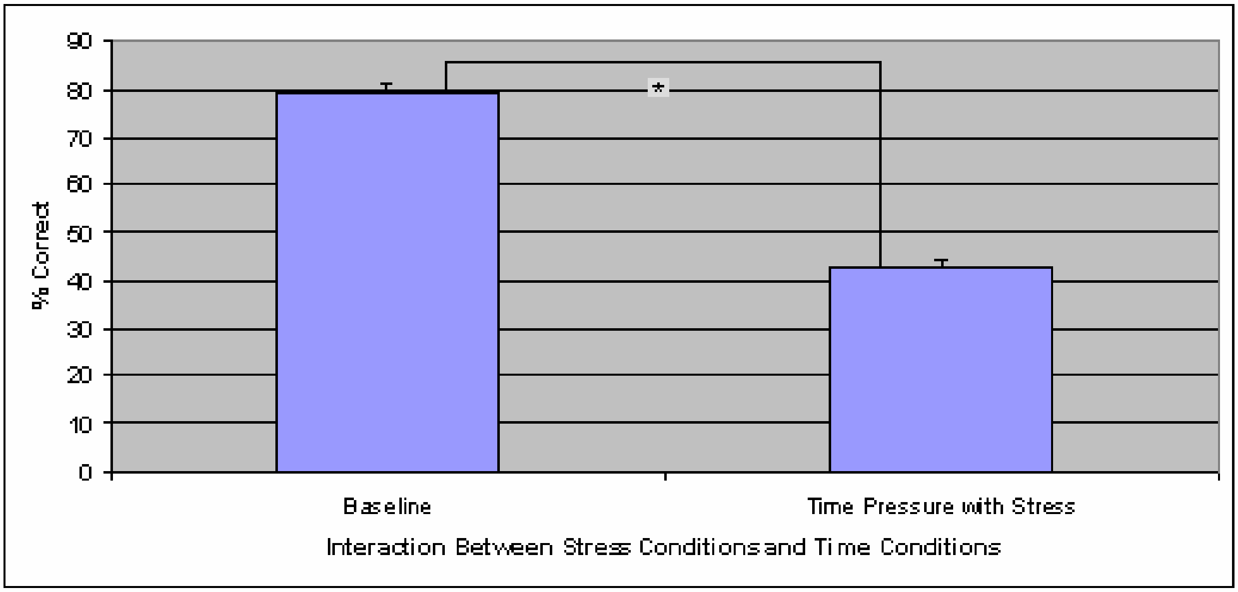


Figure 28. Secondary task accuracy for interaction between stress conditions and time conditions.

Secondary Task Response Times. For secondary task reaction times, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition on secondary task response times. The analyses showed that the combined stress condition (M = 2412.1, SD = 488.04) caused significantly longer response times than the baseline condition (M = 1101.9, SD = 698.21), auditory-only condition (M = 1550.69, SD = 412.16) and vibration-only condition (M = 1561.75, SD = 410.56), $t(44) = 9.599$, $p < .0001$, $d = 2.18$, $t(44) = -12.143$, $p < .0001$, $d = 1.91$, and $t(44) = -11.461$, $p < .0001$, $d = 1.89$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition on secondary task response times. The analyses showed that the auditory-only condition caused longer response times than the baseline, and the vibration-only condition caused longer response times than the baseline, $t(44) = 3.878$, p

< .0001, d = 0.78, and $t(44) = 3.776$, $p < .0001$, d = 0.8, respectively (see Figure 29).

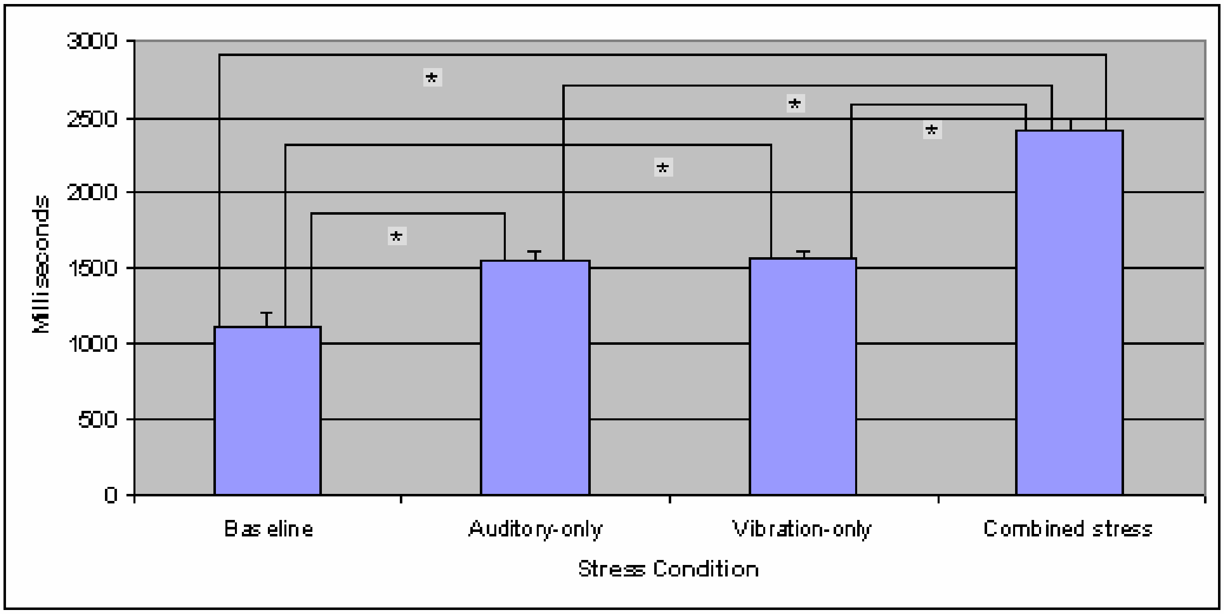


Figure 29. Secondary task response time across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials on secondary task response times. The analyses showed that the time pressure with stress conditions (M = 1841.51, SD = 345.4) caused longer response times than the baseline (M = 1101.9, SD = 412.16), $t(44) = -6.251$, $p < .0001$, d = 1.34 (see Figure 30).

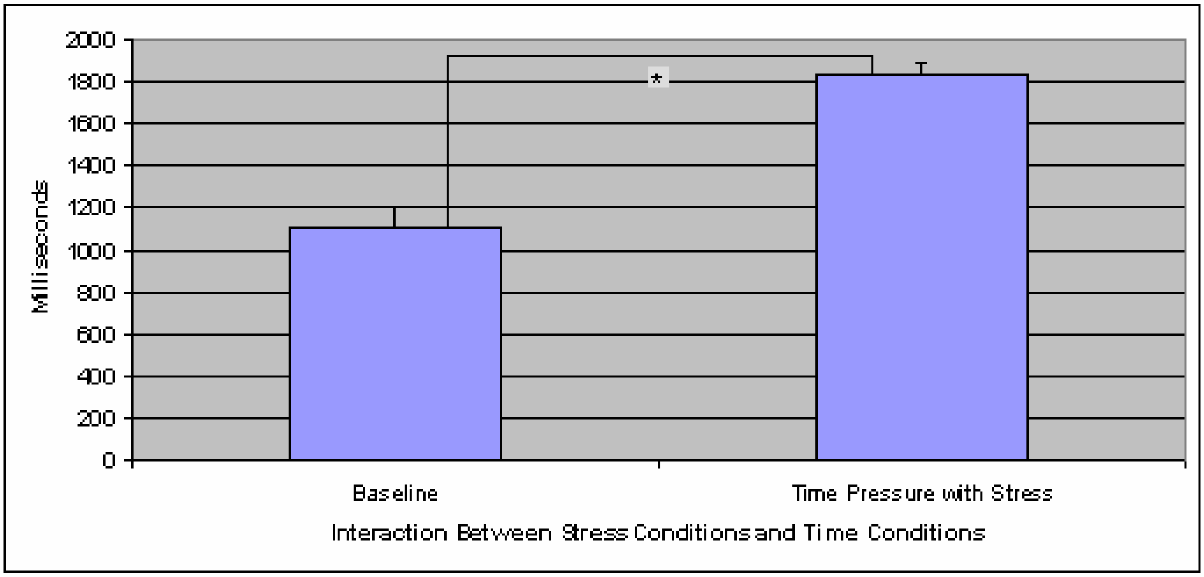


Figure 30. Secondary task response times for interaction between stress conditions and time conditions.

Time Estimation. For time estimation, paired-samples t-tests were conducted to compare the combined stress condition with single-stress conditions and the baseline condition for time estimation. The analyses showed that the combined stress condition (M = 32.51, SD = 13.92) caused significant underestimation compared to the significant underestimations of the auditory-only condition (M = 67.5, SD = 14.47), the vibration-only condition (M = 71.36, SD = 14.06), and the significant overestimation of the baseline condition (M = 115.4, SD = 10.85), $t(44) = -18.37$, $p < .0001$, $d = 2.46$, $t(44) = -14.99$, $p < .0001$, $d = 2.78$, and $t(44) = -38.45$, $p < .0001$, $d = 6.64$, respectively. Additionally, paired-samples t-tests were conducted to compare the baseline condition to the auditory-only condition and vibration-only condition for time estimation. The analyses showed that the baseline condition caused significantly higher overestimations than the auditory-only condition and the vibration-only condition, $t(44) = -23.05$, $p < .0001$, $d = 3.75$, and $t(44) = -19.99$, $p < .0001$, $d = 3.51$, respectively (see Figure 31).

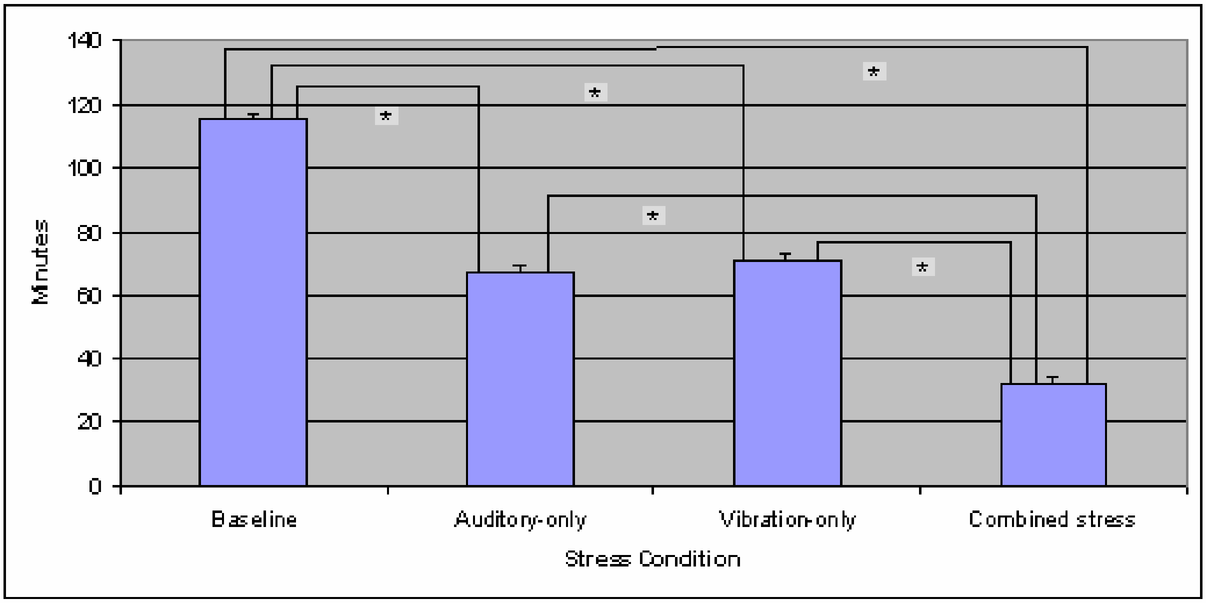


Figure 31. Time estimations across stress conditions.

Lastly, paired-samples t-tests were conducted to compare time pressure trials with baseline trials for time estimation. The analyses showed that the baseline condition (M = 115.4, SD = 14.06) had significantly higher overestimations than the time pressure trials (M = 57.12, SD = 7.81), $t(44) = -29.62$, $p < .0001$, $d = 6.17$ (see Figure 32).

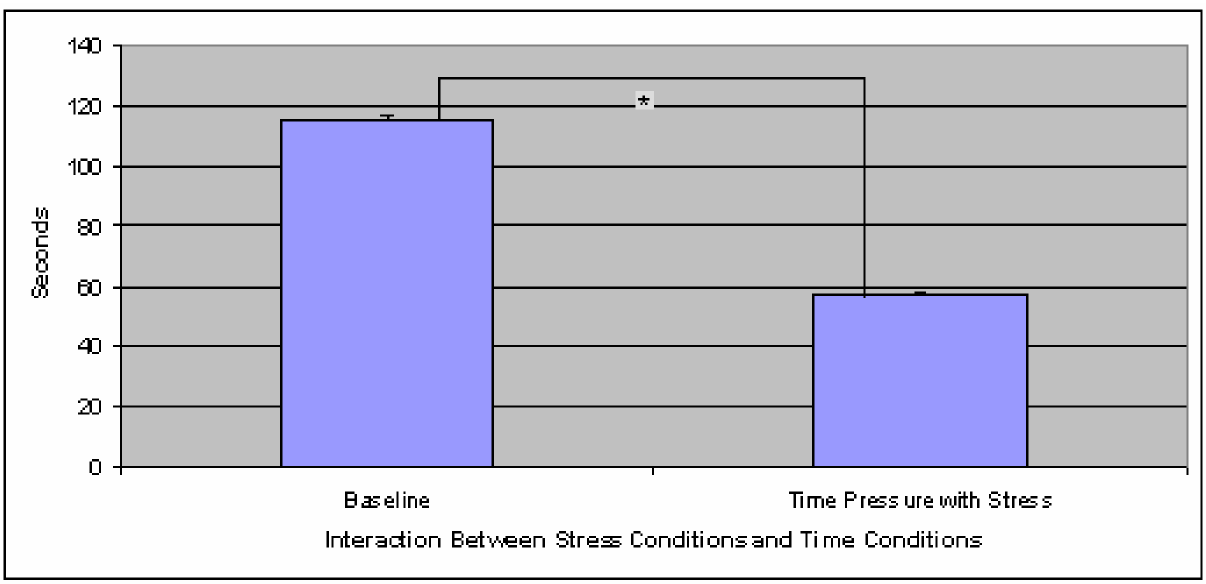


Figure 32. Time estimations for interaction between stress conditions and time conditions.

Summary of Results

The results from experiment two show that when vibration stress is combined with auditory stress, the combined stress causes poorer task performance than either type of stress alone, which in turn cause poorer performance than a baseline condition. Additionally, time pressure caused poorer task performance than the baseline condition. This was true on both primary and secondary tasks, as well as on objective and subjective measures. Finally, the greatest time distortion occurred in the combined stress condition, followed by the single-stress conditions, followed by the baseline condition, supporting the postulation that greater stress causes greater time distortion. All proposed hypotheses were supported (see Table 8). The means and standard deviations of the variables can be seen in Table 9, and the complete data set for experiment two can be seen in Appendix J.

Table 8. Experiment two hypotheses/results summary.

	Hypothesis Number							
Dependent Measure	1	2	3	4	5	6	7	8
Tourniquet Application Time	**AV>[A,V,C]**	**V>C**	**A>C**	**ST>C**				
Tourniquet Score	**AV<[A,V,C]**	**V<C**	**A<C**	**ST<C**				
Subjective Stress	**AV>[A,V,C]**	**V>C**	**A>C**	**ST>C**				
Subjective Workload	**AV>[**A,V,**C]**[1]	**V>C**	**A>C**	**ST>C**				
Secondary Task Accuracy					**AV<[A,V,C]**	**V<C**	**A<C**	**ST<C**
Secondary Task Response Time					**AV>[A,V,C]**	**V>C**	**A>C**	**ST>C**
Time Estimation					**AV<[A,V,C]**	**V<C**	**A<C**	**ST<C**

*C = Control, A = Auditory-only, V = Vibration-only, AV = Auditory + Vibration, ST = Stress + Time Pressure; Hypotheses in bold and underlined were supported by the results. Hypotheses in plain text were not supported.
[1]There were no significant differences between the combined condition and the single-stress conditions on subjective workload.

Table 9. Means and standard deviations for experiment two.

	Condition				
Dependent Measure	Baseline Condition	Auditory Stress	Vibration Stress	Auditory + Vibration Stress	Stress + Time Pressure
Tourniquet Application Time	M = 21.67 SD = 2.58	M = 32.11 SD = 6.58	M = 32.46 SD = 5.86	M = 59.27 SD = 6.70	M = 41.28 SD = 4.06
Tourniquet Score	M = 6.43 SD = 0.29	M = 4.83 SD = 0.63	M = 4.78 SD = 0.70	M = 3.73 SD = 0.56	M = 4.45 SD = 0.46
Subjective Stress	M = 1.99 SD = 0.80	M = 5.03 SD = 0.75	M = 4.89 SD = 0.63	M = 8.10 SD = 0.85	M = 6.01 SD = 0.45
Subjective Workload	M = 3.97 SD = 2.31	M = 4.55 SD = 2.38	M = 4.66 SD = 2.37	M = 4.89 SD = 2.33	M = 4.70 SD = 2.28
Secondary Task Accuracy	M = 79% SD = 11%	M = 52% SD = 14%	M = 55% SD = 13%	M = 21% SD = 6%	M = 43% SD = 8%
Secondary Task Response Time	M = 1101.90 SD = 698.21	M = 1550.69 SD = 412.16	M = 1561.75 SD = 410.56	M = 2412.10 SD = 488.04	M = 1841.51 SD = 345.40
Time Estimation	M = 115.39 SD = 10.85	M = 67.50 SD = 14.47	M = 71.36 SD = 14.06	M = 32.51 SD = 13.92	M = 57.12 SD = 7.81

CHAPTER FOUR: DISCUSSION

Combat medics are an integral part of the U.S. Army. These personnel save lives every day in theater. They must perform numerous tasks of varying difficulty on which they have had varying lengths of training. Among the leading causes of preventable battlefield deaths, exsanguination from extremities accounts for the largest number. The reasons these injuries often result in death are primarily that tourniquets do not get applied in time, and when they do, they are not applied properly. This is indicative of many medics being poorly trained for tourniquet application. Current training techniques can not fill the need for better tourniquet training because they are very rudimentary and only practiced initially. A typical combat medic receives tourniquet training in his initial MOS training, which is usually comprised of applying a tourniquet to a 2x4 board. This unrealistic scenario, practiced only a few times, has not adequately prepared these soldiers for applying tourniquets to a casualty in combat. Thus, medics need better training for this critical skill.

Another problem in combat with tourniquet application, as with other medic responsibilities, is that medics are under a tremendous amount of stress. Because they are trained with minimal stress, these medics are unprepared for the amount of distracting stress they encounter in combat. Extensive research has shown that stress alters performance by degrading it and causing performance decrements that either, might not be seen otherwise, or would not be seen to such an extent. While any stress employed in training can never accurately replicate the stresses experienced in combat, training should include different types of stress so medics get used to performing critical tasks while under stress.

In the military, as in many other domains, haptics and tactile feedback are being introduced in training devices. However, for combat medics, these technologies have not been explored with many hands-on tasks, such as tourniquet application. Because of the vast benefits of tactile interfaces in training, the studies in this experiment employed tactile vests used to induce stress for training of operators for tourniquet application.

Experiment one showed that in overall task performance, the vest in configuration 1 caused poorer performance than the vest in configuration 2, which in turn caused poorer performance than the control condition. Also, time pressure caused poorer performance to deteriorate compared to no time pressure. This was true on both the primary and secondary tasks, which indicates that resources were so limited that participants could not maintain performance on the primary task, even though they appeared to neglect the secondary task also. This finding suggests that the two tasks shared cognitive resources and this was indicated by both the objective measures and subjective measures (Gopher & Donchin, 1986; O'Donnell & Eggemeier, 1986).

Upon closer inspection, one can see that significant differences in primary task performance were in tourniquet application times, proper tourniquet application, and subjective stress. Subjective workload did not have any significant differences. Likewise, the significant differences in secondary task performance were in secondary task accuracy and time estimation. However, secondary response times did not show any significant differences. In these differences, the vest with vibration on bony areas proved much more detrimental to performance than the vest with vibration on fleshy areas. The vest with no vibration caused the smallest performance decrement. These results support pilot testing which earlier showed that area of vibration affects the perceived stress of the operator. As hypothesized, the location of vibration also affected task performance. The results of these decrements, namely increased tourniquet application times and poorer secondary task performance, have strong implications for the combat medic training.

It is important to note that while there were no significant differences in subjective workload, there may still have been differences in perceived workload, particularly because nearly every other dependent measure had significant differences between conditions. There appears to be dissociation between subjective workload and objective task performance (Hancock, Williams, Manning, & Miyake, 1995). There were no ceiling or floor effects; in fact, most participants reported subjective workload in the middle of the range. Because there appeared to be very low response set variance, the measure used, Borg's RPE, might not be sensitive enough to detect small workload differences.

The results from this study show that vibration does not have the same effect on all parts of the body. This has implications for how to induce stress for training, because vibration on soft tissue areas appears not be as stressful to operators as vibration on bony areas. Thus, the former will result in less performance decrement than the latter, which is also important in task design and environmental job considerations. This study also has implications for training operators using stress. The results suggest that personnel can wear items, such as vests, that target more sensitive areas of the body with vibration to maximize the stress effects felt. Since susceptible parts of the body have been identified, equipment that exposes only those parts of the body to vibration can be employed. Thus, devices can be manufactured that cover only a small area of the body, and perhaps they can be provided at a lower cost than exposing the whole body to vibration. Additionally, because many manual tasks require a great deal of mobility, localizing the vibration felt in something like a vest could be the best way to maximize both mobility and stress effects in training.

Furthermore, the findings regarding time pressure support the hypotheses that when under time pressure, operators feel more stress, and will experience performance decrements. The results should be considered when training operators who are involved in time-sensitive tasks. As the decrements seen in task performance due to time pressure, it can be inferred that because operators must perform tasks in a timely manner, it would be beneficial for them to train under time pressure as well. If operators, such as medics, are trained performing tasks as quickly as possible, and with an understanding of how quickly they must perform the tasks in theater, they might perform more quickly when conducting the tasks after training, both because they are used to performing the tasks quickly, and because they might be more motivated to perform them quickly given their new understanding of the importance of quick performance.

With respect to time, time perception became distorted as participants completed their tasks. The findings show that, while distortion occurred in all conditions, the distortions were the largest when participants were wearing the vest in configuration 1, followed by the baseline and then configuration 2. However, when in the baseline condition, participants overestimated their time, as opposed to configurations 1 and 2, for which participants underestimated their time. This supports the hypotheses that configuration 1 would produce the largest underestimation, followed by configuration 2. This supports Block’s (1979) postulation that participants underestimate time when that estimation is not the primary task. While participants did not underestimate the baseline condition, this could be attributed to participants paying more attention to the time estimation in the baseline condition because their other resources were not as taxed as they were in configurations 1 and 2. Additionally, participants underestimated their time when they were in the time pressure condition, which also supports Block's theory. Additionally, the overestimation could be attributed to the shorter duration of the baseline, since research shows that overestimation often occurs in shorter tasks while underestimation often occurs in longer tasks (Ruiguang & Xiting, 2006). The overall time distortion can be attributed to the fact that the time estimations were prospective time estimations, which rely heavily on working memory. Since there was a decrement in both tasks, it is assumed that they share resources, and this would affect working memory. Thus, participants may have had limited working memory to make the time estimations, causing time distortion (Zakay & Block, 2004). Research also shows that stress heavily affects working memory (Harris, Hancock, & Morgan, 2005). Furthermore, time distortion is often a result of attentional narrowing in temporal cues, such that a person under a great deal of stress, like the participants in these experiments, will underestimate the duration of a task because each perceived second is longer than "objective" reality. This means operators often fixate on stimuli at a different rate than reality, so they produce underestimations of task duration (Hancock & Weaver, 2005).

Since there was a significant interaction between the manipulated variables of vest configuration and time pressure on tourniquet application time, one cannot speak of application time caused by either vest configuration or time pressure without including the other variable. The affect of one variable is dependent on the level of the other variable, and vice versa. This study indicates that operators perform worse with vibration stress and with time pressure on their primary task as well as their secondary task. This means that not only are operators not able to do two tasks at once, but even to the detriment of their secondary task, they are not able to maintain performance on their primary task. In this context, performance decrements on the primary task mean casualties are not able to get tourniquet treatment in a timely manner, accurately, or both, which can obviously contribute to battlefield deaths. Additionally, performance decrements on the secondary task have implications on situation awareness since the task was a monitoring task. If medics are unable to monitor their surroundings and be aware of their environment while administering treatment, the results could be as deadly as incorrectly applying a tourniquet.

Experiment one showed that introducing time pressure and vibration stress effects that mimic real-world stressors impair performance of a critical task. As the stressors caused performance decrements, it can be inferred that, given time, the participants could learn to cope with these stressors, which might aid their task performance in real environments.

Experiment two showed that in overall task performance, the combined stress condition caused worse performance than the single-stress conditions, which caused worse performance than the control condition. Also, time pressure caused worse performance than no time pressure. This was true on both the primary and secondary tasks, which indicates that resources were so limited that participants could not maintain performance on the primary task, even if they neglected the secondary task. This finding suggests that the two tasks shared cognitive resources, as was expected given the results from experiment one, and this was true on both objective measures and subjective measures (Gopher & Donchin, 1986; O'Donnell & Eggemeier, 1986).

Upon a closer look at the results, one can see that the experimental manipulations, type of stress and time pressure, created significant differences for each of the dependent measures. Poor performance on tourniquet application and monitoring abilities combined with increased stress and workload has tremendous repercussions for the combat medic.

The results from this study show that stress effects are dependent on the type of stress employed. Additionally, combined stress creates greater performance decrements than single-stress conditions. The findings suggest that, as hypothesized, auditory stress and vibration stress act in a protagonistic manner, such that when they are combined, operators have worse performance than if either was employed alone (Hancock & Szalma, 2007). This is most likely because both types of stress were employed at the high end, or hyperstress end, of the stress and performance curve (Hancock & Warm, 1989). Additionally, research shows that noises ranging from 80-100 dB decrease accuracy and working memory. Stress is thought to degrade working memory by distracting from the primary tasks and increasing workload. Additionally, high levels of noise result in decreased compensatory processes, which can impair secondary task performance (Hancock, Conway, Szalma, Ross, & Saxton, 2006). This has implications for how to induce stress for training, namely because different combinations of stress could induce different stress effects, thus producing differing levels of performance.

Additionally, the findings regarding time pressure again support the hypotheses that state that when under time pressure, operators feel more stress, and will experience performance decrements. The results are similar to those in experiment one, such that it could be very beneficial to train operators with time pressure for tasks which must be performed under time pressure. Again, this could lead to better task performance, both because operators are used to performing the tasks quickly, and because they might be more motivated to perform them quickly given their new understanding of the importance of the timing of task completion.

With respect to time estimation, the second experiment showed that time perception became distorted as participants completed their tasks. The findings show that, while distortion occurred in all conditions, the distortions were the largest when participants were in the baseline condition, followed by the vibration-only condition, followed by the auditory-only condition, and lastly by the combined stress condition. In the baseline, auditory-only and vibration-only conditions, participants overestimated their time, and in the combined stress condition, participants underestimated their time, as hypothesized. The underestimation can be attributed to the estimation not being the primary task, as suggested by Block (1979). While the overestimation was unaccounted for in the hypotheses, it could be attributed to the shorter duration of the baseline and single-stress conditions, since research shows that overestimation often occurs in shorter tasks while underestimation often occurs in longer tasks (Ruiguang & Xiting, 2006). This phenomenon might be due to the perceptual slowing of time, which often happens when participants are undertasked. While the other performance measures show decrements in the single-stress conditions as well as the combined stress condition, this amount of stress might not have been translated in time estimations for the tasks. The overall time distortion can be attributed to the fact that the time estimations were prospective time estimations, which rely heavily on working memory. Since there was a decrement in both tasks, it is assumed that they share resources, and this would affect working memory. Thus, participants may have had limited working memory to make the time estimations, causing time distortion (Zakay & Block, 2004). Additionally, stress is thought to decrease working memory, which plays a result in time distortion (Harris, Hancock, & Morgan, 2005). Furthermore, time distortion is often a result of a mismatch between perceived time and clock time. Underestimations are often seen in high-stress situations due to attentional narrowing in temporal cues (Hancock & Weaver, 2005).

Similarly to experiment one, the results of experiment two indicate that operators perform worse with stress on their primary task as well as their secondary task. Even if they neglected their secondary task, they are not able to maintain performance on their primary task. In this environment, performance decrements on the primary task, secondary task, or both can be the difference between life and death.

Summary

This experimental series has important implications for combat medics. Results show that the bodily location of vibration stress makes a difference in the performance decrements experienced. Additionally, time pressure increases such performance decrements. Lastly, combining different types of stress, such as vibration and auditory stress, influences the performance decrements seen on medical tasks. According to the Hancock and Warm model (1989), these decrements would be expected since all types of stress employed were on the hyperstress side of the model. For tourniquet time and time estimation, the effects of auditory stress and vibration stress acted in an additive manner. For the remaining dependent measures, the effects of auditory stress and vibration stress simply acted in a protagonistic manner, but the effects were not directly additive. The decrements seen in these variables are operationally significant. For example, tourniquet application time was reduced on the order of 20-30 seconds. For a task in which casualties can die within four minutes, 30 seconds is a significant loss of time. This decrement combined with the time distortion that occurred is startling. If a medic's performance is slowed by 30 seconds, and he thinks he has been applying a tourniquet for one minute instead of two, grave consequences would likely be seen. Moreover, participants in these experiments obtained proficiency on the primary task, which was described as being relatively easy, and decrements were still seen. Thus, it is imperative that these soldiers be ready for the tasks they will face in combat. Since medics experience many types of stress in combat, it is advised that the training they experience employ these different types of stress. Furthermore, because a primary-secondary task paradigm was employed in these experiments, conclusions about the participants' attention have also been inferred. As decrements were seen on both the primary and secondary task, it is apparent that performance could not be maintained on the primary task, even when participants seemed to neglect the secondary task. Due to the nature of these tasks, this could prove to be a deadly issue in combat. Not only were participants unable to maintain their situation awareness through the secondary task; crucially, they were unable to apply the tourniquets adequately in order to save their patient.

Finally, transfer of training is of utmost importance. Feygin, Keehner, and Tendick (2002) found that training with haptic devices can transfer to task performance. It can be determined that transfer of training would occur with the training outlined above because it employs facets of positive transfer. The training uses the same task as operators are being asked to perform in the real world. Also, the training uses the same environment in which operators carry out their tasks. These include vibration, noise, and time pressure. Because this training is meaningful with respect to the final tasks, transfer would likely occur. Additionally, these facets of stress could be an add-on to current training to enhance transfer.

Implications for Design and Training

The following training guidelines should be followed when designing tourniquet application training for combat medics.

- Use vibration as a form of training stress
    - Place vibration on fleshy areas of the body to start; as training progresses, place vibration on bony areas
- Use time pressure as a form of training stress
- Use white noise as a form of training stress
- Combine vibration with white noise, if possible, to induce greater training stress than either condition alone

- Combine time pressure with vibration, white noise, and/or both to induce greater training stress than any condition alone
- Provide feedback on time passage at the end of exercises; over time, this feedback can serve to train operators on how to approximate the passage of time while engaging in activities
- Use a secondary task, such as monitoring and responding, while training tourniquet application as an added dimension of workload
- Be prepared for loss of situation awareness; warn operators it could occur, and train them to maintain awareness of their surroundings

Future Work

This research has sought to lay the foundation for further investigation of strategies for coping with battlefield stressors. The next logical step would be to train operators with stressors included in the training, rather than merely training them on a task and then employing stressors during task performance, though the task is a stressor in itself (Hancock, 1986). If different combinations of stress could be mapped out according to their subsequent performance decrements on different types of tasks, this could be leveraged in not only military training, but all training in which operators are under stress (Hancock & Pierce, 1989). Additionally, these results could be extrapolated to other domains that encounter vibration, auditory, and temporal stress. This includes areas such as other military personnel, law enforcement officers, construction workers, and pilots, to name a few. This training would likely be similar to other types of stress inoculation training. Given the results of these experiments, training and job considerations should be taken into account for these personnel because these jobs, and others, are high-stress and high-workload, and could benefit from specialized training employing differing types of stress.

APPENDIX A: FRIENDLY AND ENEMY FORCE PICTURES

(Friendly images differed from foe images in color of soldier uniform and type of weapon.)

Enemy Forces

Friendly Force

APPENDIX B: TOURNIQUET SCORING

Participant # ________

Trial # _____________

Tourniquet Scoring

Please watch the video of the corresponding trial and circle "P" if the participant completes the action correctly and "F" if the participant does not complete the action, does so incorrectly, or does so out of order. Each "P" is worth one point, and each "F" is worth zero points. Please sum up the points at the bottom.

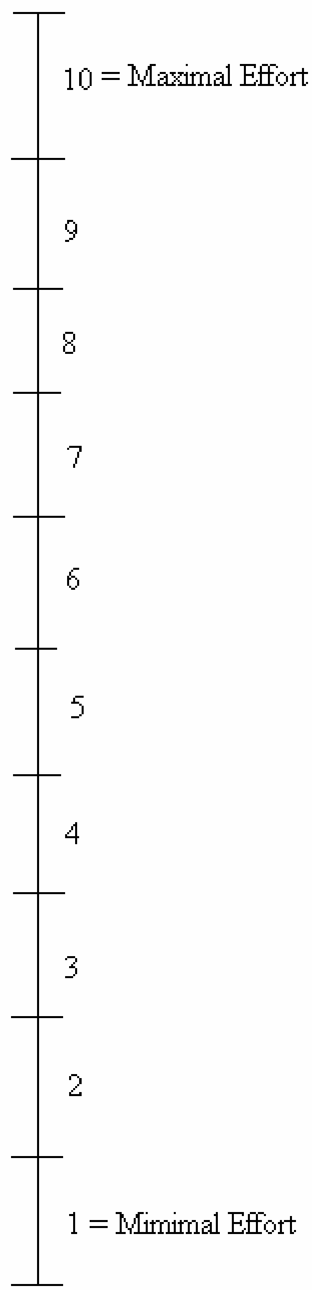
- Place tourniquet between the heart and the wound, leaving at least 2 inches of uninjured skin between the tourniquet and the wound P / F
- Wrap the tourniquet around the extremity P / F
- Tie a half-knot on the anterior surface of the extremity P / F
- Place a stick or similar object on top of the half-knot P / F
- Tie an additional full-knot on top of the stick P / F
- Twist until the bleeding stops P / F
- Secure the stick or windlass in place so it will not unwind P / F

Total = _____

APPENDIX C: BORG RATE OF PERCEIVED EXERTION

<u>Borg Rate of Perceived Exertion</u> (Borg, 1998)

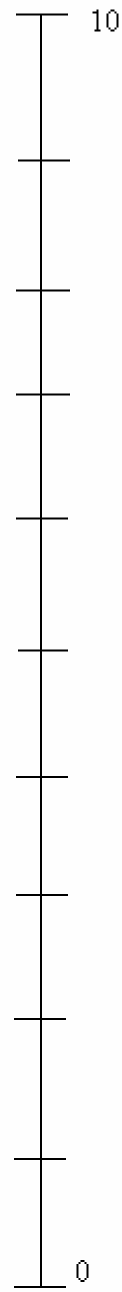
Please rate the task you just completed by marking on the following scale.



APPENDIX D: SUBJECTIVE STRESS SCALE

<u>Subjective Stress Scale</u> (Bollini, Walker, Hamann, & Kestler, 2004)

On this scale from 0 to 10, with 0 as "no stress" and 10 as "very stressed", how stressed do you feel at this time?



APPENDIX E: INFORMED CONSENT

Informed Consent

Name: ________________________________ Participant Number: ____________

In order to participate in this study, you must be at least 18 years of age, in your usual state of fitness, and you may not be pregnant.

Introduction to Study:

This research, "Investigating Tactile Stress Effects**:** Phase II," is being conducted by principal investigator Razia Nayeem.

This research is investigating how we can use the sense of touch to induce stress in simulated medical tasks. You will participate in a task using a mannequin arm and a vest with vibrating tactors. Your task is to correctly administer a tourniquet under different conditions.

We will be collecting the following data: the time it takes to administer the tourniquet, responses to a discrimination task, your opinions on the use of the mannequin arm and vest (Usability Questionnaire), the task workload (RPE), and the task stress (SSS). In addition, we will be **video recording the communications that occur during the experiment**. The time required for this research is approximately 1 hour. All data collected will remain confidential (see below). Finally, you will receive extra credit in a course of your choosing for your time.

Risks and Benefits:

A possible risk of this study will be the possibility that potentially harmful electrical voltage potentials could affect you. To safeguard against this, the electrical apparatus worn by you is powered with a low-voltage battery; a wireless RF data link is used to eliminate conductive wiring; and you shall not be able to contact any conductors coupled earth-to-ground. It is also a possible risk that a battery could potentially explode and expel potentially harmful materials. The safeguard against this, the battery is packaged in a plastic case (as procured); it is further encased in a nylon wearable "pouch;" the output shall be fuse-protected at a physical point in close proximity to the battery case; and the battery shall not be recharged or short-circuited while being worn by you.

There are no direct benefits to you, other than remuneration made to you for participating in this study. You will receive extra credit for participating at the completion of this experiment. You may terminate your participation at any time and receive the remuneration due to you at that time.

If you believe you have been injured during participation in this research project, you may file a claim with UCF Environmental Health & Safety, Rick and Insurance Office, P.O. Box 163500, Orlando, FL, 32816-3500 (407) 823-6300. The University of Central Florida is an agency of the State of Florida and that the university's and the state's liability for personal injury or property damage is extremely limited under Florida law. Accordingly, the university's and the state's ability to compensate you for any personal injury or property damage suffered during this research project is very limited.

Information regarding your rights as a research volunteer may be obtained from:

Barbara Ward
Institutional Review Board (IRB)
University of Central Florida (UCF)
12443 Research Parkway, Suite 207
Orlando, FL 32826-3252
Telephone: (407) 823-2901.

Confidentiality of Personal Data:
All data you contribute to this study will be held in strict confidentiality by the researchers and your individual data will not be revealed to anyone other than the researchers and their immediate assistants.

To insure confidentiality, the following steps will be taken: (a) only researchers will have access to the data; (b) data will be stored in locked facilities; (c) the actual forms will not contain names or other personal information. Instead, the forms will be matched to each participant by a number assigned by and only known to the experimenters; and (d) only group means scores and standard deviations, but not individual scores, will be published or reported.

YOUR PARTICIPATION IN THIS RESEARCH IS COMPLETELY VOLUNTARY. YOU MAY WITHDRAW FROM PARTICIPATION AT ANY TIME WITHOUT PENALTY – THIS INCLUDES REMOVAL/DELETION OF ANY DATA YOU MAY HAVE CONTRIBUTED. SHOULD YOU DECIDE NOT TO COMPLETE THE STUDY, YOU WILL RECEIVE REMUNERATION AT THAT TIME.

I have read and understand the consent form. I acknowledge that I meet participation requirements outlined in this consent form, and I voluntarily agree to participate in this research experiment.

____

Signature of Participant Date

____

Signature of Researcher Date

APPENDIX F : DEMOGRAPHIC QUESTIONNAIRE

Demographic Questionnaire

Participant Number: __________

Age: __________ Gender: __________

Do you have any military experience? Yes __________ No _________

If so, please indicate your specialty:

____

Do you have any formal medical training (including EMT, medical school, nursing school, CPR, etc.)? Yes___________ No __________

If so, please indicate how much training you have received and when you received it (e.g., "EMT Basic 3 years ago")

____

Have you ever applied a tourniquet? Yes __________ No ________

Have you ever applied an improvised tourniquet? Yes _______ No _____

Are you familiar with military firearms? Yes __________ No ___________

Are you in your usual state of fitness? Yes ___________ No ___________

APPENDIX G: INSTRUCTIONS TO PARTICIPANTS

Instructions to Participants

Experiment One:

Participants will receive the following instructions regarding the mannequin limb and procedure:

"The limb that is on the table in front of you is a mannequin limb. This limb will be used in the experiment today. Please pick up the limb and familiarize yourself with its texture and thickness while I continue. The piece of equipment I am holding is called an improvised tourniquet. I will demonstrate how this tourniquet is applied to the mannequin limb. *Demonstration by experimenter detailing the steps for a successful application* Please apply the tourniquet to the mannequin limb *Participants apply improvised tourniquet* Do you have any questions about this procedure? *Answer questions*"

Participants will receive the following instructions regarding the tactile vest:

"The vest I am holding has been fitted with tactors that vibrate. The tactors are cell phone vibrators. This vest will be worn for the duration of the experiment. I will now fit the vest on you. *Put vest on participant* You will now feel a demonstration of the tactors as they are activated *Activate tactors * Do you have any questions about this vest? *Answer questions*"

Participants will receive the following instructions regarding the secondary task:

"While you are performing the tourniquet task, you will also be performing a monitoring discrimination task. You will monitor this screen and discriminate between images of friendly and enemy soldiers. You may take as long as you wish to familiarize yourself with these images. Do you have any questions? *Answer questions*"

Participants will receive the following instructions regarding the baseline trial:

“Please apply the tourniquet as accurately as possible.”

Participants will receive the following instructions regarding the experimental trials:

“After each trial, you will estimate how long you were performing the task. The experiment will begin in 5 seconds. *Vest is turned on* Now please apply the tourniquet as quickly and accurately as possible.”

<u>Experiment Two:</u>

Participants will receive the following instructions regarding the mannequin limb and procedure:

“The limb that is on the table in front of you is a mannequin limb. This limb will be used in the experiment today. Please pick up the limb and familiarize yourself with its texture and thickness while I continue. The piece of equipment I am holding is called an improvised tourniquet. I will demonstrate how this tourniquet is applied to the mannequin limb. *Demonstration by experimenter detailing the steps for a successful application* Please apply the tourniquet to the mannequin limb *Participants apply improvised tourniquet* Do you have any questions about this procedure? *Answer questions*”

Participants will receive the following instructions regarding the tactile vest:

“The vest I am holding has been fitted with tactors that vibrate and a cooling panel. The tactors are cell phone vibrators. This vest will be worn for the duration of the experiment. I will now fit the vest on you. *Put vest on participant* You will now feel a demonstration of the tactors as they are activated *Activate tactors * Do you have any questions about this vest? *Answer questions*”

Participants will receive the following instructions regarding the auditory stress:

“The noise you will hear through the headphones is white noise. You will now hear a demonstration of the noise. *Play noise*”

Participants will receive the following instructions regarding the secondary task:

“While you are performing the tourniquet task, you will also be performing a monitoring discrimination task. You will monitor this screen and discriminate between images of friendly and enemy soldiers. You may take as long as you wish to familiarize yourself with these images. Do you have any questions? *Answer questions*”

Participants will receive the following instructions regarding the baseline trial:

“Please apply the tourniquet as accurately as possible.”

Participants will receive the following instructions regarding the experimental trials:

“After each trial, you will estimate how long you were performing the task. The experiment will begin in 5 seconds. *Stressors are turned on for experimental conditions* Now please apply the tourniquet as quickly and accurately as possible.”

APPENDIX H : USABILITY QUESTIONNAIRE

Usability Questionnaire

Participant Number: ___________

1. What was your experience using the mannequin?

____

____

____

2. What was your experience with the tactile vest?

____

____

____

3. Do you have any additional comments about this experiment?

____

____

____

APPENDIX I : COMPLETE DATA SET FOR EXPERIMENT ONE

Participant #	CS (RPE)	CS (SSS)	BaseT (TS)	BaseT (TT)	BaseT (SS)	BaseT (ST)	BaseT (TE)	BaseT (RPE)	BaseT (SSS)
2.00	2.50	0.00	6.67	24.67	0.75	1889.60	40.00	9.25	4.50
3.00	1.40	0.40	6.00	23.00	0.77	1917.20	80.00	7.00	7.50
4.00	3.40	1.00	6.33	25.67	0.71	2200.50	140.00	2.67	3.83
5.00	3.00	2.50	5.33	20.30	0.00	0.00	8.67	4.33	3.67
6.00	3.50	0.00	6.33	26.50	0.84	1627.50	17.50	5.33	5.33
7.00	2.50	0.00	7.00	22.12	0.83	2115.75	11.33	6.00	3.67
8.00	2.00	1.50	6.00	21.50	0.83	2505.50	20.00	3.00	2.67
9.00	1.50	2.00	6.33	20.23	0.80	1960.00	18.33	6.00	8.00
11.00	0.20	0.00	6.00	23.33	0.75	2409.60	70.00	2.17	1.85
12.00	0.20	0.00	5.66	20.33	0.75	2075.50	18.33	4.67	2.57
13.00	1.00	0.50	6.00	23.00	0.84	2072.86	27.33	2.67	2.17
14.00	2.00	1.50	6.67	28.00	0.75	2576.00	38.33	3.75	3.42
15.00	1.50	1.00	5.67	24.00	0.76	2485.60	38.33	4.50	4.50
16.00	1.50	0.00	6.00	22.67	0.77	2455.00	21.67	5.00	4.83
17.00	2.50	3.00	5.33	23.67	0.83	2216.25	45.00	2.83	3.00
18.00	2.00	0.00	5.33	23.00	0.82	2486.60	18.33	2.00	0.83
19.00	0.00	0.00	6.00	24.33	0.77	2327.80	10.67	3.17	4.00
20.00	1.50	3.00	6.66	23.67	0.77	107.00	33.33	1.33	2.00
21.00	1.00	0.00	4.33	24.67	0.77	1886.80	20.67	3.83	2.83
22.00	0.00	0.00	6.00	20.67	0.75	2356.60	31.67	6.50	6.33
23.00	4.50	3.00	6.33	25.67	0.76	2036.17	15.00	5.00	5.00
24.00	2.00	1.00	6.33	23.33	0.75	2155.40	31.67	8.00	7.67
25.00	1.50	1.00	6.00	24.00	0.83	2002.50	41.67	3.50	4.00
26.00	1.50	0.50	4.00	22.00	0.75	2372.50	10.00	1.33	0.67
27.00	2.50	0.00	6.00	21.33	0.84	1765.75	19.00	4.67	4.83
28.00	1.00	0.50	6.33	24.67	0.77	1922.50	22.67	2.50	2.00
29.00	1.50	0.00	6.33	23.00	0.77	2375.25	22.67	3.67	3.50
30.00	1.50	2.50	5.33	24.00	0.75	1912.33	25.00	4.17	4.67
31.00	0.50	0.50	6.00	20.67	0.80	2188.33	33.33	8.17	7.17
32.00	0.00	0.00	6.33	22.00	0.80	2371.00	35.00	3.17	2.67
33.00	2.50	0.00	6.33	24.33	0.75	2217.20	19.33	6.17	6.50

34.00	1.00	0.00	6.67	22.00	0.00	0.00	15.00	1.93	1.57
35.00	1.00	0.00	5.33	23.67	0.76	1723.00	9.33	9.67	8.17
36.00	0.00	0.00	5.33	23.33	0.83	2297.00	36.67	7.83	5.00
37.00	1.50	0.00	6.33	24.00	0.77	2111.00	9.00	2.33	2.17
38.00	1.50	4.00	5.67	25.00	0.78	1710.33	60.00	2.33	3.50
39.00	0.00	0.00	6.00	21.67	0.74	2120.71	26.00	3.00	3.33
40.00	4.50	3.00	6.33	21.33	0.81	2324.25	48.33	5.17	3.67
41.00	0.40	0.00	6.00	22.33	0.80	2066.25	33.00	1.83	1.33
42.00	1.00	0.50	6.67	20.00	0.75	2632.00	36.67	4.00	5.50

BaseNT (TS)	**BaseNT (TT)**	**BaseNT (SS)**	**BaseNT (ST)**	**BaseNT (TE)**	**BaseNT (RPE)**	**BaseNT (SSS)**	**Base (TS)**	**Base (TT)**
6.00	13.33	0.98	1889.20	21.67	10.00	6.00	6.34	19.00
5.00	19.00	0.90	2203.50	70.00	5.33	5.17	5.50	21.00
6.33	18.67	0.89	2202.67	106.67	3.83	4.50	6.33	22.17
5.50	18.95	0.90	2480.20	10.00	4.33	4.00	5.42	19.63
6.00	22.94	0.90	1838.00	17.33	6.33	7.00	6.17	24.72
7.00	19.93	0.91	1849.67	18.33	4.33	3.50	7.00	21.03
6.00	16.75	0.92	2447.67	16.67	3.50	3.20	6.00	19.13
6.66	15.87	0.93	1885.67	35.00	3.75	5.75	6.50	18.05
6.00	14.33	0.85	2326.00	70.00	1.57	1.03	6.00	18.83
5.67	19.67	0.90	2252.75	18.67	6.33	4.67	5.67	20.00
6.33	16.33	0.92	2071.18	76.66	1.67	1.17	6.17	19.67
6.67	18.67	0.90	2372.17	43.33	4.25	3.75	6.67	23.34
5.67	17.33	0.92	2438.00	70.00	3.50	3.33	5.67	20.67
5.00	11.33	0.93	1718.67	17.33	4.50	3.33	5.50	17.00
5.67	18.00	0.87	2267.67	100.00	2.67	2.67	5.50	20.84
6.00	18.67	0.90	1857.25	21.67	2.00	1.00	5.67	20.84
5.33	17.00	0.95	2275.00	21.67	2.50	1.67	5.67	20.67
6.00	20.00	0.00	0.00	27.33	3.17	2.10	6.33	21.84
6.33	14.33	0.86	1759.20	44.00	4.17	2.67	5.33	19.50
6.67	19.33	0.98	1938.17	45.00	6.83	7.33	6.34	20.00
7.00	23.33	0.85	1907.20	21.67	4.50	4.00	6.67	24.50

6.67	18.00	0.87	2018.50	21.67	8.33	7.67	6.50	20.67
6.67	19.00	0.90	2522.00	55.00	4.50	4.33	6.34	21.50
3.33	19.33	0.94	2424.40	12.33	1.33	0.83	3.67	20.67
7.00	17.67	0.85	2350.67	27.67	4.00	4.17	6.50	19.50
7.00	11.33	0.96	2391.20	22.67	2.67	2.83	6.67	18.00
6.67	12.33	0.86	2111.20	25.00	2.83	2.00	6.50	17.67
5.33	16.00	0.84	2246.57	20.00	4.00	3.17	5.33	20.00
5.67	18.67	0.85	2126.78	106.67	4.50	3.67	5.84	19.67
7.00	17.67	0.88	2373.00	30.00	2.83	2.33	6.67	19.84
6.33	16.00	0.90	2092.25	24.00	5.50	5.00	6.33	20.17
6.00	13.67	0.91	2452.33	16.33	4.00	3.00	6.34	17.84
6.00	14.67	0.97	2003.40	23.33	6.00	6.83	5.67	19.17
6.67	15.33	0.93	2110.00	30.00	10.00	4.33	6.00	19.33
6.67	16.33	0.98	2502.00	23.33	2.83	2.50	6.50	20.17
5.67	25.00	0.97	1419.25	66.67	2.50	3.00	5.67	25.00
7.00	17.67	0.90	2199.17	30.00	2.83	2.33	6.50	19.67
5.67	15.33	0.86	2233.60	30.00	4.17	2.33	6.00	18.33
6.00	20.00	0.90	2725.67	31.67	1.67	0.67	6.00	21.17
6.33	20.33	0.88	2221.00	43.33	4.17	5.17	6.50	20.17

Base (SS)	Base (ST)	Base (TE)	Base (RPE)	Base (SSS)	BT (TS)	BT (TT)	BT (SS)	BT (ST)	BT (TE)
0.87	1889.40	30.84	9.63	5.25	6.00	55.67	0.13	2076.30	38.33
0.84	2060.35	75.00	6.17	6.34	5.67	55.67	0.05	2102.30	80.00
0.80	2201.59	123.34	3.25	4.17	6.33	55.33	0.18	2472.00	133.33
0.45	1240.10	9.34	4.33	3.84	5.33	57.33	0.00	0.00	10.67
0.87	1732.75	17.42	5.83	6.17	6.66	59.25	0.13	2589.50	20.00
0.87	1982.71	14.83	5.17	3.59	6.00	54.95	0.13	1725.00	19.67
0.88	2476.59	18.34	3.25	2.94	6.66	60.00	0.01	1665.00	22.50
0.87	1922.84	26.67	4.88	6.88	5.66	57.79	0.16	1910.20	15.00
0.80	2367.80	70.00	1.87	1.44	4.33	66.00	0.17	1900.50	60.00
0.83	2164.13	18.50	5.50	3.62	6.00	59.00	0.10	1930.80	21.67
0.88	2072.02	52.00	2.17	1.67	6.33	68.00	0.13	1833.00	22.00

0.83	2474.09	40.83	4.00	3.59	6.33	57.33	0.16	2146.00	50.00
0.84	2461.80	54.17	4.00	3.92	6.00	59.33	0.10	2322.50	23.33
0.85	2086.84	19.50	4.75	4.08	6.00	52.33	0.23	2115.50	12.33
0.85	2241.96	72.50	2.75	2.84	5.00	61.67	0.05	2359.00	40.00
0.86	2171.93	20.00	2.00	0.92	5.00	58.33	0.14	2125.75	30.00
0.86	2301.40	16.17	2.84	2.84	5.00	58.67	0.10	1760.33	8.67
0.39	53.50	30.33	2.25	2.05	6.33	60.00	0.00	0.00	26.33
0.82	1823.00	32.34	4.00	2.75	4.00	61.33	0.17	1742.25	19.67
0.87	2147.39	38.34	6.67	6.83	6.00	60.00	0.13	2337.00	33.33
0.81	1971.69	18.34	4.75	4.50	6.67	57.00	0.11	1582.80	12.67
0.81	2086.95	26.67	8.17	7.67	6.00	60.00	0.18	1733.00	21.67
0.87	2262.25	48.34	4.00	4.17	6.00	63.00	0.10	1866.00	20.00
0.85	2398.45	11.17	1.33	0.75	4.00	62.33	0.13	2458.00	17.33
0.85	2058.21	23.34	4.34	4.50	5.33	62.33	0.05	2059.67	28.67
0.87	2156.85	22.67	2.59	2.42	5.67	63.67	0.10	1807.25	22.67
0.82	2243.23	23.84	3.25	2.75	6.00	65.00	0.11	1518.40	23.00
0.80	2079.45	22.50	4.09	3.92	3.33	53.00	0.10	2203.00	21.00
0.83	2157.56	70.00	6.34	5.42	5.33	59.00	0.07	1731.67	41.67
0.84	2372.00	32.50	3.00	2.50	6.33	62.00	0.00	2800.67	25.00
0.83	2154.73	21.67	5.84	5.75	5.67	61.00	0.05	2479.00	19.67
0.46	1226.17	15.67	2.97	2.29	6.33	56.33	0.13	1968.50	11.33
0.87	1863.20	16.33	7.84	7.50	6.67	62.00	0.10	1642.00	9.00
0.88	2203.50	33.34	8.92	4.67	6.00	55.00	0.10	2227.50	22.67
0.88	2306.50	16.17	2.58	2.34	6.00	62.00	0.00	0.00	8.67
0.88	1564.79	63.34	2.42	3.25	5.33	56.00	0.13	1317.50	47.33
0.82	2159.94	28.00	2.92	2.83	5.33	59.33	0.14	2388.86	23.67
0.84	2278.93	39.17	4.67	3.00	6.33	55.67	0.05	2195.00	31.67
0.85	2395.96	32.34	1.75	1.00	5.67	58.00	0.05	2140.67	33.33
0.82	2426.50	40.00	4.09	5.34	5.33	57.67	0.10	1987.20	41.67

BT (RPE)	**BT (SSS)**	**BNT (TS)**	**BNT (TT)**	**BNT (SS)**	**BNT (ST)**	**BNT (TE)**	**BNT (RPE)**	**BNT (SSS)**	**B (TS)**
9.33	9.33	6.33	46.00	0.15	2266.50	43.33	7.50	9.33	6.17
7.50	8.17	6.00	46.67	0.30	2500.80	70.00	7.10	7.58	5.84

4.40	3.97	6.00	54.00	0.20	2183.14	133.33	4.83	3.83	6.17
6.00	6.17	5.00	51.38	0.20	1689.00	12.33	5.83	5.17	5.17
7.17	7.67	5.66	47.98	0.23	1838.00	15.00	5.83	5.67	6.16
5.00	3.67	7.00	54.10	0.23	2292.33	14.67	4.33	4.50	6.50
4.75	4.00	6.66	49.18	0.18	2415.00	16.67	4.25	3.00	6.66
6.75	9.25	6.66	52.81	0.16	2101.00	16.67	7.00	7.00	6.16
2.00	1.53	5.66	54.33	0.27	1957.80	70.00	1.67	1.33	5.00
5.25	6.17	6.00	52.00	0.30	2155.80	16.67	4.67	3.92	6.00
3.45	2.83	6.66	52.33	0.25	1880.83	28.33	2.67	3.00	6.50
5.00	4.50	6.66	51.67	0.20	2069.60	45.00	5.00	4.33	6.50
6.83	8.00	5.33	48.33	0.18	2294.40	46.67	5.50	6.33	5.67
2.75	2.33	5.67	57.00	0.23	2002.00	10.00	2.67	2.17	5.84
3.50	3.00	5.00	55.67	0.30	2135.60	80.00	3.33	3.17	5.00
2.50	2.00	4.33	46.33	0.18	2157.00	28.33	2.17	1.83	4.67
3.17	5.67	5.33	51.00	0.17	2175.00	12.33	3.50	4.67	5.17
4.50	4.50	7.00	52.22	0.00	0.00	18.67	5.17	3.50	6.67
4.83	3.67	4.00	54.33	0.17	1747.00	33.33	5.67	4.17	4.00
7.50	8.17	6.00	53.00	0.16	2148.67	20.00	3.67	4.17	6.00
6.00	6.00	5.67	50.33	0.20	1811.40	15.00	6.17	6.17	6.17
7.67	7.17	6.33	47.00	0.15	1843.50	19.17	7.50	4.67	6.17
2.00	2.00	6.33	50.00	0.18	2222.25	38.33	5.17	5.67	6.17
1.67	1.33	4.67	54.00	0.18	2154.30	19.67	1.50	1.33	4.34
4.67	4.67	6.33	53.67	0.28	2300.57	29.33	5.17	4.67	5.83
2.50	2.17	6.67	51.33	0.21	1958.40	18.33	2.50	2.00	6.17
4.83	4.67	6.33	50.00	0.16	1914.40	24.33	3.67	3.50	6.17
3.50	2.17	4.67	45.00	0.23	2070.67	16.33	3.50	1.50	4.00
9.50	8.50	6.00	47.67	0.24	2004.71	48.33	6.33	6.00	5.67
2.83	2.00	6.67	51.67	0.20	2417.25	25.00	3.17	2.00	6.50
7.83	9.33	6.67	54.33	0.20	2399.40	21.33	7.50	8.00	6.17
3.50	4.33	5.33	55.67	0.17	1814.00	10.67	3.67	3.33	5.83
3.67	3.17	6.33	45.00	0.18	1746.00	10.67	5.17	4.50	6.50
10.00	4.33	6.33	52.00	0.25	2352.00	27.67	10.00	4.50	6.17
3.50	4.00	6.33	49.67	0.20	2207.00	17.50	3.67	3.33	6.17
4.17	5.83	5.00	54.00	0.23	1295.40	51.00	4.17	7.67	5.17
3.00	3.00	6.00	45.33	0.30	1878.33	25.67	3.00	3.83	5.67
4.50	5.00	6.67	47.67	0.23	2067.78	42.00	4.67	3.17	6.50
1.50	0.83	5.67	47.00	0.18	2154.33	36.67	1.50	1.50	5.67

3.67	6.83	6.00	53.00	0.23	1913.50	33.33	4.00	6.00	5.67

B (TT)	**B (SS)**	**B (ST)**	**B (TE)**	**B (RPE)**	**B (SSS)**	**FT (TS)**	**FT (TT)**	**FT (SS)**	**FT (ST)**	**FT (TE)**	**FT (RPE)**
50.84	0.14	2171.40	40.83	8.42	9.33	5.67	34.33	0.40	2361.00	35.00	10.00
51.17	0.18	2301.55	75.00	7.30	7.88	6.67	36.67	0.43	2011.67	56.67	7.67
54.67	0.19	2327.57	133.33	4.62	3.90	6.67	37.33	0.39	2485.83	145.00	5.00
54.36	0.10	844.50	11.50	5.92	5.67	5.33	35.10	0.43	1476.00	10.00	6.00
53.62	0.18	2213.75	17.50	6.50	6.67	6.66	37.96	0.43	1348.50	15.00	5.50
54.53	0.18	2008.67	17.17	4.67	4.09	7.00	40.65	0.40	1932.17	18.67	8.33
54.59	0.10	2040.00	19.59	4.50	3.50	5.66	41.28	0.32	2297.00	17.50	3.50
55.30	0.16	2005.60	15.84	6.88	8.13	6.00	37.69	0.43	1818.00	14.00	9.25
60.17	0.22	1929.15	65.00	1.84	1.43	5.33	43.67	0.50	1700.00	60.00	1.33
55.50	0.20	2043.30	19.17	4.96	5.05	6.00	39.00	0.50	1916.75	19.67	4.67
60.17	0.19	1856.92	25.17	3.06	2.92	5.33	36.67	0.52	1862.00	27.33	3.25
54.50	0.18	2107.80	47.50	5.00	4.42	5.33	38.00	0.42	2322.83	50.00	5.17
53.83	0.14	2308.45	35.00	6.17	7.17	5.67	38.67	0.42	2148.50	26.67	8.50
54.67	0.23	2058.75	11.17	2.71	2.25	6.00	37.33	0.40	1752.00	21.67	4.83
58.67	0.18	2247.30	60.00	3.42	3.09	5.33	39.67	0.30	2107.33	30.00	2.57
52.33	0.16	2141.38	29.17	2.34	1.92	5.00	38.33	0.43	2096.80	25.00	2.33
54.84	0.14	1967.67	10.50	3.34	5.17	5.00	40.00	0.50	2049.50	8.67	2.50
56.11	0.00	0.00	22.50	4.84	4.00	6.33	37.67	0.00	0.00	31.00	4.00
57.83	0.17	1744.63	26.50	5.25	3.92	3.33	40.33	0.50	1956.50	11.67	4.17
56.50	0.15	2242.84	26.67	5.59	6.17	6.00	33.33	0.55	2034.17	35.00	9.00
53.67	0.16	1697.10	13.84	6.09	6.09	6.33	38.00	0.43	1551.00	11.33	6.00
53.50	0.17	1788.25	20.42	7.59	5.92	6.33	39.33	0.43	2105.60	21.67	8.17
56.50	0.14	2044.13	29.17	3.59	3.84	6.33	40.00	0.47	2138.00	20.00	1.83
58.17	0.16	2306.15	18.50	1.59	1.33	3.00	38.67	0.50	2122.00	15.00	1.50
58.00	0.17	2180.12	29.00	4.92	4.67	6.67	41.67	0.46	2273.20	30.00	5.67
57.50	0.16	1882.83	20.50	2.50	2.09	6.33	34.67	0.41	2045.60	22.33	2.50
57.50	0.14	1716.40	23.67	4.25	4.09	6.00	38.67	0.41	1787.00	21.33	3.83
49.00	0.17	2136.84	18.67	3.50	1.84	6.00	38.67	0.46	2061.00	23.33	3.50
53.34	0.16	1868.19	45.00	7.92	7.25	6.67	39.33	0.40	1572.33	28.33	9.17
56.84	0.10	2608.96	25.00	3.00	2.00	6.33	36.67	0.43	2334.00	33.33	2.83
57.67	0.13	2439.20	20.50	7.67	8.67	6.00	36.67	0.43	2417.33	15.67	8.16

56.00	0.15	1891.25	11.00	3.59	3.83	5.67	36.00	0.43	2045.67	11.67	1.83
53.50	0.14	1694.00	9.84	4.42	3.84	6.00	35.67	0.47	1736.80	8.00	3.50
53.50	0.18	2289.75	25.17	10.00	4.42	6.00	34.00	0.45	2134.33	26.00	9.83
55.84	0.10	1103.50	13.09	3.59	3.67	6.33	39.33	0.00	0.00	9.00	3.00
55.00	0.18	1306.45	49.17	4.17	6.75	5.67	35.00	0.47	1660.80	103.33	4.00
52.33	0.22	2133.60	24.67	3.00	3.42	6.67	40.00	0.42	1990.75	23.33	3.00
51.67	0.14	2131.39	36.84	4.59	4.09	6.33	35.33	0.40	1942.33	30.00	4.00
52.50	0.12	2147.50	35.00	1.50	1.17	4.67	38.67	0.45	1686.50	33.33	1.00
55.34	0.17	1950.35	37.50	3.84	6.42	6.00	35.00	0.46	2272.75	33.33	3.67

FT (SSS)	FNT (TS)	FNT (TT)	FNT (SS)	FNT (ST)	FNT (TE)	FNT (RPE)	FNT (SSS)	F (TS)	F (TT)
8.33	5.33	31.00	0.55	1605.00	23.33	10.00	9.00	5.50	32.67
8.08	6.67	33.33	0.50	2279.33	60.00	6.67	5.83	6.67	35.00
4.67	6.33	34.33	0.57	2269.43	136.67	4.67	4.17	6.50	35.83
5.50	5.66	30.31	0.50	1967.00	12.00	6.00	5.83	5.50	32.71
6.67	6.33	29.54	0.60	2386.00	19.33	6.33	6.67	6.50	33.75
5.00	5.33	34.89	0.60	1801.60	19.67	6.17	4.08	6.17	37.77
3.50	6.00	36.63	0.54	2252.40	13.33	4.25	3.50	5.83	38.96
8.75	6.00	34.86	0.55	1867.00	15.00	8.17	9.75	6.00	36.28
1.00	5.33	33.33	0.53	1604.67	60.00	1.33	0.87	5.33	38.50
3.83	6.00	34.00	0.50	1872.40	21.67	5.08	5.17	6.00	36.50
2.75	5.33	34.67	0.68	1798.14	30.33	3.00	2.50	5.33	35.67
4.58	7.00	31.67	0.54	1908.50	38.33	4.50	4.17	6.17	34.84
8.83	6.00	31.00	0.43	2389.40	30.00	7.50	7.67	5.84	34.84
4.50	5.00	32.33	0.50	2316.75	16.00	3.33	2.83	5.50	34.83
2.17	5.33	36.00	0.59	2042.00	60.00	3.50	3.00	5.33	37.84
1.83	5.00	30.00	0.56	1839.60	28.33	2.33	1.67	5.00	34.17
6.00	5.00	33.67	0.57	2345.50	12.33	2.50	5.33	5.00	36.84
2.58	7.00	33.67	0.00	0.00	18.67	2.67	2.08	6.67	35.67
3.17	3.67	33.33	0.55	1945.00	40.00	5.50	5.17	3.50	36.83
9.00	6.00	36.33	0.55	2416.17	30.00	7.33	8.33	6.00	34.83
6.00	6.00	31.00	0.56	1973.67	11.33	6.00	6.00	6.17	34.50
6.33	6.67	31.67	0.53	1857.25	21.67	7.83	5.83	6.50	35.50
1.33	6.67	32.00	0.50	2042.33	26.67	1.83	1.67	6.50	36.00

1.00	3.33	30.33	0.60	2377.00	14.67	1.50	1.00	3.17	34.50
4.83	6.00	34.67	0.56	1790.00	29.00	5.33	4.67	6.34	38.17
2.00	6.67	33.33	0.53	1757.40	19.67	2.33	2.00	6.50	34.00
3.83	6.67	35.00	0.60	1589.75	22.33	3.00	2.67	6.34	36.84
2.33	5.00	32.33	0.50	2069.33	20.00	3.33	2.00	5.50	35.50
8.17	6.33	31.33	0.50	1792.43	50.00	7.33	7.33	6.50	35.33
2.67	7.00	33.33	0.50	2453.67	30.00	2.50	2.00	6.67	35.00
8.17	6.67	35.33	0.50	2552.40	22.00	7.50	8.00	6.34	36.00
2.17	6.00	32.33	0.50	2024.80	11.00	2.17	1.83	5.84	34.17
4.17	6.33	34.33	0.60	1903.43	13.00	4.67	5.50	6.17	35.00
4.17	6.00	33.67	0.57	2562.40	23.33	9.67	3.67	6.00	33.84
3.83	5.33	33.33	0.55	2148.75	10.67	3.67	3.83	5.83	36.33
4.50	6.00	35.33	0.60	1303.00	45.33	4.50	5.50	5.84	35.17
3.17	5.67	37.00	0.53	2128.38	26.00	3.00	3.67	6.17	38.50
4.33	7.00	34.33	0.55	1978.50	36.67	4.50	2.33	6.67	34.83
0.67	6.33	32.33	0.52	1870.75	34.67	1.17	0.67	5.50	35.50
6.00	5.67	30.00	0.55	2065.50	41.67	3.67	7.00	5.84	32.50

F (SS)	F (ST)	F (TE)	F (RPE)	F (SSS)	T (TS)	T (TT)	T (SS)	T (ST)	T (TE)	T (RPE)	T (SSS)
0.48	1983.00	29.17	10.00	8.67	5.84	45.00	0.27	2218.65	36.67	9.67	8.83
0.47	2145.50	58.34	7.17	6.96	6.17	46.17	0.24	2056.99	68.34	7.59	8.13
0.48	2377.63	140.84	4.84	4.42	6.50	46.33	0.29	2478.92	139.17	4.70	4.32
0.47	1721.50	11.00	6.00	5.67	5.33	46.22	0.22	738.00	10.34	6.00	5.84
0.52	1867.25	17.17	5.92	6.67	6.66	48.61	0.28	1969.00	17.50	6.34	7.17
0.50	1866.89	19.17	7.25	4.54	6.50	47.80	0.27	1828.59	19.17	6.67	4.34
0.43	2274.70	15.42	3.88	3.50	6.16	50.64	0.17	1981.00	20.00	4.13	3.75
0.49	1842.50	14.50	8.71	9.25	5.83	47.74	0.30	1864.10	14.50	8.00	9.00
0.52	1652.34	60.00	1.33	0.94	4.83	54.84	0.34	1800.25	60.00	1.67	1.27
0.50	1894.58	20.67	4.88	4.50	6.00	49.00	0.30	1923.78	20.67	4.96	5.00
0.60	1830.07	28.83	3.13	2.63	5.83	52.34	0.33	1847.50	24.67	3.35	2.79
0.48	2115.67	44.17	4.84	4.38	5.83	47.67	0.29	2234.42	50.00	5.09	4.54
0.43	2268.95	28.34	8.00	8.25	5.84	49.00	0.26	2235.50	25.00	7.67	8.42
0.45	2034.38	18.84	4.08	3.67	6.00	44.83	0.32	1933.75	17.00	3.79	3.42
0.45	2074.67	45.00	3.04	2.59	5.17	50.67	0.18	2233.17	35.00	3.04	2.59

0.50	1968.20	26.67	2.33	1.75	5.00	48.33	0.29	2111.28	27.50	2.42	1.92
0.54	2197.50	10.50	2.50	5.67	5.00	49.34	0.30	1904.92	8.67	2.84	5.84
0.00	0.00	24.84	3.34	2.33	6.33	48.84	0.00	0.00	28.67	4.25	3.54
0.53	1950.75	25.84	4.84	4.17	3.67	50.83	0.34	1849.38	15.67	4.50	3.42
0.55	2225.17	32.50	8.17	8.67	6.00	46.67	0.34	2185.59	34.17	8.25	8.59
0.50	1762.34	11.33	6.00	6.00	6.50	47.50	0.27	1566.90	12.00	6.00	6.00
0.48	1981.43	21.67	8.00	6.08	6.17	49.67	0.31	1919.30	21.67	7.92	6.75
0.49	2090.17	23.34	1.83	1.50	6.17	51.50	0.29	2002.00	20.00	1.92	1.67
0.55	2249.50	14.84	1.50	1.00	3.50	50.50	0.32	2290.00	16.17	1.59	1.17
0.51	2031.60	29.50	5.50	4.75	6.00	52.00	0.26	2166.44	29.34	5.17	4.75
0.47	1901.50	21.00	2.42	2.00	6.00	49.17	0.26	1926.43	22.50	2.50	2.09
0.51	1688.38	21.83	3.42	3.25	6.00	51.84	0.26	1652.70	22.17	4.33	4.25
0.48	2065.17	21.67	3.42	2.17	4.67	45.84	0.28	2132.00	22.17	3.50	2.25
0.45	1682.38	39.17	8.25	7.75	6.00	49.17	0.24	1652.00	35.00	9.34	8.34
0.47	2393.84	31.67	2.67	2.34	6.33	49.34	0.22	2567.34	29.17	2.83	2.34
0.47	2484.87	18.84	7.83	8.09	5.84	48.84	0.24	2448.17	17.67	8.00	8.75
0.47	2035.24	11.34	2.00	2.00	6.00	46.17	0.28	2007.09	11.50	2.67	3.25
0.54	1820.12	10.50	4.09	4.84	6.34	48.84	0.29	1689.40	8.50	3.59	3.67
0.51	2348.37	24.67	9.75	3.92	6.00	44.50	0.28	2180.92	24.34	9.92	4.25
0.28	1074.38	9.84	3.34	3.83	6.17	50.67	0.00	0.00	8.84	3.25	3.92
0.54	1481.90	74.33	4.25	5.00	5.50	45.50	0.30	1489.15	75.33	4.09	5.17
0.48	2059.57	24.67	3.00	3.42	6.00	49.67	0.28	2189.81	23.50	3.00	3.09
0.48	1960.42	33.34	4.25	3.33	6.33	45.50	0.23	2068.67	30.84	4.25	4.67
0.49	1778.63	34.00	1.09	0.67	5.17	48.34	0.25	1913.59	33.33	1.25	0.75
0.51	2169.13	37.50	3.67	6.50	5.67	46.34	0.28	2129.98	37.50	3.67	6.42

APPENDIX J: COMPLETE DATA SET FOR EXPERIMENT TWO

Participant #	CS (RPE)	CS (SSS)	Base1 (TS)	Base1 (TT)	Base1 (SS)	Base1 (ST)	Base1 (TE)	Base1 (RPE)	Base1 (SSS)
1.00	0.50	3.00	6.67	16.67	0.71	942.00	140.00	8.33	3.00
2.00	1.00	1.00	6.67	20.67	0.71	939.83	105.00	1.50	1.00
3.00	0.00	0.00	6.00	22.67	0.67	1352.00	125.00	3.50	2.33
4.00	2.00	0.50	6.67	25.00	0.70	522.11	126.67	2.00	1.50
5.00	2.50	2.00	6.33	26.00	0.70	1526.50	97.33	4.83	3.00
6.00	2.25	2.50	6.33	18.00	0.00	10073.40	111.33	3.67	3.75
7.00	0.00	0.00	7.00	24.67	0.80	649.67	131.67	3.08	1.25
8.00	1.50	1.00	6.67	25.00	0.75	900.00	127.33	2.67	3.00
9.00	2.50	1.00	6.33	18.67	0.98	992.67	100.00	3.67	2.67
10.00	1.50	0.00	6.00	17.00	0.80	282.25	96.67	3.50	1.67
11.00	1.00	0.00	6.67	18.67	0.93	972.75	103.33	1.50	1.50
12.00	0.00	0.00	6.67	15.33	0.93	1172.75	105.00	3.83	1.00
13.00	2.50	1.00	6.00	20.33	0.70	1371.33	123.33	5.50	3.00
14.00	1.00	0.00	7.00	19.00	0.85	1849.91	118.33	2.83	1.58
15.00	1.00	1.00	6.67	23.67	0.86	958.33	95.00	6.67	2.00
16.00	8.00	0.00	6.33	18.67	0.70	812.00	136.67	9.33	2.00
17.00	2.00	0.50	6.33	25.00	0.80	948.00	95.00	3.50	3.50
18.00	1.50	0.00	6.00	24.67	0.77	861.83	133.33	3.75	2.17
19.00	1.50	0.00	6.67	34.00	0.87	992.75	140.00	1.83	0.67
20.00	2.50	0.00	6.67	16.00	0.77	1449.29	104.00	2.00	1.67
21.00	0.00	0.00	7.00	22.67	0.70	756.00	119.50	0.00	0.17
22.00	1.50	0.25	6.33	28.00	0.85	998.80	90.00	6.33	2.33
23.00	1.00	0.50	6.33	20.00	0.83	1335.00	105.00	1.83	1.33
24.00	1.50	2.00	6.00	17.33	0.79	963.00	143.33	4.50	2.33
25.00	1.50	3.00	6.33	16.00	0.82	887.33	117.33	4.67	3.00
26.00	2.50	0.50	5.33	17.50	0.71	929.50	95.00	3.33	1.00
27.00	1.00	0.50	6.33	18.33	0.67	1290.88	105.00	1.50	3.00
28.00	0.00	0.00	6.00	22.67	0.95	838.88	115.00	1.83	1.50
29.00	1.50	1.00	6.67	20.00	0.80	1098.43	96.00	7.17	1.83
30.00	3.00	2.50	7.00	20.33	0.73	1186.00	115.00	4.33	2.83
31.00	1.50	0.00	6.00	25.00	0.70	1262.75	100.00	3.17	2.00

32.00	2.50	1.00	6.00	17.33	0.91	1058.60	140.00	5.17	3.00
33.00	1.00	0.50	7.00	23.00	0.80	1526.00	94.67	2.00	0.50
34.00	1.50	1.00	6.33	27.00	0.79	903.00	123.33	4.17	3.00
35.00	1.50	1.00	6.67	25.00	0.50	899.50	126.00	1.75	2.33
36.00	1.00	0.00	6.00	24.33	0.77	1116.00	93.33	9.33	2.17
37.00	1.50	0.00	6.67	19.00	0.80	956.00	133.33	2.50	1.67
38.00	1.50	1.00	6.00	20.00	0.86	932.67	138.33	1.50	1.00
39.00	5.00	2.50	6.00	27.67	0.83	956.50	140.00	7.17	2.33
40.00	1.00	0.70	6.67	18.33	0.80	1087.71	97.50	6.33	2.00
41.00	1.00	0.00	7.00	23.00	0.71	1092.92	95.33	3.00	1.67
42.00	1.50	0.00	6.67	24.00	0.69	1300.00	95.00	4.75	3.00
43.00	1.00	0.00	7.00	18.33	0.97	936.33	136.67	2.33	0.83
44.00	2.50	2.00	7.00	13.33	0.78	876.00	123.33	4.67	3.33
45.00	1.50	2.00	5.67	15.67	0.71	1296.50	125.00	7.50	2.00

A (TS)	**A (TT)**	**A (SS)**	**A (ST)**	**A (TE)**	**A (RPE)**	**A (SSS)**	**V (TS)**	**V (TT)**	**V (SS)**	**V (ST)**	**V (TE)**	**V (RPE)**	**V (SSS)**
5.33	43.00	0.58	1444.14	110.00	8.67	4.67	5.33	48.00	0.67	1969.10	90.00	8.50	4.33
4.00	34.00	0.70	1954.30	65.00	2.83	5.33	4.00	42.67	0.59	1760.79	80.00	3.00	5.00
4.33	29.00	0.43	1800.33	58.33	3.50	6.67	4.67	29.33	0.65	1851.88	58.33	3.17	5.67
5.33	28.67	0.48	2001.63	61.67	2.67	4.17	5.33	34.33	0.65	1775.20	68.33	2.33	4.50
5.33	31.00	0.59	1962.38	74.33	6.00	5.25	4.67	40.67	0.59	2032.44	54.33	5.60	5.25
4.00	28.00	0.34	1861.80	59.33	2.75	5.33	4.00	33.33	0.49	1564.14	78.83	4.75	4.63
5.00	25.67	0.25	1439.00	68.33	3.83	4.25	5.33	29.00	0.67	2070.33	75.00	3.75	4.92
4.00	29.33	0.56	1650.57	75.67	2.00	4.50	5.67	38.67	0.63	1676.58	98.67	2.00	4.67
5.67	30.33	0.43	1781.67	60.00	3.67	4.33	4.33	28.33	0.43	2021.75	80.00	2.33	5.00
4.67	32.33	0.68	1413.20	58.33	4.17	5.33	4.33	28.67	0.34	1760.00	73.33	4.83	5.33
5.00	32.33	0.56	1389.00	51.67	2.17	4.17	5.67	34.00	0.30	1201.50	58.33	2.83	6.33
4.33	28.00	0.56	2389.00	64.00	4.33	4.67	4.67	27.00	0.30	2201.50	67.67	3.33	4.00
5.33	35.67	0.63	1928.17	54.33	7.17	5.00	5.00	24.33	0.68	1883.88	90.00	5.17	5.00
5.00	50.33	0.25	1907.19	66.67	2.67	5.50	5.00	45.33	0.62	1353.00	48.33	3.08	4.83
4.00	27.67	0.43	2042.40	72.67	5.67	4.33	4.33	33.67	0.67	1117.60	59.67	6.33	5.50
4.00	34.33	0.41	1538.00	65.00	9.50	4.67	5.00	35.66	0.62	1756.00	65.00	9.67	5.50

5.67	29.67	0.67	1760.00	90.00	7.00	4.17	7.00	29.67	0.67	1700.50	90.00	4.33	4.50
5.33	32.67	0.60	1363.67	51.67	9.83	5.58	5.33	19.00	0.57	1099.50	68.33	10.00	6.17
4.33	32.67	0.53	1229.00	61.67	2.50	5.33	4.00	32.67	0.63	1967.83	50.00	1.83	5.00
4.00	26.33	0.61	1461.00	46.67	5.67	3.00	3.00	29.67	0.67	1122.63	61.67	4.33	4.00
5.00	25.33	0.50	1168.00	98.00	0.67	6.00	4.33	33.00	0.57	1121.80	53.00	1.17	4.33
6.00	20.00	0.67	1727.00	51.67	7.00	6.17	5.00	23.00	0.50	1306.00	68.33	7.00	5.50
5.33	26.33	0.55	1667.50	70.00	2.00	5.00	5.67	31.00	0.50	1701.25	71.67	2.50	4.75
4.00	27.00	0.33	1282.60	52.33	4.50	5.33	4.00	34.00	0.40	1185.25	83.33	5.17	5.00
5.00	33.33	0.51	1583.10	60.00	4.67	4.83	5.00	29.33	0.68	1886.29	62.00	5.00	5.50
5.33	36.88	0.43	1146.13	53.33	3.33	4.75	4.00	40.33	0.63	1180.70	57.33	4.17	4.00
5.33	30.00	0.48	1274.68	63.33	2.50	5.00	5.00	27.00	0.63	1917.00	86.67	3.00	4.67
4.67	56.00	0.50	2043.73	60.00	3.00	4.67	4.00	33.00	0.67	1018.56	58.33	4.17	3.50
4.00	25.33	0.50	1227.67	56.00	8.67	5.00	4.67	29.00	0.63	1147.00	90.00	8.83	4.33
4.00	28.00	0.65	1730.00	75.00	5.33	4.83	4.00	26.67	0.65	1693.58	59.00	6.00	6.17
5.33	47.33	0.57	1375.75	90.00	3.17	5.67	6.00	34.33	0.50	1217.60	65.00	2.50	5.00
5.00	28.67	0.61	1110.83	75.00	2.50	4.33	4.67	35.67	0.56	1866.80	86.67	5.83	5.33
5.00	30.67	0.55	1427.00	55.67	1.67	5.83	5.00	37.67	0.57	1939.67	94.00	1.83	4.83
6.00	35.00	0.62	1198.11	67.50	3.83	4.67	4.00	32.00	0.50	1900.63	88.33	3.83	5.00
5.67	31.67	0.67	1741.20	52.67	1.50	5.00	5.00	34.33	0.47	1265.00	76.00	1.50	4.00
5.00	33.67	0.65	1810.67	68.33	9.50	4.00	4.33	25.33	0.65	1872.76	74.00	10.00	4.67
5.33	31.00	0.25	1082.00	56.67	3.83	6.00	5.33	36.67	0.50	1487.65	56.67	4.67	4.50
5.00	29.00	0.65	1091.50	61.67	2.17	4.67	5.00	29.33	0.50	1644.50	90.00	2.50	5.00
4.00	30.33	0.65	1827.00	70.00	5.83	5.67	4.00	30.67	0.50	1888.33	53.33	6.83	4.00
4.33	39.33	0.67	1859.60	83.33	6.33	4.50	5.00	32.33	0.63	1247.40	62.67	6.50	5.00
4.00	32.00	0.59	1019.33	90.00	5.13	4.50	4.00	40.67	0.65	1292.50	58.33	4.67	4.67
5.00	34.33	0.61	1674.64	86.00	5.00	5.83	5.00	36.00	0.43	1858.82	63.33	4.50	4.67
5.33	32.67	0.50	2219.60	75.00	2.33	6.00	5.00	29.67	0.47	1419.67	90.00	2.67	5.83
5.00	32.67	0.50	1177.00	97.33	7.00	6.83	5.00	31.67	0.40	1333.67	59.00	4.50	4.17
4.00	27.33	0.00	0.00	53.33	6.83	5.00	5.33	24.00	0.00	0.00	88.33	9.17	5.50

AV (TS)	**AV (TT)**	**AV (SS)**	**AV (ST)**	**AV (TE)**	**AV (RPE)**	**AV (SSS)**	**Base2 (TS)**	**Base2 (TT)**	**Base2 (SS)**	**Base2 (ST)**
3.33	51.00	0.25	2171.50	45.00	9.17	9.33	6.33	19.33	0.74	1084.29

4.00	53.00	0.17	2784.25	43.33	3.33	7.83	7.00	17.67	0.71	845.33
3.33	67.00	0.25	1966.33	51.67	3.83	8.00	6.33	23.00	0.80	742.25
4.00	57.00	0.25	2613.08	50.00	2.67	7.17	6.00	21.67	1.00	804.29
3.33	57.33	0.25	2717.00	27.00	6.50	6.25	6.00	21.33	0.78	957.29
4.00	61.00	0.25	2023.57	13.33	5.58	7.67	6.33	24.00	0.80	1030.50
4.00	66.33	0.15	2188.00	24.00	3.58	8.83	6.00	16.67	0.67	902.50
4.33	51.33	0.19	2373.63	26.33	2.25	8.50	7.00	26.33	1.00	793.14
5.67	58.67	0.20	2900.40	20.00	3.67	7.50	6.33	18.33	0.88	1013.43
3.33	52.00	0.30	2150.29	43.33	5.17	7.33	6.67	26.00	0.73	927.67
3.67	55.33	0.25	2947.00	53.33	2.33	8.83	6.00	24.67	0.80	959.33
4.00	67.00	0.25	1947.00	28.33	4.00	7.33	5.33	24.00	0.70	859.67
3.00	65.00	0.17	2120.50	23.33	5.17	6.67	7.00	25.67	0.71	743.33
3.67	65.33	0.18	2071.00	43.33	3.17	9.92	6.33	21.67	0.86	1130.11
3.67	38.00	0.13	2968.14	13.33	7.33	8.83	6.33	22.67	0.90	816.50
3.33	55.33	0.22	2152.00	41.00	9.67	9.00	6.67	24.67	0.83	1017.00
3.67	62.33	0.20	2929.00	60.00	6.00	7.50	7.00	21.33	1.00	1153.00
5.00	65.33	0.40	2323.50	25.00	7.25	8.67	7.00	20.67	0.00	888.00
3.00	60.00	0.25	2863.68	40.00	2.83	7.00	6.67	25.00	1.00	1085.73
3.00	63.33	0.23	2265.33	27.67	3.50	8.00	6.67	30.67	0.88	949.00
3.33	57.33	0.16	2297.50	21.00	1.17	9.25	5.33	19.00	0.83	881.00
4.00	51.00	0.25	2397.00	16.67	7.00	9.00	7.00	22.33	0.70	978.00
4.00	59.33	0.15	2600.75	9.33	2.50	8.00	6.67	16.33	0.77	1057.00
3.67	66.33	0.23	2457.60	48.33	6.17	7.67	6.67	23.00	0.80	953.60
4.00	62.33	0.18	2441.88	37.67	6.33	6.75	6.67	24.00	0.91	769.91
3.67	48.33	0.19	2170.00	41.67	3.67	7.75	6.00	18.33	0.80	1168.65
4.33	55.00	0.20	2811.68	35.00	3.00	7.00	7.00	24.67	0.83	960.41
3.00	68.00	0.22	2807.11	46.00	3.50	8.50	6.00	19.67	0.82	978.92
3.33	69.33	0.23	2697.00	21.33	8.17	9.67	6.33	19.67	1.00	983.00
4.00	51.67	0.13	2057.92	56.67	7.33	7.83	7.00	18.67	1.00	853.00
4.00	67.33	0.23	2178.64	55.00	2.50	8.00	6.00	23.00	0.78	1080.28
3.33	51.00	0.15	2206.58	18.33	4.83	7.33	5.67	28.67	0.63	958.50
4.00	68.00	0.17	2534.33	13.00	1.67	9.00	6.67	19.33	0.75	1259.25
3.00	53.67	0.20	2231.70	20.83	4.17	8.00	6.00	25.33	1.00	943.00
3.00	60.33	0.10	2722.00	9.67	1.50	8.00	6.00	21.33	0.70	860.60
4.33	61.33	0.25	2702.00	30.67	9.83	9.50	6.67	25.00	1.00	1107.67
3.00	59.33	0.33	2926.57	21.67	3.00	8.50	7.00	16.33	0.84	947.20

4.00	68.67	0.25	2823.75	25.00	3.50	7.67	6.67	21.33	0.75	848.33
3.33	54.00	0.23	2365.00	35.00	6.83	7.00	6.00	21.33	0.84	1013.25
4.00	61.00	0.25	2100.83	37.33	6.67	8.33	6.00	23.33	0.78	980.63
3.00	58.33	0.23	2255.90	48.33	6.33	9.00	6.67	23.33	0.78	937.67
3.67	63.33	0.19	2859.68	43.33	4.33	8.33	7.00	23.00	0.83	931.94
4.33	61.33	0.15	2983.67	20.00	3.00	8.17	6.00	19.00	0.67	901.67
4.00	54.00	0.20	2440.00	20.00	6.50	8.50	5.67	19.33	0.90	876.67
4.33	65.33	0.00	0.00	31.67	9.50	7.67	7.00	26.33	0.93	1185.00

Base2 (TE)	Base2 (RPE)	Base2 (SSS)	Base(TS)	Base(TT)	Base(SS)	Base(ST)	Base(TE)	Base(RPE)	Base(SSS)	Time(TS)
95.00	8.50	3.00	6.50	18.00	0.73	1013.15	117.50	8.42	3.00	4.66
120.00	1.00	0.17	6.84	19.17	0.71	892.58	112.50	1.25	0.59	4.00
128.33	2.50	2.00	6.17	22.84	0.74	1047.13	126.67	3.00	2.17	4.11
96.67	2.00	1.50	6.34	23.34	0.85	663.20	111.67	2.00	1.50	4.89
120.67	5.00	2.17	6.17	23.67	0.74	1241.90	109.00	4.92	2.59	4.44
108.83	2.83	3.00	6.33	21.00	0.40	5551.95	110.08	3.25	3.38	4.00
121.67	3.00	2.17	6.50	20.67	0.74	776.09	126.67	3.04	1.71	4.78
123.67	1.92	1.50	6.84	25.67	0.88	846.57	125.50	2.30	2.25	4.67
90.00	1.67	1.42	6.33	18.50	0.93	1003.05	95.00	2.67	2.05	5.22
135.00	2.83	2.67	6.34	21.50	0.77	604.96	115.84	3.17	2.17	4.11
143.33	2.17	1.50	6.34	21.67	0.87	966.04	123.33	1.84	1.50	4.78
119.00	3.33	1.33	6.00	19.67	0.82	1016.21	112.00	3.58	1.17	4.33
121.67	5.83	1.00	6.50	23.00	0.71	1057.33	122.50	5.67	2.00	4.44
90.00	2.00	1.50	6.67	20.34	0.86	1490.01	104.17	2.42	1.54	4.56
117.00	3.83	3.00	6.50	23.17	0.88	887.42	106.00	5.25	2.50	4.00
137.00	10.00	1.67	6.50	21.67	0.77	914.50	136.84	9.67	1.84	4.11
130.00	5.00	3.17	6.67	23.17	0.90	1050.50	112.50	4.25	3.34	5.45
116.67	9.92	2.83	6.50	22.67	0.39	874.92	125.00	6.84	2.50	5.22
115.00	1.67	1.00	6.67	29.50	0.94	1039.24	127.50	1.75	0.84	3.78
123.33	1.00	0.00	6.67	23.34	0.83	1199.15	113.67	1.50	0.84	3.33
122.00	1.50	0.75	6.17	20.84	0.77	818.50	120.75	0.75	0.46	4.22
115.00	5.50	2.17	6.67	25.17	0.78	988.40	102.50	5.92	2.25	5.00

117.00	1.75	1.25	6.50	18.17	0.80	1196.00	111.00	1.79	1.29	5.00
95.00	4.83	3.33	6.34	20.17	0.80	958.30	119.17	4.67	2.83	3.89
129.33	4.50	3.17	6.50	20.00	0.87	828.62	123.33	4.59	3.09	4.67
133.33	3.33	0.58	5.67	17.92	0.76	1049.08	114.17	3.33	0.79	4.33
123.33	3.00	2.33	6.67	21.50	0.75	1125.65	114.17	2.25	2.67	4.89
138.33	2.00	1.67	6.00	21.17	0.89	908.90	126.67	1.92	1.59	3.89
112.00	9.67	0.33	6.50	19.84	0.90	1040.72	104.00	8.42	1.08	4.00
115.67	3.67	3.17	7.00	19.50	0.87	1019.50	115.34	4.00	3.00	4.00
91.67	2.50	2.00	6.00	24.00	0.74	1171.52	95.84	2.84	2.00	5.11
115.00	2.50	1.67	5.84	23.00	0.77	1008.55	127.50	3.84	2.34	4.33
114.00	1.67	1.00	6.84	21.17	0.78	1392.63	104.34	1.84	0.75	4.67
117.00	3.50	3.00	6.17	26.17	0.90	923.00	120.17	3.84	3.00	4.33
113.33	1.50	2.33	6.34	23.17	0.60	880.05	119.67	1.63	2.33	4.56
91.00	9.50	2.00	6.34	24.67	0.89	1111.84	92.17	9.42	2.09	4.55
98.33	3.00	2.50	6.84	17.67	0.82	951.60	115.83	2.75	2.09	4.55
120.67	1.33	0.50	6.34	20.67	0.81	890.50	129.50	1.42	0.75	4.67
116.67	5.17	2.33	6.00	24.50	0.84	984.88	128.34	6.17	2.33	3.78
90.00	6.17	1.58	6.34	20.83	0.79	1034.17	93.75	6.25	1.79	4.44
133.33	4.67	2.00	6.84	23.17	0.75	1015.30	114.33	3.84	1.84	3.67
95.00	3.67	3.33	6.84	23.50	0.76	1115.97	95.00	4.21	3.17	4.56
116.67	2.00	1.83	6.50	18.67	0.82	919.00	126.67	2.17	1.33	4.89
117.67	6.17	2.67	6.34	16.33	0.84	876.34	120.50	5.42	3.00	4.67
123.33	9.50	2.50	6.34	21.00	0.82	1240.75	124.17	8.50	2.25	4.55

Time(TT)	**Time(SS)**	**Time(ST)**	**Time(TE)**	**Time(RPE)**	**Time(SSS)**
47.33	0.50	1861.58	81.67	8.78	6.11
43.22	0.49	2166.45	62.78	3.05	6.05
41.78	0.44	1872.85	56.11	3.50	6.78
40.00	0.46	2129.97	60.00	2.56	5.28
43.00	0.48	2237.27	51.89	6.03	5.58
40.78	0.36	1816.50	50.50	4.36	5.88
40.33	0.36	1899.11	55.78	3.72	6.00

39.78	0.46	1900.26	66.89	2.08	5.89
39.11	0.35	2234.61	53.33	3.22	5.61
37.67	0.44	1774.50	58.33	4.72	6.00
40.55	0.37	1845.83	54.44	2.44	6.44
40.67	0.37	2179.17	53.33	3.89	5.33
41.67	0.49	1977.52	55.89	5.84	5.56
53.66	0.35	1777.06	52.78	2.97	6.75
33.11	0.41	2042.71	48.56	6.44	6.22
41.77	0.42	1815.33	57.00	9.61	6.39
40.56	0.51	2129.83	80.00	5.78	5.39
39.00	0.52	1595.56	48.33	9.03	6.81
41.78	0.47	2020.17	50.56	2.39	5.78
39.78	0.50	1616.32	45.34	4.50	5.00
38.55	0.41	1529.10	57.33	1.00	6.53
31.33	0.47	1810.00	45.56	7.00	6.89
38.89	0.40	1989.83	50.33	2.33	5.92
42.44	0.32	1641.82	61.33	5.28	6.00
41.66	0.46	1970.42	53.22	5.33	5.69
41.85	0.42	1498.94	50.78	3.72	5.50
37.33	0.44	2001.12	61.67	2.83	5.56
52.33	0.46	1956.47	54.78	3.56	5.56
41.22	0.45	1690.56	55.78	8.56	6.33
35.45	0.48	1827.17	63.56	6.22	6.28
49.66	0.43	1590.66	70.00	2.72	6.22
38.45	0.44	1728.07	60.00	4.39	5.66
45.45	0.43	1967.00	54.22	1.72	6.55
40.22	0.44	1776.81	58.89	3.94	5.89
42.11	0.41	1909.40	46.11	1.50	5.67
40.11	0.52	2128.48	57.67	9.78	6.06
42.33	0.36	1832.07	45.00	3.83	6.33
42.33	0.47	1853.25	58.89	2.72	5.78
38.33	0.46	2026.78	52.78	6.50	5.56
44.22	0.52	1735.94	61.11	6.50	5.94
43.67	0.49	1522.58	65.55	5.38	6.06
44.55	0.41	2131.05	64.22	4.61	6.28
41.22	0.37	2207.65	61.67	2.67	6.67

39.45	0.37	1650.22	58.78	6.00	6.50
38.89	0.00	0.00	57.78	8.50	6.06

APPENDIX K: IRB HUMAN SUBJECTS APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 5/07/10, IRB00001138

To: **Razia V Nayeem**

Date : **June 28, 2007**

IRB Number: **SBE-07-05013**
Study Title: **Investigating Tactile Stress Effects**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Chair 6/27/2008. **The expiration date is 6/26/2008.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

> 4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed they must be cleared/approved for marketing.
>
> 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at http://iris.research.ucf.edu .

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 06/28/2007 10:21:41 AM EDT

IRB Coordinator
University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

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