Firefighters' stress response to a virtual reality occupationally relevant stressor and a virtual reality laboratory stressor

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Firefighters’ stress response to a virtual reality occupationally relevant stressor and a virtual reality laboratory stressor

by

Christina Sauder

A thesis submitted to the graduate faculty in partial fulfillment of the requirements of the degree of

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Major: Kinesiology

Program of Study Committee:
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2012

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## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER 2. LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>Cardiovascular disease (CVD) and firefighters</td>
<td>4</td>
</tr>
<tr>
<td>Conventional risk factors for CVD</td>
<td>5</td>
</tr>
<tr>
<td>Work stress as a risk factor for CVD</td>
<td>6</td>
</tr>
<tr>
<td>Pathophysiological mechanisms underlying stress</td>
<td>8</td>
</tr>
<tr>
<td>Relationship between firefighting, work stress and CVD</td>
<td>9</td>
</tr>
<tr>
<td>Physiological measurements of stress</td>
<td>11</td>
</tr>
<tr>
<td>Subjective measurements of stress</td>
<td>14</td>
</tr>
<tr>
<td>Laboratory stress tests</td>
<td>16</td>
</tr>
<tr>
<td>Virtual reality as a stressor</td>
<td>22</td>
</tr>
<tr>
<td>Conclusion</td>
<td>25</td>
</tr>
<tr>
<td>CHAPTER 3. MATERIALS AND METHODS</td>
<td>27</td>
</tr>
<tr>
<td>General experimental design</td>
<td>27</td>
</tr>
<tr>
<td>Virtual reality environment</td>
<td>27</td>
</tr>
<tr>
<td>Occupationally-relevant stressor</td>
<td>27</td>
</tr>
<tr>
<td>Laboratory stressor</td>
<td>29</td>
</tr>
<tr>
<td>Participants</td>
<td>33</td>
</tr>
<tr>
<td>Protocol</td>
<td>33</td>
</tr>
<tr>
<td>Data collection</td>
<td>35</td>
</tr>
<tr>
<td>Data analysis</td>
<td>36</td>
</tr>
<tr>
<td>CHAPTER 4. RESULTS</td>
<td>40</td>
</tr>
<tr>
<td>Participants</td>
<td>40</td>
</tr>
<tr>
<td>Subjective measures</td>
<td>40</td>
</tr>
<tr>
<td>Physiological measures</td>
<td>40</td>
</tr>
<tr>
<td>CHAPTER 5. DISCUSSION</td>
<td>50</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>58</td>
</tr>
</tbody>
</table>
APPENDIX A: IRB APPROVAL 66
APPENDIX B: RECRUITMENT SCRIPT 83
APPENDIX C: INFORMED CONSENT 85
APPENDIX D: MEDICAL HISTORY 89
APPENDIX E: GLOVAL MEASURE OF CHRONIC STRESS 94
APPENDIX F: SIMPLE ARITHMETIC 95
APPENDIX G: AFFECT GRID 97
APPENDIX H: NASA-TLX 98
APPENDIX I: NASA-TLX RATING SCALE DEFINITIONS 99
APPENDIX J: NASA-TLX COMPARISON CARDS 100
APPENDIX K: ANAGRAMS 102
APPENDIX L: PHOTO OF ANAGRAM STRESSOR 105
APPENDIX M: PHOTO OF COLOR WORD STROOP TEST STRESSOR 106
APPENDIX N: PHOTO OF ARITHMETIC STRESSOR 107
APPENDIX O: PHOTO OF PREPPED FIREFIGHTER 108
APPENDIX P: PHOTO OF FIREFIGHTER IN OCCUPATIONALLY-RELEVANT STRESSOR 109
APPENDIX Q: MEAN PHYSIOLOGICAL RESPONSES OF FIREFIGHTERS IN BASELINE, LS AND ORS 110
LIST OF TABLES

Table 4.1. Mean physiological responses of firefighters during Baseline and baseline II 42

Table 4.2. Mean physiological responses of firefighters during LS and ORS 43
LIST OF FIGURES

Figure 4.1. Heart rate (HR, bpm) as a function of time in LS and ORS (time expressed as % of time in stressor) 44

Figure 4.2. Mean arterial pressure (MAP, mmHg) as a function of time in LS and ORS (time expressed as % of time in stressor) 45

Figure 4.3. Pre-ejection period (PEP, sec) as a function of time in LS and ORS (time expressed as % of time in stressor) 46

Figure 4.4. Cardiac output (CO, L/min) as a function of time in LS and ORS (time expressed as % of time in stressor) 47

Figure 4.5. Stroke volume (SV, mL) as a function of time in LS and ORS (time expressed as % of time in stressor) 48

Figure 4.6. Total peripheral resistance (TPR, mmHg/L/min) as a function of time in LS and ORS (time expressed as % of time in stressor) 49
ABSTRACT

Purpose: The purpose of this study was to compare the stress responses of an occupationally-relevant stress (ORS) in a virtual reality environment to a well-established laboratory stressor (LS).

Hypothesis: It was hypothesized that the ORS would be as effective at eliciting a stress response as a well-established LS.

Methods: Firefighters (n=14) from Iowa underwent two different stressor scenarios: LS and ORS. Heart rate (HR), mean arterial pressure (MAP), stroke volume (SV), cardiac output (CO), pre-ejection period (PEP), and total peripheral resistance (TPR) were continuously assessed throughout the two scenarios. Subjective measures of affect (“arousal” and “pleasure”) and workload were assessed immediately after each stressor.

Results: No significant differences in mean responses of HR, MAP, SV, CO, PEP, and TPR were found between the LS and ORS. There were no statistical differences in all physiological responses throughout the journeys of the LS vs. ORS. Measures of “arousal” were similar in the ORS and LS, while measures of “pleasure” were significantly higher in the ORS (p<0.05). Workload scores were significantly higher in the LS than the ORS (p<0.0001).

Discussion: Although subjective measures of “pleasure” and workload were different between the LS and ORS, the firefighters had similar physiological stress responses. This suggests that the ORS is at least as stressful as the LS in terms of physiological responses and is a valid stressor for firefighters when compared to a well-
established laboratory stressor. Thus, the ORS can be used as a stressor in future research assessing issues such as work stress in firefighters and its effect on cardiovascular disease and decision-making.
CHAPTER 1: INTRODUCTION

Firefighters are at an increased risk of experiencing a cardiovascular related event while on duty (Fahy, 2005). Wearing heavy protective equipment, heat stress, irregular physical exertion, smoke and chemical exposure, high prevalence of cardiovascular risk factors, and psychological stressors may all contribute to some of these deaths (Guidotti et al., 1992; Barnard et al., 1975; Kuorinka et al., 1981; Burgess et al., 2001; Smith et al., 2001; Friel et al., 1992). Although most of these factors are unique to the firefighting profession, it is unclear which has the greatest effect on triggering a cardiovascular event. This lack of clarity impedes efforts in minimizing cardiovascular events in the firefighting profession, making it important to fill this existing gap. Psychological stress from within the workplace is regarded as a contributor because of the marked effects it has on the cardiovascular system (Eller et al., 2009).

Chronic or frequent stress can result in changes to the two main axes of the stress response: (1) the sympatho-adrenal medullary axis (SAM), which includes activation of the sympathetic nervous system, leading to changes in peripheral adrenaline and noradrenaline levels (Chandola et al., 2010), and (2) the hypothalamic-pituitary-adrenal (HPA) axis, leading to changes in a wide variety of endocrine factors including cortisol (Singh et al., 1999; Chandola et al., 2010). A change in either of these axes could have a negative effect on cardiovascular integrity.

Some evidence suggests that activation of the SAM and HPA axes may precipitate endothelial dysfunction, which is one of the earliest signs of atherosclerosis (Mangos et
Atherosclerosis occurs when there is a rupture of vulnerable plaque and consequent activation and aggregation of platelets, leading to the formation of a blood clot (thrombus) that occludes the artery and prevents blood flow to the heart (Hansson, 2005). This can ultimately result in myocardial infarction. Activation of the SAM and HPA axes due to stress could contribute towards firefighters’ increased risks for cardiovascular events while on duty. In this proposed study, the response of the SAM axis to acute stress will be assessed in firefighters.

There are numerous mechanisms in which to elicit an acute stress response. Laboratory stressors, such as the Stroop test (Santos and Montgomery, 1962; Jensen, 1965; Smith and Nyman, 1974), mental arithmetic (Allen et al., 1991), and puzzle solving (Boyes & French, 2010) have demonstrated the ability to provoke a stress response (Joensson et al., 2009; Fauvel et al., 1996). These laboratory stressors typically require the subject to take a written or computerized test, or to perform a stressful task such as difficult subtraction or tracing a pattern while peering at its image in a mirror. These tasks, while stressful, are unrelated to the events that firefighters face while on duty. The laboratory stressors do not embody events relevant to firefighters, and although they may have the ability to trigger a stress response, they lack external validity in terms of the firefighting profession. Ideally, physiologic stress responses (e.g., changes in heart rate, blood pressure, cardiac output, stroke volume, pre-ejection period, and total peripheral resistance) would be measured in firefighters while on duty. However, this would compromise the safety of the firefighters, civilians and the experimenters. A safer alternative is to use virtual reality. Here stress
measurements would be taken while participants experience an occupationally-relevant stressor in a virtual reality environment. This would increase the generalizability of the stressor while maintaining the safety of all involved.

Research involving the use of virtual reality for an occupationally-relevant stressor is scarce. Virtual reality has become mature enough to be successfully used in clinical applications such as exposure therapy (Côté, 2005), pain distraction (Schmitt et al., 2011) and neuropsychological assessment (Weniger et al., 2011). Therefore, virtual reality could be a useful tool for creating an occupationally-relevant acute bout of stress.

In summary, firefighters are at an increased risk for experiencing a cardiovascular event while on duty, and this increased risk may be attributed to physiological responses to acute stressors presented in the work place. To determine whether stress plays a significant role in firefighters’ increased risk for cardiovascular events while on duty, physiological measurements need to be taken while the subject is exposed to an occupationally-relevant stressor. The purpose of this study is to compare stress responses in an occupationally-relevant stressor to a well-established laboratory stressor. It is hypothesized that the occupationally-relevant stressor will demonstrate to be just as or more effective in eliciting a stress response when compared to well-established laboratory stressors.
CHAPTER 2: LITERATURE REVIEW

Cardiovascular disease and firefighters

Nearly 100 of the ~1.1 million firefighters in the United States die each year in the line of duty (Fire Fighter Fatality Investigation and Prevention Program 2007). Nearly 45% of the deaths that occur while firefighters are on duty are related to cardiovascular events (Fahy, 2005). These fatalities are most strongly associated with fire suppression, where firefighters respond and return from an alarm (Kales et al., 2007). Various possible biologic explanations for the high mortality from cardiovascular events among firefighters have been proposed. These explanations include the effects of bearing heavy protective equipment, heat stress, irregular physical exertion, smoke and chemical exposure, high prevalence of cardiovascular risk factors, and psychological stressors (Guidotti et al., 1992; Barnard et al., 1975; Kuorinka et al., 1981; Burgess et al., 2001; Smith et al., 2001; Friel et al., 1992).

In one study, Kales and colleagues (2007) built on the observation that cardiovascular events that occur while firefighters are on duty appear to cluster around specific activities (e.g. fire suppression and emergency response) and on their own earlier case-control study suggesting that specific duties are associated with deaths due to coronary heart disease (Kales et al. 2003). In this study, data was reviewed on all deaths that occurred while firefighters were on duty over an 11-year period (1144 deaths). Odds ratios for death were calculated by comparing five specific emergency duties and nonemergency duties. These comparisons were based on three separate sources of data indicating how much time firefighters typically spend in each of these
activities. Kales et al. found that the odds of death from coronary heart disease were 12.1 to 136 times as high during fire suppression, 2.8 to 14.1 times as high during alarm response, 2.2 to 10.5 times as high during alarm return, and 2.9 to 6.6 times as high during physical training.

The authors did not necessarily show an overall increased risk of death from CVD among firefighters, but convincingly showed that such an event is far more likely to occur during specific firefighter duties - dramatically so during fire suppression, but also during alarm response and return and physical training.

**Conventional risk factors for cardiovascular disease**

Traditional CVD risk factors, as outlined in the Framingham Study, include cigarette smoking, hypertension, diabetes mellitus, dyslipidemia, family history of premature coronary disease, and sedentary lifestyle (Forrester et al., 1996). These characteristics have been designated major risk factors for CVD given their relatively high prevalence in CVD-prone populations, causal relations to CVD, dominance in risk prediction over other risk factors, and their role in prevention and control (Wilson et al., 1998; Stamler et al., 1993). Cardiovascular disease, however, often occurs in the absence of any major risk factors, justifying a search for new or currently unrecognized factors accounting for CVD causation (e.g., psychosocial stress) (Magnus et al., 2001; Ridker 1999).

Studies have demonstrated an association between on duty cardiovascular events and firefighters, but the causes of these events remain unclear (Fahy, 2005). On duty cardiovascular related deaths seem to be confined to firefighters with either a
number of conventional CVD risk factors, such as physical inactivity, hypertension, smoking, obesity, hypercholesterolemia and hyperinsulinemia, or preexisting CVD (Kales et al., 2007). In a cross-sectional study by Kay et al. (2001), 84% of the firefighters assessed were overweight, 28% had high cholesterol, and 22% had high blood pressure even though the International Association of Firefighters stipulates that applicants for firefighting positions who have hypertension may be denied employment because of the health risk that this diagnosis poses. These values, however, do not appear to be above those of the average United States population (Rogers et al., 2012) and so may not fully explain firefighters increased risk for CVD events while on duty. This again leads to the need for more research assessing other potential CVD risk factors (e.g., psychosocial stress) besides the conventional risk factors. A better understanding of the behavioral and physiologic associations between psychosocial stress and CVD will assist researchers in identifying effective approaches for reducing or reversing the damaging effects of stress and may lead to further reductions of CVD morbidity and mortality amongst firefighters.

Work stress, a form of psychosocial stress, has been correlated with CVD (Landsbergis, 2004; Eller et al., 2009) and given the stressful conditions under which firefighters work, may be one plausible mechanism behind firefighters increased risk for on duty cardiovascular events.

**Work stress as a risk factor for cardiovascular disease**

Psychosocial stress appears to contribute to all recognized mechanisms underlying cardiac events, specifically, (a) clustering of traditional risk factors, (b)
endothelial dysfunction, (c) myocardial ischemia, (d) plaque rupture, (e) thrombosis, and (f) malignant arrhythmias (Merz et al., 2002).

There is a cumulating body of evidence on the association between psychosocial hazards at work and the cardiovascular health of workers. A meta-analysis suggests there was 50% increased risk for CVD among employees with work stress (Kivimaki et al., 2006). There are several job stress models indicating this relationship between work stress and CVD. Two commonly used models are the job strain model (Karasek et al., 1979) and the effort-reward imbalance model (Siegrist et al., 1996).

The job strain model postulates that job strain results from the joint effects of high job demands and low job control (Karasek et al., 1990; Schnall et al., 1994). Several publications underscore the special importance of low job control for a range of outcomes, including CVD (Alterman et al., 1994; Bosma et al., 1997; Johnson et al., 1996).

According to the effort-reward model, effort at work is spent as part of a social contract that reciprocates effort by adequate reward. Rewards are distributed by three transmitter systems: money, esteem, and career opportunities including job security. Each one of these components of work-related rewards was shown to matter for health (Siegrist, 1996). A study by Siegrist and colleagues (1990) linked this model with cardiovascular disease.

It is estimated that up to 23% of CVD related deaths per year could be prevented if the levels of job strain in the most stressful occupations were reduced to average levels seen in other occupations (Karasek and Theorell, 1990). The mechanisms leading from
exposure to workplace stressors to CVD are hypothesized to be indirect effects through unhealthy behaviors (e.g. smoking, unhealthy diet, lack of exercise), as well as direct effects on neuroendocrine stress responses (Chandola et al., 2008). For the purpose of this study, neuroendocrine responses to stress will be measured. Such responses will be addressed in the next section.

**Pathophysiological mechanisms underlying stress**

The pathophysiological mechanisms underlying stress-related triggering of acute cardiac events are poorly understood. There is evidence that stress activates two main axes: (1) the sympatho-adrenal-medullary (SAM) axis and (2) the hypothalamic-pituitary-adrenal (HPA) axis (Black and Garbutt, 2002). The activation of these axes can negatively affect the cardiovascular system both acutely—by precipitating myocardial infarction, left-ventricular dysfunction, or dysrhythmia; and chronically—by accelerating the atherosclerotic process (Brotman et al., 2007).

Atherosclerosis is a chronic inflammatory process involving the progressive recruitment and activation of leukocytes, lipid, platelets, and smooth muscle cells in the endothelial lining of coronary arteries, resulting in the formation of a fibrous plaque that protrudes into the arterial lumen. Atherosclerosis occurs when there is a rupture of vulnerable plaque and consequent activation and aggregation of platelets, leading to the formation of a blood clot (thrombus) that occludes the artery and prevents blood flow to the heart (Hansson, 2005). Some evidence suggests that activation of the SAM and HPA axes may precipitate endothelial dysfunction, which is one of the earliest signs of atherosclerosis (Mangos et al., 2000). Atherosclerosis can also lead to lethal
ventricular arrhythmias. Approximately half of the cardiovascular deaths experienced in the United States annually occur suddenly because of the lethal ventricular arrhythmia (ventricular fibrillation), as the culmination of atherosclerotic plaque/rupture/ischemia/infarction (Sytkowski et al., 1990). Electrical stability and ventricular fibrillation thresholds are influenced by many factors, including the autonomic nervous system. Lowered levels of parasympathetic nervous system tone and increased levels of sympathetic nervous system tone, due to SAM activation, promote ventricular fibrillation in the myocardial tissue at risk.

Acute activation of the SAM and HPA can potentially harm the vasculature by increasing blood pressure, decreasing insulin sensitivity, and activating hemostasis (Brotman et al., 2007). Acute elevations in blood pressure can provoke plaque rupture by disrupting blood flow across the diseased vessel and increasing endothelial shear stress (Steptoe & Brydon, 2007). Decreasing insulin sensitivity may lead to plaque instability as glucocorticoids regulate a number of processes involved in plaque stability including vascular endothelial function and inflammation (Girod & Brotman, 2004). Circulating levels of inflammatory cytokines are also up-regulated during stress, and these molecules play a pivotal role in plaque rupture and thrombosis (Steptoe & Brydon, 2007; Steptoe et al., 2007).

The mechanisms leading from exposure to workplace stressors to CVD are hypothesized to be direct effects on neuroendocrine stress response (SAM and HPA activation) (Chandola et al., 2008).

Relationship between firefighting, work stress, and cardiovascular disease
Firefighting is recognized as one of the most physically demanding and hazardous of all civilian occupations (Kales et al., 2007), including variable working conditions and unpredictable and heavy physical demands (Bos et al., 2004). Typically, the work of emergency responders involves long stretches of relative inactivity, punctuated by unpredictable and stressful bursts of high intensity, and potentially life-threatening activities. The latter produce adrenergic surges and higher demands on the cardiovascular system (Barnard et al., 1975; Kuorinka et al., 1981). These working conditions contain high job demands and low job control, which according to the job strain model, result in jobs strain (Karasek et al., 1990; Schnall et al., 1994), and ultimately an increased risk for CVD (Alterman et al., 1994; Bosma et al., 1997; Johnson et al., 1996). Consistently, evidence that such strenuous stimuli can trigger acute CVD events has been documented in a variety of contexts (Mittleman et al., 1993; Franklin et al., 1996; Wilbert-Lampen et al., 2008). For example, although fire suppression represents only 1-5% of annual professional time among firefighters, fire suppression accounts for over 30% of on-duty CVD deaths (Kales et al., 2007). Thus, the relative risk of on-duty events during fire suppression is 10-100 times higher than that of nonemergency duties. Likewise, alarm response, which results in elevated heart rates and blood pressure through a fight-or-flight response, carries risks of on-duty CVD events on the order of 3-15 times higher than nonemergency duty (Kales et al. 2007; Holder et al, 2006; Kales et al, 2003).

The high demand/low control scenario is not uncommon to the firefighting profession. Firefighting duties such as fire suppression, rescue, emergency medical
services, and fire investigation are very physically and mentally demanding. In addition, firefighters have low control over these duties because of the unpredictability of the occurrence of emergencies. The relationship between work stress, firefighting and on duty cardiovascular events is unfinished business and further research needs to be conducted in this area.

Although physical and emotional stressors activate the same neuroendocrine systems, physical stressors, such as toxins in the air or trauma, are also associated with many other physiological changes (e.g., inflammation, blood loss, and hemostatic activation) that challenge the cardiovascular system. The cardiovascular effect that physical stress has on firefighters has been fairly well documented; however, there is little research on the effect that psychological stress has on firefighters. The effect that psychological stress can have on firefighters must not be undermined as one study demonstrated that emotional stress was a more common precipitant of acute infarction than was physical exertion (Tofler et al., 1990). In this study, the focus will be on the effect that psychological stress has on firefighters’ cardiovascular reactivity in the absence of physical stress.

**Physiological measurements of stress**

Physiological measurements of stress involve measuring changes in the two stress axes (SAM and HPA). Measurements indicating activity in the SAM and HPA axes include, but are not limited to, adrenaline or noradrenaline levels, blood pressure, heart rate variability, cardiac output, electrodermal activity, respiration rate, and cortisol levels.
Activation of the SAM axis can be directly assessed by measurement of peripheral adrenaline or noradrenaline levels (i.e., catecholamines). These, however, are short-acting and short-lived molecules making it difficult for data collection. Conversely, blood pressure, heart rate variability, cardiac output, electrodermal activity (EDA), and respiration rate are indirect measurements of SAM activity, and can be obtained easily and noninvasively.

An elevated blood pressure has been characterized by an increase in sympathetic activity (Grassi et al., 2007) making it a useful indirect measurement of SAM axis activity. Blood pressure has been used as a measure of autonomic nervous system activity in studies assessing the effects of an acute psychological stressor on cardiovascular, endocrine, and cellular immune responses (Sgoutas-Emch et al., 1994), blood pressure reactivity to psychological stress as a predictor of hypertension (Matthews et al., 2004), and blood pressure reactivity to psychological stress and coronary calcification (Matthews et al., 2006). The wide use of blood pressure as a measure of reactivity to stress indicates its usefulness for this study.

Heart rate variability, obtained from electrocardiographic recordings (Akselrod et al., 1981), is a noninvasive correlate of autonomic nervous system tone that is responsive to both acute (Sloan et al., 1991) and chronic (Pardo et al., 1996) stress conditions. Because heart rate variability measure has been demonstrated to predict future cardiovascular events (La Rovere et al., 1998), this tool provides insight into the correlation between stress and CVD.

Activation of the sympathetic nervous system will cause an increase in cardiac
output, making cardiac output a good indicator of SAM axis activity. Cardiac output has been used widely in studies assessing autonomic reactivity to stress (Sherwood et al., 1986, Ohlsson & Henningsen, 1982, Goldstein et al., 1982).

EDA is a widely used index of SAM activity in psychological research and is usually measured by either skin conductance level or non-specific skin conductance responses (Dawson et al., 2007). EDA has been utilized in research examining attention (Naccache et al., 2005), emotion (Bradley et al., 2001), and psychopathology (Strauman, 1989), among other constructs. Activation of eccrine sweat glands is mediated by acetylcholine, a neurotransmitter involved in the peripheral sympathetic system.

The autonomic nervous system also plays a role in respiratory rate with the sympathetic nervous system acting to relax and contract the smooth muscles of the bronchioles and the parasympathetic system acting to contract the smooth muscles of the bronchioles. Increased random respiratory variability has been shown to be characteristic of mental stress (Vlemincx et al., 2011) and panic disorder (Wilhelm et al., 2001). A study by Vlemincx and colleagues (2012) assessed whether respiratory variability was a stable marker of mental stress with mental arithmetic as the stressor. Sigh frequency was significantly increased during the mental stress tasks compared to baseline (p<0.0001). Additionally respiratory variability was significantly higher during the mental stress tasks compared to baseline (p<0.01). These results suggest that respiratory variability is a stable marker of mental stress.

Activation of the HPA axis can be determined by the measurement of cortisol levels. Stressful stimuli activate the HPA axis and cause an increase in peripheral
cortisol. Cortisol can affect physiological changes that encompass most of the main organ systems, and help to provide the energetic resources needed to face acute stressors. Cortisol also helps to modulate and contains other components of the physiological stress response (Sapolsky, 2000). Salivary free cortisol has been shown to be a reliable and valid measure of the biologically active plasma unbound cortisol, with correlations of $r = 0.90$ (Kirschbaum and Hellhammer, 1989; Lac, 2001).

**Subjective measurements of stress**

There are numerous means to measure psychological stress subjectively. Two means that will be discussed are the NASA Task Load Index (TLX) (Hart & Staveland, 1988) and the Affect Grid (Russell et al., 1989).

**NASA Task Load Index**

The NASA-TLX is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of ratings on six subscales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration (Hart & Staveland, 1988). The NASA-TLX can be applicable in complex real-word tasks. A major goal of work psychology is the analysis of task demands in order to design jobs that bring about a lower mental workload. This in turn will lead to lower stress levels and accident rates, and to a decrease in the likelihood of errors. Additionally, in respect to firefighters, lower stress levels could help reduce risk for cardiovascular events while on duty. Workload evaluation, therefore, is important.

A study conducted by Rubio and colleagues (2004) evaluated three different methods to measure subjective mental workload: NASA-TLX, subjective workload
assessment technique (SWAT), and Workload Profile. The three techniques were compared with respect to the following issues: intrusiveness, sensitivity, validity, diagnosticity, implementation requirements, and operator acceptability. The study yielded a very high correlation coefficient (near to 1) between the three measures; hence, there was high convergence validity between them. Additionally, for the NASA-TLX, the Pearson correlation coefficient between global workload scores and performance was high (r=0.653, p<0.01) indicating strong concurrent validity. In the conclusion of their study, recommendations were given to use the NASA-TLX if the goal is to predict the performance of a particular individual in a task.

Xiao and colleagues (2005) assessed the reliability and validity of the NASA-TLX and SWAT. The re-test reliability coefficients of the two scales and their items ranged from 0.516 to 0.753 (p<0.01), indicating good re-test reliability. Both the split-half reliability and Cronbach’s alpha coefficient for the NASA-TLX were greater than 0.80 and the correlation coefficients between its items score and total score were all more than 0.60 (p<0.01) except the item of performance. Additionally, the Pearson correlation coefficient between the two scales was 0.492 (p<0.01), implying consistency between results of the two scales. In conclusion, the NASA-TLX had good reliability and validity and can be used as a valid tool to assess mental workload.

**Affect Grid**

The Affect Grid (Russell et al., 1989) was designed as a quick means of assessing affect along the dimensions of pleasure-displeasure and arousal-sleepiness; it has been found to be a moderately valid measure of pleasure and arousal (Killgore, 1998). The
Affect Grid is brief and easy to fill out and, therefore, can be used rapidly and repeatedly. Participants rate their feelings to a certain stimulus by placing an “X” in the position within a 9 x 9 matrix that best represents their emotional state along pleasure (horizontal) and arousal (vertical) dimensions. The axes of the matrix are labeled to represent various states of arousal and pleasure (Russell et al., 1989). The selected position of the “X” is translated into a measure of arousal and pleasure on scales of one to nine.

The Affect Grid has been used in a variety of settings including decision making (Menon & Kahn, 2002) and assessing the role for the human amygdala in recognizing emotional arousal from unpleasant stimuli (Adolphs et al., 1999).

Killgore (1998) assessed the validity of the Affect Grid as a measure of pleasure and arousal. Scores on the Affect Grid were obtained from 284 college students and correlated with scores on the Beck Depression Inventory, Positive and Negative Affect Schedule, and the Profile of Mood States. Factor analytic and correlational findings suggested that the Affect Grid is a moderately valid measure of the general dimensions of pleasure and arousal. Although the Affect Grid was found to be only moderately valid, it has value in its brevity and ease of administration and therefore useful in situations where more time-consuming measures would not be appropriate.

**Laboratory stress tests**

Laboratory studies have utilized a range of stressors that differ to the extent that they elicit psychological versus physical stress. Firefighters experience both psychological and physical stress on the job, but in this study, the focus is on
psychological stress and the physiological affects it has on firefighters. The review, therefore, will focus on psychological stressors.

Psychological stressors may be nonsocial or social in nature. Nonsocial psychological stressors include, but are not limited to, mental arithmetic (e.g., serial subtractions), mirror tracing (e.g., tracing a star looking only at its reflection in a mirror), reaction time (e.g., pressing a button rapidly in response to specific stimuli), the Color Word Stroop Test (CWST), video games, puzzle-solving tasks (e.g., anagrams), and films (often consisting of graphic footage). Social stressors include speech stressors (preparing and presenting a speech) and interviews designed to elicit general or specific emotional responses, as well as tasks intended to mimic “real world” social interactions, such as discussions of current events and role-playing tasks involving interpersonal conflict.

For the purpose of this study, nonsocial cognitive stressors, in particular, the CWST, mental arithmetic, and puzzle-solving (e.g., anagrams) will be discussed in further detail.

**Color Word Stroop Test (CWST)**

The Color Word Stroop Test (CWST) is a psychological test of mental vitality and flexibility. The CWST demands that the color of a word designating a different color be named (Stroop, 1935). The cognitive mechanism involved in this task is called directed attention, the subject will have to manage attention by inhibiting one response in order to say or do something else.

The CWST has been utilized as a psychological or cognitive stressor because of
its capability to induce emotional responses and heightened levels of physiological, especially autonomic reactivity. This application is currently found in stress and psychophysiological research (Collins and Franeknhaeuser, 1978; Forsman and Lindbald, 1983; Lawler and Schmied, 1986; Graham et al., 1996).

A study completed by Renaud and Blondin (1997) assessed heart rate, frequency of skin conductance responses, and self-reported anxiety during performance of a computerized version of the CWST, and during a non-conflicting control task involving the color naming of color patches. The CWST and control stimuli were presented individually in order to vary task pacing. Subjects (n=48) were divided into three groups assigned to self-paced, externally-paced, and fast externally-paced conditions. Performance data revealed that the relative proportion of speed and accuracy reductions which resulted from the CWST interference varied according to task pacing and pacing speed. CWST performance was accompanied by heightened HR levels (p<0.001), which were sustained through the series. State-Anxiety scores increased after both tasks (p<0.001), but only among subjects who completed a large number of trials, i.e., subjects in the self-paced and fast externally-paced groups. Skin conductance responses only varied according to task order and time within series, irrespective of CWST interference or task pacing. It can be concluded from this study that the CWST affects physiological and emotional responses.

Fauvel and colleagues (Fauvel et al., 1996) researched the reproducibility of cardiovascular reactivity to a computerized version of the CWST. The 1-month reproducibility of hemodynamic and sympathoadrenal responses to this computerized
version of the CWST was studied in 10 normotensive and 10 hypertensive individuals. Three-way analysis of variance (stress, session, blood pressure) revealed significant increases in systolic (p<0.0001) and diastolic (p<0.0001) blood pressures and in HR (p<0.001) during the stress test, indicating sympathetic excitation. Test-retest correlation coefficients for basal stress levels and stress-induced variations were significant (r from 0.59 to 0.88). The stress test induced significant increases in urinary noradrenaline excretion (p<0.01) with large intra- and inter-individual variability, also indicating increased sympathetic activity. The significant test-retest correlations and the lack of period effect for hemodynamic parameters indicated good temporal stability, but a slight decrease in stress-induced reactivity was observed.

Another study assessed physiological responses to both the CWST and mirror tracing (Steptoe et al., 2001). The influence of acute mental stress on cardiovascular responses was assessed in 12 subjects exposed to stress and in eight control subjects. The tasks were rated as stressful by the participants. Also, the stress group showed significant increases in systolic and diastolic blood pressure and heart rate (P<0.001). The increases in blood pressure and heart rate were comparable with those recorded previously using these stimuli (Steptoe et al., 1999; Steptoe et al., 1996).

The CWST has demonstrated a clear effect on cardiovascular reactivity, making it a useful tool for this study.

**Mental arithmetic task**

A mental arithmetic task is widely accepted as a mental stressor (Carter et al., 2005; Condren et al., 2002). Although there are variations of the mental arithmetic
task, it usually requires serial subtraction of a given number from a randomly selected 4-digit number.

Noto and colleagues (2005) demonstrated the usefulness of mental arithmetic as a laboratory stressor. They studied the relationship between salivary biomarkers and State-Trait Anxiety Inventory score (STAI-s) under mental arithmetic stress. The participants were confronted with a mental arithmetic task of 15 min duration. The task required serial subtraction of 13 from a randomly selected 4-digit number shown on a computer screen. Volunteers were instructed to answer verbally at each subtraction. After confirming that the answer was correct, another subtraction of 13 from the correct number of the previous trial shown on the screen was preformed. The data showed that a 15-minute mental arithmetic task significantly increased both heart rate and STAI-s score (p<0.01), with a good correlation between the two measures (r=0.449; p<0.05). This study shows a mental arithmetic task is useful in inducing psychophysiologi- cal stress given the relationship between the STAI-s score and increased heart rate.

Anagrams

An anagram is a type of word play, the result of rearranging the letters of a word or phrase to produce a new word or phrase, using all the original letters exactly once (e.g. orchestra = carthorse).

Anagrams have been used as stressors in various realms of research. They have been used in examining the relationship between neuroticism and coping (Boyes & French, 2010) and in determining whether emotional intelligence may predict stress
responses and coping strategies (Matthews et al., 2006). Additionally, anagrams have been used in assessing glycemic control (Blair et al., 1991) and the relationship between problem solving efficiency and cardiovascular responses (Schijndel et al., 1985).

Blair and colleagues (1991) used an active coping task (computerized version of anagrams, mental arithmetic, and Atari games) and a passive coping task (cold pressor) to measure the effect of laboratory stressors on glycemic control and gastrointestinal transit time. Cardiovascular and catecholamine responses were measured in addition to measurements of glycemic control and gastrointestinal transit time. As expected, cardiovascular responses (i.e., heart rate and blood pressure) were heightened during stress conditions compared with the nonstress condition (p<0.001). The computerized task, which included anagrams, elicited significantly greater increases in diastolic pressure than nonstress (p<0.001) and significantly greater increases in heart rate than nonstress (p<0.001). This study demonstrates the ability for the anagram task to elicit a cardiovascular response.

There are numerous studies that examine physiological reactivity to low-level stressors like the CWST, arithmetic tasks, and anagrams. These approaches lend themselves to tight experimental control, but their generalizability to "real world" stress is questionable. Another way of saying this is that although such stressors are highly reliable, they are questionable in terms of their external validity as markers of response to real life stressors such as fires and car accidents, in the case of firefighters. Ideally, a study of firefighters and their responses to work-related stress would involve
an actual stressful work-related situation. However, this is neither practical nor ethical, as it would compromise the safety of the firefighters, experimenters and potentially civilians. An alternative to using a real situation is through the use of virtual reality.

**Virtual reality as a stressor**

The use of virtual reality (VR) can help maximize the external validity that the laboratory psychological stressors lack. VR has become mature enough to be used successfully in clinical applications such as exposure therapy (Côté, 2005), pain distraction (Schmitt et al., 2011) and neuropsychological assessment (Weniger et al., 2011).

Hemmeter and colleagues (2005) showed that immersive VR systems could serve as a powerful tool for simulating stressful scenarios close to reality. Hemmeter’s study evaluated cortisol secretion as an indicator of stress within a virtual reality environment. Ninety-four healthy subjects were subjected to a VR environment and a cognitive stress task. All subjects were randomly assigned to one of four different groups: Group 1 underwent a control condition using a static VR, without cognitive stress; Group 2 underwent a concentration speed task including aspects of divided attention, also using the static VE; Group 3 used a dynamic VR environment that performed yaw, pitch and roll movements with a frequency of 2 Hz, without cognitive stress; and Group 4 used the same dynamic VR environment as group 3, combined with the cognitive stress situation used in group 2. The cognitive stress task consisted of three three-dimensional items that randomly showed up within the participants’ field of vision. If a black object appeared, no actions were required of the participants.
When colored objects appeared, the participants had to press the upper button of the input device, and when gray figures appeared, participants were required to press the lower button of the input device. Subjects were advised to react as fast and correctly as possible. In pretests, this condition had been rated as quite stressful. The aim of this study was to test whether the modification of reality induced by dynamic VR as opposed to static VR could be regarded as a stressor. Additionally, they tested whether VR could modify an additional cognitive stress response. A significant cortisol increase ($p<0.01$) was observed only after the combined application of both conditions, but not after the dynamic VR or the cognitive stress alone. They concluded that tasks requiring the modification of reality impression combined with effort-demanding tasks comparable to intensified daily life demands may induce secretion of cortisol. This provides the basis for the application of VR in research assessing HPA axis regulation.

Turner and colleagues (1997) completed a virtual reality car-driving stressor on two occasions several weeks apart. Immediately prior and throughout task performance, blood pressure, cardiac output, and total peripheral resistance were assessed. The amount of hemodynamic responsivity elicited by the task, was ultimately addressed via one-tailed paired $t$ tests comparing baseline and task values. Collectively, the results indicated statistically significant increases from baseline on all four parameters (all $p<0.05$). Test-retest reliability was addressed via Pearson product-moment correlation coefficients. For reactivity scores, all coefficients were significant at least at the $p<0.05$ level, whereas for task levels, all parameters were significant at $p<0.001$. Additionally, the simulation was shown to be realistic as indicated by high
levels of self-reported task realism, engagement, excitement, and nervousness. These findings suggest that a virtual reality stressor is a suitable means to study cardiovascular responses to stress.

Lastly, VR has been used successfully as a tool for Stress Inoculation Training (SIT). The concept behind SIT, developed in the late 1970s by Donald Meichenbaum (Meichenbaum, 1977), is to prepare individuals for stressful situations. SIT is accomplished through gradual, controlled, and repeated exposure to a stressor. The goal behind this exposure is to desensitize or “inoculate” the person to the possible stimuli of a stressful situation in order to avoid a “fight or flight” response (i.e., activation of the SAM and HPA axes) to the real thing. This repetition allows the individual to become able to calmly and accurately accomplish the tasks at hand in a stressful environment. A study conducted by Stetz et al. (2007) used SIT in the context of VR for military personnel in combat training in Iraq. Additional Wiederhold & Wiederhold (2004) established SIT through the use of a laptop simulator to train military personnel for stressful situations.

Both of these studies show that the VR can be a very resourceful tool in creating stressful scenarios. More detail on these studies can be found in the discussion section. These studies show that VR has become mature enough to be used successfully in creating stressor scenarios and therefore should be useful for creating an occupationally relevant stressor for firefighters.

VR typically refers to projection surfaces where stereo graphics are used with three-dimensional viewing and input devices such as shutter glasses and data gloves.
For the purpose of this study, VR will be defined as three-dimensional computer-generated graphics that are displayed large enough to encompass a majority of the user’s visual field and controls allowing users to interact with the system, thereby creating a virtual world that users are likely to experience as if they are inside it. Immersion, presence, situation awareness, and understanding the limitations of VR simulation are all required in order for this simulation to be successful. This study will use a system known as the C6, which will address these elements. The C6 is located at the Virtual Reality Application Center at Iowa State University (VRAC), and is a six-sided immersive system in which a participant is fully enclosed with 10’ x 10’ screens. Each screen projects representations with a resolution of 4,000 x 4,000 pixels, which is over twice the resolution of high-definition television. In addition, the C6 incorporates a three-dimensional eight-channel surround sound system. All of these elements help create a sense of immersion.

VR allows a degree of control and manipulation impossible in the real world while still allowing for a level of realism not usually attained in the laboratory. For this reason, virtual reality can be a useful tool in studying the affects of occupationally relevant stress on firefighters.

**Conclusion**

A review of the literature suggests that stress, through its varied biological consequences, may be an important mechanism underlying an on-duty firefighter’s increased risk for cardiovascular events. Conventional risk factors cannot fully account for the increased CVD risk in this population. Further research needs to be conducted
on firefighters and their responses to stressful scenarios to determine whether stress indeed plays a significant role. There are numerous ways in which to induce stress, and laboratory stress tests seem capable of eliciting a significant level of stress. Laboratory stress tests do not, however, present real life situations and therefore lack external validity. Through the use of VR, a stress response can be produced in a more realistic situation (i.e., fire scenarios) and increase external validity without compromising the safety of the participants involved. The purpose of this study is to validate an occupationally-relevant VR stressor as a means to induce acute stress in firefighters. The occupationally-relevant stressor will be compared to previously validated laboratory stressors (i.e. Stroop test, mental arithmetic, anagrams) to determine validity.
CHAPTER 3: MATERIALS AND METHODS

General experimental design

In this study, participants underwent two different stressor scenarios in a virtual reality environment (VRE): an occupationally-relevant stressor (ORS), and a laboratory stressor (LS). The ORS consisted of two different fire scenes, while the LS included the Color Word Stroop Test (CWST), anagrams, and mental arithmetic. Firefighters’ physiological and subjective stress responses were then compared between these two stressors.

Virtual reality environment (VRE)

The VRE was in the C6 simulator located in the VRAC on Iowa State University’s campus. The C6 provides an intensely detailed, high-resolution, immersive, and life-like experience.

Both the ORS and LS took place in the C6 as 3-dimensional VRE’s. In the C6 care was taken to ensure that the firefighters could mimic natural behavior at fire scenes. The subject could control and interact with the VRE through wand commands and movements within the VRE. The location of the subject was tracked continuously for accurate three-dimensional positioning of the simulation and to ensure that an accurate perspective of the environment was presented to the firefighter in real-time.

Occupationally-relevant stressor (ORS)

Before participating in the ORS, the firefighter underwent a brief orientation on how to move and operate within the VRE. The orientation consisted of navigating through a three dimensional maze, where the participant was required to turn,
maneuver and respond to the VRE. Additionally, the participant completed a scenario in which they were required to select a car and bicycle from a variety of options. This scenario was designed to orient the participant on how to use the wand, or the handheld device, used to communicate with the VRE as well as the decision matrix.

During the ORS, the firefighters engaged in a scenario incorporating two different stressful fireground scenarios. During this session, the firefighter was able to communicate with a virtual incident commander (VIC) and other firefighters using a virtual decision matrix and the wand. The VIC was established through automated, prerecorded radio traffic that covered all potential communication traffic. The wand allowed the firefighter to “push” virtual buttons on the decision matrix to establish inquiries from the VIC.

The two different ORS scenarios were a pre-backdraft scenario and a pre-flashover scenario. The first scenario [pre-backdraft (Cote, 2004, pp. 123-199)] was a static situation in which conditions did not change until an action was taken. The participant approached a virtual house with varying cues of pre-backdraft conditions. Examples of cues that indicated pre-backdraft conditions were windows that were covered from the inside with a black coating from smoke particles, a red glowing door knob, smoke pushing through windows and doors cracks, and the absence of flames. The firefighter had time to inspect the area and then used the virtual decision matrix to make a choice on how he would respond to the situation.

In the second scenario, the environment was changed to a more time-intensive attack scenario. The pre-flashover scenario was a dynamic situation in which the
firefighter was located in the house. While in the house, the firefighter experienced time pressure, inferred by the speed at which smoke began to accumulate downward from the ceiling. Again, the firefighter chose how he would respond to the scenario via a virtual decision matrix. These scenarios were meant to be lifelike and to induce a psychophysiological stress response similar to that in real fire situations.

**Laboratory stressor (LS)**

Participants went through a brief training session prior to involvement in the LS, where they were given voiceover instructions for each of the three stress scenarios within the LS and 2 minutes of practice for each scenario.

The LS was performed in the VRE and was a combination of cognitive tasks. Here the participant performed a continuous cycle of the following stressors: (1) the Color-Word Stroop Test (CWST), (2) an anagram task, and (3) a mental arithmetic task. These tasks are well-established stressors with known response characteristics (Boyes & French, 2010; Renaud & Blondin, 1997; Acevedo et al., 2006). The firefighters performed these stressors in a standing position to match the firefighters’ position in the ORS. Each of the stressors lasted 2 minutes and continued to cycle through until the firefighter either reached 10 minutes or matched their time in the ORS. The LS scenario was matched for time to the ORS scenario. Thus, the length of time in the LS was dependent on the order in which the firefighter completed the stressor scenarios.

Previous studies showed that the average completion time (+3 SD) for the ORS was ~10 minutes (Bayouth, 2011); therefore, the firefighters underwent the LS for 10 minutes if it was performed first. If the LS was performed second, then the firefighter underwent
the LS for the amount of time it took him to complete the ORS. The stressors were slightly modified during subsequent cycles to maintain task novelty. For instance, participants were given different anagrams to solve for the anagram task and different subtraction problems in the mental arithmetic task.

**Color Word Stroop Test (CWST)**

The CWST consists of naming the ink-color of color words under conditions where word meanings and ink colors either mismatch or are incongruent (e.g., the word *red* is displayed in the color green). The protocol for the CWST was a modification of a computerized version used previously (Renaud and Blondin, 1997).

Voiceover instructions for the CWST were as follows: “For this task you will be presented with a color word on this projection screen. You are asked to identify the font color in which the word will be presented. You must respond quickly because a new color word will appear approximately one-second later. The colors you will identify are yellow, green, blue, and red. The keyboard in front of you has designated the “y” button for yellow, the “g” button for green, the “b” button for blue, and the “r” button for red. Press the button on the keyboard that corresponds with the color of the word on the projection screen. This will last for 2 minutes after which you will proceed to the next task. Try to respond as quickly and accurately as possible. We will be recording the number of colors you correctly identify.”

The projection screen provided instant, continually updated feedback on the number of correct and incorrect responses and a countdown clock on the screen portrayed the amount of time left to respond. Additionally, a loud unpleasant noise was
triggered with every incorrect response and a pleasant ding was triggered with every correct response. The words were presented individually on the screen and disappeared after 1100 milliseconds. The participant had to respond within this time. The next word was presented immediately after the image disappeared.

**Mental Arithmetic**

The arithmetic task consisted of subtracting a two-digit number from a four-digit number (Acevedo et al., 2006).

Voiceover instructions for the mental arithmetic task were as follows: “For this task you will be presented with a formula in which you will subtract a two-digit number from a four-digit number. Type your response to the formula using the number pad on the keyboard in front of you, then press enter. After entering your response, you will be informed of whether you are correct or incorrect. In either case, the correct answer will be presented, and you will be asked to subtract the same two-digit number from this new four-digit number. This sequence will continue for two minutes after which you will proceed to the next task. Try to work as quickly and accurately as possible. We will be recording the number of problems you answer correctly and incorrectly.”

The participant was given a maximum of 7 seconds to enter his solution in the computer. If he exceeded this time, the projection screen automatically displayed the next number to subtract from. A countdown timer was visible on the projection screen so that participant was aware of the time he had to respond. Additionally, a loud unpleasant noise was triggered with every incorrect response and a pleasant ding was triggered with every correct response.
Anagrams

The protocol for the anagram task was a modification of that used by Boyes & French (2010).

Voiceover instructions for the anagram task were as follows: “For the anagram task you will be given a series of anagrams to solve. An anagram is a word formed by rearranging the letters of a scrambled word. For this task, a scrambled word will appear on the projection screen. Unscramble the word and type your solution into the keyboard in front of you and press enter. All anagrams in this task only have a single correct solution. You must complete the anagrams in the order provided and within the time allotted. The amount of time allowed per anagram ranges from 10 to 160 seconds. The time will be displayed on the screen and you must type in your response within that amount of time. The projection screen will automatically go to the next anagram if you fail to enter your solution within the time allotted. The screen will display the number of correct and incorrect responses so that we know the number you answer correctly. This task will last for 2 minutes.”

The anagrams used in this study were sourced from Tresselt and Mayzner (1966), who provide normative solution times for a sample of 134 words and 378 associated anagrams. The anagrams chosen for this study had average solution times between 10 and 160 seconds. The participant was given the corresponding average solution time to solve each anagram. Appendix G provides the anagrams used in the anagram task and their average solution times.
Participants

Participants were 14 male career and volunteer firefighters with varying years of experience (6.6±3.7 yrs). Ranks among the firefighters consisted of firefighter (n=2), firefighter-paramedic (n=6), firefighter-EMT (n=2), lieutenant (n=3), and chief (n=1). Participants were recruited through a recruitment script (Appendix A) sent via e-mail to firefighters in the Ames, IA area. The criteria for participation were that they had to be an active duty firefighter, apparently healthy with no history of cardiovascular or endocrine disease, not color blind, and not subject to motion sickness. Each subject came to the Virtual Reality Applications Center (VRAC) on Iowa State University’s campus. They were told to abstain from eating and drinking three hours prior to arrival at the VRAC except water. In addition, they were asked to refrain from exercise, alcohol, and tobacco 12 hours prior to arrival. The firefighters underwent two separate stressor scenarios: a virtual reality occupationally relevant stressor (ORS) and a virtual reality laboratory stressor (LS). Written and signed informed consent from each participant was obtained prior to participation in this study.

Protocol

Upon arrival, participants completed a medical history and a global measure of chronic stress [Perceived Stress Scale (Cohen, 1983)]. Height was measured using a stadiometer and weight was measured with a digital scale. Additionally, participants were questioned on whether or not they were color-blind.

Next, the participant was instrumented for the continuous assessment of heart rate (HR) (3-lead ECG), stroke volume (SV) (impedance cardiography), respirations
(respiration transducer), and electrodermic activity (EDA) (EDA finger transducer). These were measured using wireless Bionomadix hardware (Biopac, Aero Camino Goleta, CA). The participants were also instrumented for continuous assessment of beat-by-beat mean arterial pressure (MAP), which was measured using a CNAP\textsuperscript{TM} Monitor 500 (CNSystems Medizintechnik AG, Austria). Respiration rate was acquired at 125 Hz. MAP, HR, and EDA were acquired at 500 Hz, and all other data were acquired at 1000 Hz. All physiological data was acquired in real-time using Acqknowledge 4.2 software (Biopac, Aero Camino Goleta, CA).

Following instrumentation, participants rested for 20 minutes before undergoing the stressors. After 5 minutes seated rest, the participants stood quietly for 15 minutes. The last 5 minutes of rest consisted of completing a low cognitive challenge [i.e., simple arithmetic (Fishel et al., 2007)] (Appendix B). During the first 3 minutes of standing rest, cardiac output was measured using a noninvasive inert gas re-breathing technique (Innocor, Atlanta, GA). This measurement was used to standardize SV measurements obtained from the impedance cardiography.

After 20 minutes rest, the participant underwent the stressor scenarios. The stressor scenarios were administered in a counterbalanced randomized design, so participants performed either the LS or the ORS first, depending on what was assigned as the first stressor. After the first stressor was performed, the firefighter rested by sitting quietly for 15 minutes to obtain a second baseline (baseline II). After baseline II, the firefighter underwent the second stressor scenario.
Data collection

Physiological assessments

Physiological assessments of HR, SV, beat-by-beat MAP, respirations, and EDA were collected continuously throughout the entire session. CO was calculated using the measured HR and SV (CO=HRxSV). TPR was determined using the calculated CO and corresponding MAP (TPR=CO/MAP). PEP was determined as the interval from the peak of the Q-wave of the electrocardiogram to the B-point of the first derivative of the impedance signal.

Subjective assessments

Subjective assessments of affect and workload estimate were assessed after each stressor scenario. To measure affect, the Affect Grid was used in order to assess participants’ feelings of pleasure and arousal in response to the stimuli (Russell, 1989). The Affect Grid was designed to assess affect along the dimensions of pleasure-displeasure and arousal-sleepiness and has been found to be a valid measure of pleasure and arousal (Russel, 1989). The Affect Grid showed strong evidence of convergent validity with other measures of pleasure and arousal and showed strong evidence of discriminant validity between the dimensions of pleasure and arousal. Aggregated affective judgments gathered with the Affect Grid appeared to be reliable (Russell, 1989). Participants were asked to rate their feelings during the stressor by placing an “X” in the position within a 9 x 9 matrix that best represented their emotional state along pleasure (horizontal) and arousal (vertical) dimensions (see Appendix G). The axes of the matrix were labeled to represent various states of arousal.
and pleasure (Russell et al., 1989). The selected position of the “X” was translated into a measure of arousal and pleasure on scales of one to nine.

The NASA Task Load Index (NASA-TLX) was used to assess workload estimates (Hart & Staveland, 1988). The NASA-TLX is a multi-dimensional rating procedure that provides an overall workload score based on the weighted average of ratings on six subscales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration. The closer the workload score is to 100, the higher the perceived workload. A definition of each subscale was provided for the participants (Appendix E). The participants were asked to mark an “X” on each of the six scales at the point that matched their experience (see Appendix H). Each scale was presented as a 12-cm line divided into 20 equal intervals anchored by bipolar descriptors (e.g., HighLow). The 21 vertical tick marks on each scale divided the scale from 0 to 100 in increments of 5. If a subject marked between two ticks, the value of the right tick was used (i.e., rounded up). After the study was completed, the participants marked a rating on each scale, they were presented with a series of 15 pairs of rating scale titles (Appendix F) (for example Effort vs. Mental Demands) and asked to choose which of the items was more important to their experience of workload in the tasks they performed.

Data analysis

Physiological data

In this study, changes from baseline in HR (bpm), SV (mL), CO (L/min), TPR (mmHg/L/min), PEP (sec), and MAP (mmHg) were used to assess stress-induced arousal of the sympathetic nervous system.
This study was separated into 4 different phases for data analysis purposes: baseline, LS, ORS, and baseline II (the 15 minute rest interval between the LS and ORS). To assess SV responses, impedance cardiography (ICG) analyses were made using AcqKnowledge software (Biopac) for all 4 phases. Data for the LS, ORS, baseline, and non-intervention periods were then reduced to discrete mean 10-second intervals.

Baseline and baseline II measures were determined by taking the mean of each physiological variable (HR, SV, CO, TPR, PEP, and MAP) for the last 5 minutes of these periods. Similarly, the mean value for each variable was determined for the entire duration of the ORS and LS interventions. Paired t-tests were made for HR, SV, CO, TPR, PEP, and MAP to compare baseline vs. baseline II and to compare LS vs. ORS interventions. Appropriate post hoc tests were made to control for Type II error.

To assess physiological changes from baseline and over the course of the two stressors, mean physiological values over 20 second time periods were determined at 5 different time points within the LS and the ORS (baseline, 0%, 25%, 50%, 75%, and 100% of time in the scenarios). Because each participant spent a different amount of time in the LS and the ORS scenarios, time was expressed as a percentage in order to normalize for this difference in duration. A two-way repeated measures analysis of variance (ANOVA), with Intervention (ORS vs. LS) and Time Point (baseline, 0%, 25%, 50%, 75%, 100%) as the independent variables, was conducted on the values of all the cardiovascular measures: MBP, HR, SV, CO, TPR, and PEP. When the overall F-value was significant, the location of these differences were located using the Student-Newman-Keuls post hoc test.
A repeated measures ANOVA with intervention (LS vs. ORS) and order of intervention (1st vs. 2nd) as the independent variables was performed to assess whether there was an effect due to the order in which the stressors were administered.

**Subjective data**

*NASA Task Load Index (TLX).* Twenty-step bipolar scales were used to obtain ratings for each of the 6 dimensions in the NASA-TLX (mental demand, physical demand, temporal demand, performance, effort, and frustration). A score from 0 to 100 (assigned to the nearest point 5) was obtained on each scale. A weighting procedure was used to combine the six individual scale ratings into a global score. To determine a weight for each subscale, the participant performed a paired comparison task in which they had to choose which dimension was more relevant to workload across all pairs of the 6 dimensions. The number of times a dimension was chosen as more relevant was the weighting of that dimension scale. A workload score from 0 to 100 was obtained for each stressor scenario by multiplying the weight by the individual dimension scale score, summing across scales, and dividing by 15 (the total number of paired comparisons). A paired t-test was utilized to determine if there was a difference between the LS and the ORS in the average workload scores.

*Affect Grid.* A score ranging from 1 to 9 was obtained for two separate variables (pleasure and arousal) for both the LS and the ORS. The selected position of the “X” on the Affect Grid was translated into measure of arousal (vertical axis) and pleasure (horizontal axis). A score of 1 indicated a low level of pleasure/arousal, while 9 indicated a high level of pleasure/arousal. Paired t-tests were used to determine if
there was a difference between the LS and the ORS in average pleasure scores and in the average arousal scores.

SPSS software was used to perform all physiological data analyses, while Excel software was used to perform all subjective data analyses. Significance was set at $P<0.05$ and all values are presented as means $\pm$ SD.
CHAPTER 4: RESULTS

Participants

The participants in this study were 14 male Caucasian firefighters among which 6 were firefighter-paramedics, 3 were lieutenants, 2 were firefighter-EMTs, 2 were firefighters, and 1 was a chief. Years of experience ranged from 1 to 14 years with a mean of 6.6 ± 3.7 years. The age, weight, and height were 32 ± 6 years, 183.1 ± 29.8 lbs, and 70.9 ± 3.4 inches, respectively. The medical history forms completed by the firefighters prior to participation indicated no medication use or history of cardiovascular or endocrine disease that would alter the physiological responses that were measured. The Perceived Stress Score (PSS) for the firefighters was 21.6 ± 5.3 which is slightly higher than that of the average male population PSS of 18.8 (n=949; Cohen and Williamson, 1988).

Subjective measures

As indicated by the Affect Grid, mean “Pleasure” scores on a scale of 1 to 9 (1=pleasure, 9=displeasure) were 5.1 ± 2.6 for the LS and 7.7 ± 1.0 for the ORS (p<0.05). Mean “Arousal” scores on a scale of 1 to 9 (1=sleepy, 9=aroused) were 6.6 ± 1.8 for the LS and 6.6 ± 1.7 for the ORS. The mean workload score, as measured by the NASA-TLX, was 75.6 ± 13.2 in the LS and 45.4 ± 16.8 in the ORS (p<0.0001).

Physiological measures

Comparisons of the physiological responses of HR, MAP, PEP, SV, CO, and TPR in the baseline and baseline II periods indicated no significant differences between PEP, SV, CO, and TPR. However, significantly lower HR (p<0.0001), and MAP (p<0.01) values
were seen in the baseline II period than the baseline. A paired t-test comparing mean physiological responses to the LS and ORS scenarios indicated no significant differences between HR, MAP, PEP, SV, CO, and TPR. Mean MAP in the ORS (122±23 mmHg) was higher than the mean MAP in the LS (110±25 mmHg), and although not statistically significant (p=0.132), suggests a trend towards a higher MAP in the ORS. No significant order of intervention effect on any data was found. Table 1 presents mean physiological responses in the baseline, non-intervention, LS and ORS.

There were no statistical differences in the time course of any of the physiological responses to LS vs. ORS. Additionally, no significant interaction was found between Time Point and LS vs. ORS for all physiological data. Lastly, no significant difference in mean values of MAP, PEP, SV, CO, or TPR was found during the different levels of Time Point. However, there was a significant increase in HR from baseline to 0% (p<0.05), 25% (p<0.001), 50% (p=0.001), 75% (p<0.001), and 100% (p<0.001).

Also, there appeared to be a trend in decreased TPR from baseline throughout the journeys of both the LS and ORS (p=0.113). Figures 1-6 display HR, MAP, PEP, CO, SV, and TPR respectively for both the LS and ORS over the course of their journeys (i.e., at baseline, 0%, 25%, 50%, 75%, 100%).
Table 4.1. Mean physiological responses of firefighters during baseline and baseline II

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<th>SV (mL)</th>
<th>CO (L/min)</th>
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*Significant difference between non-intervention and baseline (p<0.05)
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Table 4.2. Mean physiological responses of firefighters during LS and ORS
Figure 4.1. Heart rate (HR, bpm) as a function of time in LS and ORS (time expressed as % of time in stressor)

* Significant difference from baseline in both the LS and ORS (p<0.05)
Figure 4.2. Mean arterial pressure (MAP, mmHg) as a function of time in LS and ORS (time expressed as % of time in stressor)
Figure 4.3. Pre-ejection period (PEP, sec) as a function of time in LS and ORS (time expressed as % of time in stressor)
Figure 4.4. Cardiac output (CO, L/min) as a function of time in LS and ORS (time expressed as % of time in stressor)
Figure 4.5. Stroke volume (SV, mL) as a function of time in LS and ORS (time expressed as % of time in stressor)
Figure 4.6. Total peripheral resistance (TPR, mmHg/L/min) as a function of time in LS and ORS (time expressed as % of time in stressor)

[Graph showing the variation of TPR over time in LS and ORS]
CHAPTER 5: DISCUSSION

The purpose of the current study was to compare the responses to an occupationally-relevant stressor (ORS) in a virtual reality environment (VR) to a group of well-established laboratory stressors (LS). This study hypothesized that the ORS would be as effective in eliciting a stress response in firefighters as a LS.

Results in this study revealed that firefighters had similar physiological stress responses (i.e., change in HR, MAP, SV, CO, PEP, and TPR) in the ORS as in the LS. There were no significant differences in the physiological responses between the two scenarios suggesting that the ORS is at least as stressful as the LS in terms of physiological responses. Mean MAP in the ORS (122mmHg) was higher than the mean MAP in the LS (110 mmHg), and while not statistically significant (p=0.132), there was a modest trend towards a higher MAP in the ORS. This trend suggests there may have been heightened sympathetic activation in the ORS in comparison to the LS.

Physiological responses to stress may vary depending on how the stressor is perceived by the person experiencing the stressor. A stressor can be viewed as either a “challenge” or as a “threat,” and evaluations of personal resources and situational demands determine to what extent an individual experiences the psychological states of challenge versus threat. Challenge occurs when evaluated resources meet or exceed evaluated demands, whereas threat occurs when demands exceed resources. Challenge results in SAM axis activation, which lowers TPR and increase CO. Threat results in SAM and HPA activation, which produces an opposite effect of increased TPR and lower CO (Seery, 2011). With the findings in this study, there was large variability in the data,
but no robust challenge or threat responses.

Subjective measures of “arousal” were similar in the ORS (6.6 ± 1.7) and LS (6.6 ± 1.8) indicating there was a similar degree of readiness to respond in the two scenarios. An “arousal” score of 5 on the Affect Grid indicates neutral arousal and a score of 9 indicates high arousal (Russel et al., 1989) so a score of 6.6 is an indication of mild arousal in both the LS and ORS. Measures of “pleasure,” however, were significantly higher in the ORS, (p<0.05) and the NASA-TLX data suggest that the ORS was less demanding. This suggests that the firefighters found the fire scenarios more agreeable than the laboratory stressors, perhaps because they felt as if they were in a more natural environment. Also, the likelihood that the firefighters are familiar with the LS scenarios is very low, while they are likely to be familiar with the ORS scenarios. In this context, it is somewhat surprising then that the physiological responses were relatively similar. In general, the ORS appears to be a valid acute stressor for firefighters as indicated by the similar physiological and arousal stress responses to the more conventional LS.

Subjective scores of “workload” measured via the NASA-TLX were significantly higher in the LS than in the ORS (p<0.0001) suggesting a higher perceived workload in the LS. On average temporal demand was rated as the highest adjusted rating sub-score in the LS (334.3±98.1) of the 6 subscales of the NASA-TLX (mental demand, physical demand, temporal demand, performance, effort, and frustration). Mental demand was rated as the highest adjusted rating sub-score in the ORS (232.1±85.2). These results suggest that temporal demand contributed the most to perceived workload in the LS,
while mental effort contributed the most to perceived workload in the ORS.

The fire scenarios used in this study were those developed by Bayouth (2011). The purpose of his study was to assess decision-making in firefighters under different types of stress scenarios (i.e., high/low tradeoff and high/low time pressure). The tradeoff scenario took place outside of a single-family home from which thick black smoke can be observed billowing from the doors, windows, and eaves of all sides of the residence. Under low tradeoff, the scenario cues suggested that there were no potential victims in the home (e.g., no vehicle in driveway, full mailbox). Search and rescue, therefore, was a lower priority and speed would do little to affect the outcome. Under high tradeoff, the scenario suggested that potential victims were inside the home (e.g., vehicle in driveway, empty mailbox), thus search and rescue was a high priority. Analyses revealed that the stress response in the low tradeoff group was not significantly different from the stress response in the high trade off group. In the time pressure scenarios, participants were located inside a structure where conditions were indicative of fire slowly (low time pressure) or rapidly (high time pressure) progressing to pre-flashover conditions (e.g., fire in an enclosed point of origin, dense stratified smoke with rapid progression from the ceiling level downward). Analyses revealed a significantly larger normalized maximum change in HR yield \( (p=0.03) \) in the low time pressure compared to high time pressure. The analyses in this study compared physiological stress responses between stressor scenarios in the ORS, but did not necessarily validate the scenarios as actual stressors.

There is very limited published research validating an ORS in VR as a stressor
per se, which makes it difficult to compare the results of this study to the literature. There is, however, some research demonstrating the effectiveness of VR as a tool for Stress Inoculation Training (SIT). The concept behind SIT, developed in the late 1970s by Donald Meichenbaum (Meichenbaum, 1977), is to prepare individuals for stressful situations. SIT is accomplished through gradual, controlled, and repeated exposure to a stressor. The goal behind this exposure is to desensitize or “inoculate” the person to the possible stimuli of a stressful situation in order to avoid a “fight or flight” response (i.e., activation of the SAM and HPA axes) to the real thing. This repetition allows the individual to become able to calmly and accurately accomplish the tasks at hand in a stressful environment.

SIT, for military personnel, is designed to decrease stress and improve performance pre-deployment. Training under stressful conditions improves performance by training personnel to recognize signs of physiological and emotional arousal and control their stress levels. Studies demonstrating the success of SIT for military personnel suggest the utility of a similar concept in firefighter training (i.e., occupationally-relevant stressors in VR). Firefighters will learn, via SIT, how to handle stress and make appropriate decisions under stress. Ultimately, the fire scenarios used in this study will lay the foundation for purposes similar to SIT; hence, further discussion will be made involving this topic.

A study conducted by Stetz et al. (2007) used SIT for military personnel in combat training in Iraq. In their study, soldiers (e.g., first responders or “medics”) navigated through a VR while performing tasks, such as putting a tourniquet on a
casualty in a stressful, controlled, simulated combat environment. Participants received feedback on their psychological, physiological and bio-chemical stress levels, and practiced coping strategies such as combat breathing. To assess psychological stress, a “Multiple Affect Adjective Check List-Revised” was used to measure anxiety, depression and hostility. A salivary amylase test was used to measure biochemical stress. Peripheral body temperature, breathing rate and pulse rate were used as measures of physiological stress. Preliminary findings with a sample of 25 medics suggested that those who learned coping techniques during the VR training exhibited lower levels of stress than what was seen in the control group. Also, preliminary comparative analyses indicated that this study had possibly identified a tool and set of techniques that would induce a level of stress high enough to potentially produce an “inoculation” effect. Specifically, their results indicated that the VR environment increased levels of post-treatment anxiety (p<0.05) and dysphoria (p<0.05). These results in validating the VR scenario as an actual stressor are inconclusive and demonstrate that there is a need for more research validating occupationally-relevant stressors as actual stressors.

An additional study conducted by Wiederhold & Wiederhold (2004) established SIT through the use of a laptop simulator to train military personnel for stressful situations. The purpose of the study was to maximize performance of military personnel using a technique that implemented training under stressful conditions. Results indicated that those training in a VR simulation while having stressors added (i.e., being shot at while tending to the wounded) were able to perform skills more effectively in the test phase of the study when compared to those trained in a “sterile”
VR environment (i.e., no one shooting at them while tending to the wounded). Participants who had trained under stress scored significantly higher in the test phase than those who had trained in the sterile environment. In addition, physiological monitoring showed that those who had trained under stress remained calm and relaxed in the test phase while the stress of those who had trained in a sterile environment rebounded to near-initial levels.

These studies suggest that VR is a useful tool in reducing stress and improving decision-making among emergency responders. These studies, however, lack validation of whether the scenarios they used are truly stressful, and this issue was confronted in this study. This study showed that the VR could be used as a means to induce stress in addition to being used as a tool in reducing stress and improving decision-making.

Limitations of the present study warrant discussion. First, although the ORS and LS produced similar stress responses, neither showed significant changes in physiological values from baseline, with the exception of increased HR (p<0.001), indicating that the stressors used in this study were not extremely stressful. Lack of significant differences from baseline could be attributed to the variability in the data, which showed considerable variability in physiological and subjective responses. Second, this study included firefighters who were Caucasian males and apparently healthy, and recruited from the state of Iowa. Results of this study, therefore, may not be representative of other firefighting populations since there were no females or other races included in this study. Third, this study only examined the stress responses in 14
firefighters. This small sample size may have contributed to the large variability within the physiological data and hence, may have affected the accuracy of the results. Fourth, the Affect Grid and NASA-TLX are both subjective measures, which may be distorted by biasing factors, such as the “halo effect” and acquiescence. Fifth, the impedance cardiography used here was found to be highly sensitive to motion artifact despite the minimal movement required in this study. Corrections for motion artifact were made using Innocor (a validated noninvasive inert gas re-breathing technique) measurements. In spite of the corrections made, motion artifact is a limitation worth noting as it may have contributed to lack of statistical differences in SV, CO, PEP, and TPR. Sixth, this study relied heavily on Acqknowledge software to run the impedance cardiography analyses. Limitations within the software could have affected the outcomes of the analyses. Seventh, each firefighter spent a different amount of time completing the stressors. Physiological responses could have varied due to differences in exposure time to the stressors. Lastly, chronic stress was measured in this study via the Perceived Stress Score, but there was no measurement of acute stress. Firefighters’ acute stress scores could have affected the results in this study and should have been taken into consideration.

Despite these limitations, the use of the ORS has the potential to solve many of the educational, economic, ethical, and safety issues related to teaching firefighters how to respond to fires. Ideally, by creating a safe, life-like learning environment, firefighters will learn how to quickly and effectively respond to stressful fire scenarios. Fire scenarios within VR, such as those in the ORS, can enhance firefighter training
while reducing the safety risks that accompany traditional firefighter training. Reviews and reports on VR as a training tool within the military and aerospace industry have shown VR to be successful (Rizzo et al., 2011; Hays et al., 1992), and this success has the potential to be translated into the firefighting profession. Ultimately, through the use of the ORS as a training tool, the issues of cardiac risk and decision-making under stress can be addressed. With proper training, firefighters may experience decreased stress responses while on duty. Decreased stress responses will subdue activity in the sympathetic-adrenal medullary and hypothalamic-pituitary-adrenal axes, and therefore, alleviate the negative cardiac effects produced by over-activation of these axes.

Additionally, in situations requiring complex cognition (e.g., responding to fires or other emergency situations), low stress or arousal levels enhance performance (Schmidt, 1991). Lack of validation of the VR as a training tool hampers the incorporation of the VR into firefighter training. By validating the ORS in this study as a stressor, pathways can be opened for future research assessing firefighters’ stress responses to work related stress and how this may impact their increased risk for cardiac events while on duty. Additionally, it will open pathways for research assessing decision-making under stress. This study determined that the fire scenarios used in this study were valid stressors for firefighters when compared to validated laboratory stressors. It can be concluded, therefore, that the ORS used in this study can be used as a stressor in future research assessing work stress in firefighters and its effect on cardiovascular disease and decision-making.
REFERENCES CITED


Hypertension, 47, 391-395.


Sapolsky, R. M. (2000). Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. Arch Gen Psychiatry, 57, 925-935.


APPENDIX A: IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Date: 1/17/2012
To: Christina Sauder
2810 Grand Ave #8
Ames, IA 50010

CC: Dr. Warren Franke
247 Foraker Bldg

From: Office for Responsible Research

Title: Response to Acute Stressors in Firefighters

IRB ID: 11-485

Approval Date: 1/17/2012
Date for Continuing Review: 12/19/2012

Submission Type: New
Review Type: Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 50), please be sure to:

- Use only the approved study materials in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- Retain signed informed consent documents for 3 years after the close of the study, when documented consent is required.
- Obtain IRB approval prior to implementing any changes to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.
- Stop all research activity if IRB approval lapses, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- Complete a new continuing review form at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.
- Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.
APPENDIX A: IRB APPROVAL (cont.)

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INSTITUTIONAL REVIEW BOARD (IRB) Application for Approval of Research Involving Humans

SECTION I: GENERAL INFORMATION

| Principal Investigator (PI): Christina Sauder | Phone: 608-921-7823 | Fax: |
| Degrees: BS | Correspondence Address: 2816 Grand Ave #B, Ames, IA 50010 |
| Department: Kinesiology | Email Address: cjaunder@iastate.edu |
| Center/Institute: College; Iowa State University |
| PI Level: Faculty | Staff | Postdoctoral | Graduate Student | Undergraduate Student |
| Alternate Contact Person: Dr. Warren Franke | Email Address: wfranke@iastate.edu |
| Correspondence Address: 247 Foraker Bldg, Ames, IA 50011-1160 | Phone: 515-294-8257 |

Title of Project: Response to acute stressors in firefighters

Project Period (Include Start and End Date): [mm/dd/yy][ASAP after approved] to [mm/dd/yy][1/15/12]

FOR STUDENT PROJECTS

| Name of Major Professor/Supervising Faculty: | Signature of Major Professor/Supervising Faculty: |
| Phone: 515-294-8257 | Campus Address: 247 Foraker Bldg, Ames, IA 50011-1160 |
| Department: Kinesiology | Email Address: wfranke@iastate.edu |
| Type of Project: (check all that apply) | |
| ☑ Research | ☑ Thesis | ☐ Dissertation | ☐ Class project |
| ☐ Independent Study (490, 590, Honors project) | ☐ Other. Please specify: |

KEY PERSONNEL

List all members and relevant experience of the project personnel. This information is intended to inform the committee of the training and background related to the specific procedures that each person will perform on the project.

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<th>NAME &amp; DEGREE(S)</th>
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<td>Christina Sauder</td>
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<td>Dr. Nir Keren</td>
<td>Assist with data collection, analysis, and interpretation</td>
<td>Human Subjects Training, 11/2/2005</td>
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<td>Dr. Amy Welch</td>
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<td>Kevin Godby</td>
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<td>Shawn Bayouth</td>
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<tr>
<td>Dr. Warren Franke</td>
<td>Major professor</td>
<td>Human Subjects Training,</td>
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Office for Responsible Research
Revised: 6/30/11
If you don't know your training date, contact the Office for Responsible Research for assistance.

To list additional personnel please attach separate sheet.
### FUNDING INFORMATION

- [ ] Internally funded, please provide account number:
- [ ] Externally funded, please provide funding source and account number:
- [ ] Funding is pending, please provide OSPA Record ID on GoldSheet:

Title on GoldSheet if different from above:

- [ ] Other: *(e.g., funding will be applied for later)*
- [x] Student Project—no funding or funding provided by student

### SCIENTIFIC REVIEW

Although the assurance committees are not intended to conduct peer review of research proposals, the federal regulations include language such as “consistent with sound research design,” “rationale for involving animals or humans” and “scientifically valuable research,” which requires that the committees consider in their review the general scientific relevance of a research study. Proposals that do not meet these basic tests are not justifiable and cannot be approved. If an assurance review committee(s) has concerns about the scientific merit of a project and the project was not competitively funded by peer review or was funded by corporate sponsors, the project may be referred to a scientific review committee. The scientific review committee will be an ad hoc and will consist of your ISU peers and outside experts as needed. If this situation arises, the PI will be contacted and given the option of agreeing that a consultant may be contacted or withdrawing the proposal from consideration.

- [ ] Yes [x] No Has or will this project receive peer review?

If the answer is “yes,” please indicate who did or will conduct the review:

If a review was conducted, please indicate the outcome of the review:

### COLLECTION OR RECEIPT OF SAMPLES

Will you be: *(Please check all that apply.)*

- [ ] Yes [x] No Receiving samples from outside of ISU? See examples below.
- [ ] Yes [x] No Sending samples outside of ISU? See examples below.

Examples include: genetically modified organisms, body fluids, tissue samples, blood samples, pathogens.

If you will be receiving samples from or sending samples outside of ISU, please identify the name of the outside organization(s) and the identity of the samples you will be sending or receiving outside of ISU. If the outside organizations have not been identified, please check no for both questions above.

Please note that some samples may require a USDA Animal Plant Health Inspection Service (APHIS) permit, a USDAIS Centers for Disease Control and Prevention (CDC) Import Permit for Etiologic Agents, a Registration for Select Agents, High Consequence Livestock Pathogens and Toxins or Listed Plant Pathogens, or a Material Transfer Agreement (MTA) EH&S Website

Office for Responsible Research
Revised: 6/30/11
APPENDIX A: IRB APPROVAL (cont.)

ASSURANCE

- I certify that the information provided in this application is complete and accurate and consistent with any proposal(s) submitted to external funding agencies.
- I agree to provide proper surveillance of this project to ensure that the rights and welfare of the human subject or welfare of animal subjects are protected. I will report any problems to the appropriate assurance review committee(s).
- I agree that I will not begin this project until receipt of official approval from all appropriate committee(s).
- I agree that modifications to the originally approved project will not take place without prior review and approval by the appropriate committee(s), and that all activities will be performed in accordance with all applicable federal, state, local and Iowa State University policies.

SIGNATURES

Signature of Principal Investigator Date

Signature of Department Chair Date

The Major Professor/Supervising Faculty member must sign the cover page in the section entitled “For Student Projects”.

PLEASE NOTE: Any changes to an approved protocol must be submitted to the appropriate committee(s) before the changes may be implemented.

Please proceed to SECTION II.

Office for Responsible Research
APPENDIX A: IRB APPROVAL (cont.)

SECTION II: IRB SECTION - STUDY SPECIFIC INFORMATION

Please complete all of the following questions.

STUDY OBJECTIVES

Briefly explain in language understandable to a layperson the specific aim(s) of the study.

The purpose of this study is to assess the stress response in firefighters when presented with two different forms of acute stressor scenarios. One scenario will be an occupationally relevant stressor in the context of a virtual reality environment (VRE; IRB ID# 10-510). The second stressor will be a series of validated laboratory stressors. This study is a means to validate the occupationally relevant VRE scenario as an acute stressor as compared to previously validated laboratory stressors.

BENEFITS TO SOCIETY AND PARTICIPANTS

Explain in language understandable to a layperson how the information gained in this study will advance knowledge, and/or serve the good of society. Please also describe the direct benefits to research participants; if there are no direct benefits to participants, indicate that. Note: monetary compensation cannot be considered a benefit to participants.

The information gained from this study will be used in future studies assessing work stress and the cardiovascular effects it may have on firefighters while on duty. There will be no anticipated direct benefits to research participants in this study.

PART A: PROJECT INVOLVEMENT

1) □ Yes ☒ No Is this project part of a Training, Center, Program Project Grant? Director Name: Overall IRB ID:

2) □ Yes ☒ No Is the purpose of this project to develop survey instruments?

3) □ Yes ☒ No Does this project involve an investigational new drug (IND)? Number:

4) □ Yes ☒ No Does this project involve an investigational device exemption (IDE)? Number:

5) □ Yes ☒ No Does this project involve existing data or records?

6) □ Yes ☒ No Does this project involve secondary analysis?

7) □ Yes ☒ No Does this project involve pathology or diagnostic specimens?

8) □ Yes ☒ No Does this project require approval from another institution? Please attach letters of approval.

9) □ Yes ☒ No Does this project involve DEXA/CT scans or X-rays?

PART B: MEDICAL HEALTH INFORMATION OR RECORDS

10) □ Yes ☒ No Does your project require the use of a health care provider’s records concerning past, present, or future physical, dental, or mental health information about a subject? The Health Insurance Portability and Accountability Act established the conditions under which protected health information may be used or disclosed for research purposes. If your project will involve the use of any past or present clinical information about someone, or if you will add clinical information to someone’s treatment record (electronic or paper) during the study, you must complete and submit the Application for Use of Protected Health Information.
APPENDIX A: IRB APPROVAL (cont.)

PART C: ANTICIPATED ENROLLMENT

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<td>□ Prisoners</td>
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<td>Check below if this project involves either:</td>
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<td>□ Other (explain)</td>
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List estimated percent of the anticipated enrollment that will be minorities if known:

- American Indian: 
- Alaskan Native: 
- Asian or Pacific Islander: 
- Black or African American: 
- Latino or Hispanic:

PART D: PARTICIPANT SELECTION

Please use additional space as necessary to adequately answer each question.

11. Explain the procedures and rationale for selecting participants, including the inclusion and exclusion criteria (e.g., where will names come from, what persons will be included or excluded and why, etc.).

Participants in this study will be male firefighters in the Ames, IA area. Males will be selected for this study because the firefighting profession is predominately male. Firefighters will be selected from a pool of firefighters who have participated in previous studies conducted by Dr. Nir Keren and Dr. Warren Franke. Participants must be over age 18, and not have any photosensitive epilepsy, epileptic seizure, or other seizure disorders, and not feel nausea or dizziness when exposed to flashing lights or while playing video games. In addition, firefighters should not participate if they have a history of cardiovascular disease or endocrine disease. Participants will be asked to fill out a medical history form prior to the study to assess for these limitations.

12. Describe the procedures for contacting participants (e.g., letter, email, flyer, advertisements, phone call, etc.). Attach copies of any letters, scripts, flyers, or advertisements that will be used. Recruitment materials should include a statement of the voluntary and confidential nature of the research.

Firefighters will be contacted about this study through a recruitment script sent via email. This is similar to that previously approved by the IRB.

PART E: RESEARCH PLAN

Include sufficient detail for IRB review of this project independent of the grant, protocol, or other documents.

13. The information needed here is similar to that in the “methods” or “procedures” sections of a research proposal—it should describe the flow of events that will occur during your interactions with subjects. Please describe in detail your plans for collecting data from participants, including all procedures, tasks, or interventions participants will be asked to complete during the research (e.g., random assignment, any conditions or treatment groups into which participants will be divided, mail survey or interview procedures, sensors to be worn, amount of blood drawn, etc.). This information is intended to inform the committee of the procedures used in the study and their potential risk. Please do not respond with “see attached” or “not applicable.”

Subjects
APPENDIX A: IRB APPROVAL (cont.)

Subjects will be 45 male career firefighters of varying levels of experience. The criteria for participation will be an active duty firefighter, apparently healthy with no history of cardiovascular or endocrine disease as assessed by medical history, not color blind and not subject to motion sickness. Each subject will come to the Virtual Reality Applications Center (VRAC) on campus. They will be told to abstain from eating and drinking three hours prior to arrival at the VRAC except water. In addition, they will be asked to refrain from exercise, alcohol, and tobacco in the previous 12 hours. They will undergo two separate stressor scenarios: an occupationally-relevant virtual reality environment stressor (VS) and a series of laboratory stressors (LS). Written and signed informed consent from each participant will be obtained before participation in this study.

Protocol

Firefighters typically work a 3-day shift pattern in which they have 3 days on followed by 2 days off. To avoid carryover effects from their job affecting the physiologic factors assessed in the proposed study, firefighters will be tested on their third day off.

Upon arrival, height (measured via a stadiometer) and weight (measured with a scale) will be assessed. In addition, participants will complete a medical history and a global measure of chronic stress [Perceived Stress Scale (Cohen, 1983)]. The subject will then be instrumented for the continuous assessment of heart rate (3-lead EKG), stroke volume (impedance cardiography), respirations (transducer), and galvanic skin response (fingertip transducer). These will be measured using Biomadix hardware (Bionap). Also, the subject will be instrumented for continuous assessment of beat-by-beat blood pressure, which will be measured using the CNAP™ Monitor 500 (CNSystems Medizintechnik AG, Austrian). Next, the firefighter will undergo a brief orientation to both the virtual reality environment (VRE) and to the laboratory stressor. Following the orientation, participants will rest before undergoing the stressors to obtain baseline readings. The rest period will consist of sitting quietly for 10 minutes, followed by 5 minutes of completing a low cognitive challenge (i.e. simple arithmetic). Resting data will be acquired continuously throughout. Upon obtaining baseline readings of resting blood pressure, resting heart rate, and resting stroke volume, the participant will either perform the laboratory stressor or the VRE-occupationally relevant stressor. The stressors will be administered in a counterbalanced, randomized design. After the first stressor is performed, the firefighter will rest for 30 minutes. The rest period will consist of sitting quietly for 25 minutes, followed by 5 minutes of a low cognitive challenge (i.e. mental arithmetic). After the rest, he will perform the second stressor. The VRE and laboratory stressor sessions will be matched for time for data analysis, so the length of time in the second stressor session will be influenced by the amount of time it took the firefighter to complete the first stressor session. Following the stressors, the firefighters will sit quietly for an additional 30 minutes.
APPENDIX A: IRB APPROVAL (cont.)

Heart rate, stroke volume, beat-by-beat blood pressure, respirations, and galvanic skin response will be collected continuously throughout the stressors. Immediately prior to each stressor, and at 5, 10 and 15 minutes after each stressor session has begun, stress will be assessed using an analog scale displayed in front of the firefighter that is based on the transactional stress model used elsewhere to assess endothelial responses to acute psychosocial stress (von Kanel et al., 2007). The NASA Task Load Index will also be used following each stressor scenario to assess workload estimates (Hart, 2006).

VRE

The VRE will be in the C6 simulator at the Virtual Reality Applications Center at Iowa State University. The C6 is a three-dimensional, 1000 cubic foot, fully immersive synthetic environment, where all four walls, the floor and the ceiling are projection screens capable of displaying back-projected stereoscopic images. Each wall displays over 16.7 million pixels making a high-resolution life-like VR system. In addition, audio immersion is possible through an eight-channel surround sound audio system. This provides total immersion for the participants.

In the C6, care will be taken to ensure that the firefighters mimic natural behavior at fire scenes. The subject can control and interact with the VRE through vocal commands and movements within the VRE. The location of the subject is continuously tracked for accurate three-dimensional positioning of the simulation and to ensure that an accurate perspective of the environment is presented to the firefighter in real-time. In other words, the system "moves" with the user, thereby creating a virtual reality experience.

Once in the VRE, the firefighters will engage in an approximately 15 minute long session incorporating two different stressful scenarios. During this session, the firefighter will communicate with a virtual incident commander (VIC). The VIC will be established through automated, prerecorded radio traffic that will cover all potential communication traffic. The firefighter will be provided with a handheld instrument that will allow him to establish inquiries by "pushing" virtual buttons.

The two different VRE scenarios will be a pre-backdraft scenario and an attack scenario. The first scenario (pre-backdraft); (Cole, 2004, pp. 123-199) is a static situation in which conditions do not change until an action is taken or explosion occurs. The participant will approach a virtual house with varying cues of pre-backdraft conditions. Examples of cues that indicate pre-backdraft conditions will be windows that are covered from the inside with a black coat from smoke particles, a red glowing door knob, smoke pushing from windows and doors cracks, and the absence of flames. The firefighter will have time to inspect the area and then will be presented a decision matrix from which he must decide how he would respond to the situation. In the second scenario, the environment will change to an attack scenario. The
APPENDIX A: IRB APPROVAL (cont.)

attack scenario is a dynamic situation in which the firefighter will be located in the house. While in the house, the firefighter will experience time pressure, which will be inferred by the speed at which smoke begins to accumulate downward from the ceiling. Again, the firefighter will be presented a decision matrix from which he must choose how he would respond to the scenario. These scenarios are meant to be lifelike and induce a stress response similar to that in a real life fire situation.

Laboratory Stressor

The laboratory stressor will last approximately 15 minutes and will be a combination of cognitive tasks, where the participant will perform the following cycle in the given order: (1) the Color-Word Stroop Test (CWST), (2) a mental arithmetic task, (3) a mirror-tracing task, and (4) an anagram task. These tasks are all well-established stressors with known response characteristics (Boyes & French, 2010; Sawada et al., 2002; Renaud & Blondin, 1997). These stressors will be performed inside the V6, but using a computer monitor instead of the C6 projection screens. The stressors will be performed in a standing position because the VRE stressor will also involve this position. Each of the stressors in the cycle will last 2 minutes. The cycle will repeat until the firefighter has either reached 15 minutes or matched time with the VRE stressor. The stressors will be slightly modified during subsequent cycles to maintain novelty. For instance, participants will be given different anagrams to solve for the anagram task or a different image to trace in the mirror-tracing task.

CWST

The CWST will consist of naming the ink color of color words under conditions where word meanings and ink colors either mismatch or are incongruent (e.g., the word red printed in green ink). The stimuli will be presented one by one on the screen and will disappear after 1100 milliseconds. The next stimulus will be presented 100 ms after the image disappears. Participants will be instructed to read the word aloud as quickly as possible.

Mental Arithmetic

The subsequent arithmetic task will consist of counting backwards from 1687 in steps of 13. The participant will have 7 seconds to enter his solution in the computer. The computer will display "correct" or "incorrect" after each calculation has been entered, then will display the next correct number from which he will continue his countdown.

Mirror Tracing

After the arithmetic task, the participant will undergo a mirror-tracing task. The participant's task will be to trace, by looking in the computer monitor, a series of complex star-burst shaped figures, which will be placed one at a time on the screen. The participant will be given a computer mouse to trace the figure and movement of the mouse will cause the cursor or the projection screen to move in the opposite direction. The participant will be given 30 seconds to trace
APPENDIX A: IRB APPROVAL (cont.)

along the figure with the mouse as far as he can, after which the figure will disappear and be replaced with a new one. The figures will be made up of two sets of lines approximately 10 mm apart. The participant will be instructed to trace between the lines without touching the sides using the cursor displayed on the computer screen. A high-pitched sound will be produced every time the cursor slips off the track. Also, a penalty score, which will rise in rapid increments, will be indicated in red at the center of the star (negative reinforcement).

Anagrams

Lastly, the participant will perform an anagram task. The individuals will be given a series of anagrams, and in order to minimize perceived control, participants will be given 30 seconds to solve each anagram. They will not be allowed to use pen-and-paper for assistance for the task, and have to complete the anagrams in the order provided. All anagrams will have only a single correct solution. The participant must enter his solution into the computer within 30 seconds, and the computer monitor will display whether or not his solution is correct. The correct solution will be displayed before proceeding to the next anagram.

14. For studies involving pathology/diagnostic specimens, indicate whether specimens will be collected prospectively and/or already exist "on the shelf" at the time of submission of this review form. If prospective, describe specimen procurement procedures; indicate whether any additional medical information about the subject is being gathered, and whether specimens are linked at any time by code number to the participant’s identity. If this question is not applicable, please type N/A in the response cell.

| N/A |

15. For studies involving deception or where information is intentionally withheld from participants, such as the full purpose of the study, please explain how persons will be deceived or what information will be withheld. Additionally, a waiver of the applicable elements of consent will be needed. Please complete the "Waiver of Elements of Consent" form (available at the IRB website). If this question is not applicable, please type N/A in the response cell.

| N/A |

PART F: CONSENT PROCESS

A copy of any translated informed consent documents and an English version should be submitted with the application. Provide the name of the individual who translated the consent documents, their qualifications for translating documents, and in particular informed consent documents, below.

If the consent process does not include documented consent, a waiver of documentation of consent must be requested. If any information about the study is intentionally withheld or misleading (i.e., deception is used), a waiver of the elements of consent must be requested. Forms for requesting waivers are available at the IRB website.

16. Describe the consent process for adult participants (those who are age 18 and older).

A copy of the informed consent document will be provided to potential participants prior to coming to the first visit 3 hours fasted where the informed consent document will be signed. A copy of the document will be e-mailed to potential participants prior to their arrival of the study. After reading and fully understanding the content of the form, participants will have the choice to participate or not to participate in this study. If they choose to participate,
APPENDIX A: IRB APPROVAL (cont.)

17. If your study involves minor children, please explain how parental consent will be obtained prior to enrollment of the minor(s).

18. Please explain how assent will be obtained from minors (younger than 18 years of age), prior to their enrollment. Also, please explain if the assent process will be documented (e.g., a simplified version of the consent form, combined with the parental informed consent document). According to the federal regulations assent “…means a child’s affirmative agreement to participate in research. Mere failure to object should not, absent affirmative agreement, be construed as assent.”

PART G: DATA ANALYSIS

19. Describe how the data will be analyzed (e.g. statistical methodology, statistical evaluation, statistical measures used to evaluate results).

Data analysis

In this study, changes in heart rate, heart rate variability, blood pressure, total peripheral resistance and pre-ejection period will be used to indicate changes in vagal and sympathetic activity. Changes in heart rate variability will reflect changes in vagal tone (e.g. high frequency band) and sympathovagal balance (LF/HF ratio) (Berntson et al., 1997). The magnitude of the increase in heart rate and systolic blood pressure, using per minute means as the measure, above the mean resting measures will be indicators of cardiovascular reactivity. Stress-induced arousal of the sympathetic nervous system will be reflected by changes in pre-ejection period (Cacioppo et al., 1994) and change in total peripheral resistance (TPR) (in mmHg/l/min). Pre-ejection period (PEP, in ms) will be determined as the interval from the onset of the Q-wave of the electrocardiogram to the B-point of the first derivative of the a’ the admittance signal. TPR will be calculated using mean arterial pressure (MAP) and the corresponding by cardiac output (CO) (i.e. TPR = MAP/CO).

Statistical analysis

Repeated measures analysis of variance (ANOVA) with a single factor (SESSION: VR, LS) having repeated measures on the same element will be conducted on the values of all the cardiovascular measures: MBP, HR, SV, CO, TPR, and PEP. When the overall F-value is significant, then Tukey’s HSD for pairwise comparison will be applied. A similar type of ANOVA (SESSION: VR, LS) will be conducted on the scores of the self-reported measures and on the task load measures in all analyses for the physiological measures, with experimental conditions as repeated factors. Effect sizes for differences between laboratory stressor and VRE stressor responses and baseline will be calculated.
APPENDIX A: IRB APPROVAL (cont.)

PART H: RISKS

The concept of risk goes beyond physical risk and includes risks to participants' dignity and self-respect as well as psychological, emotional, legal, social or financial risk.

20. ☐ Yes ☒ No Is the probability of the harm or discomfort anticipated in the proposed research greater than that encountered ordinarily in daily life or during the performance of routine physical or psychological examinations or tests?

21. ☐ Yes ☒ No Is the magnitude of the harm or discomfort greater than that encountered ordinarily in daily life, or during the performance of routine physical or psychological examinations or tests?

22. Describe any risks or discomforts to the participants and how they will be minimized and precautions taken. Do not respond with N/A. If you believe that there will not be risk or discomfort to participants, you must explain why.

Participants are susceptible to a few risks and discomforts if they choose to participate in this study. People who have photosensitive epilepsy, epileptic seizure, or other seizure disorders run the risk of triggering a seizure if in the virtual reality environment; however, these are exclusion criteria so should not be of risk to the firefighters. The affects of being in a virtual reality environment may cause motion sickness, so participants prone to motion sickness may feel dizzy or nauseous upon entering the virtual reality environment. Participants will be warned of potential motion sickness and may terminate participation in the study at any tie if feeling uncomfortable.

23. If this study involves vulnerable populations, including minors, pregnant women, prisoners, the cognitively impaired, or those educationally or economically disadvantaged, what additional protections will be provided to minimize risks?

PART I: COMPENSATION

24. ☐ Yes ☒ No Will participants receive compensation for their participation? If yes, please explain.

Do not make the payment an inducement, only a compensation for expenses and inconvenience. If a person is to receive money or another token of appreciation for their participation, explain when it will be given and any conditions of full or partial payment. (E.g., volunteers will receive $5.00 for each of the five visits in the study or a total of $25.00 if he/she completes the study. If a participant withdraws from participation, they will receive $5.00 for each of the visits completed.) It is considered undue influence to make completion of the study the basis for compensation.

PART J: CONFIDENTIALITY

25. Describe below the methods that will be used to ensure the confidentiality of data obtained. (For example, who has access to the data, where the data will be stored, security measures for web-based surveys and computer storage, how long data or specimens will be retained, anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased, etc.)

Nobody will be identified by name. The physiological and personal data collected during this study will be identified with a code (e.g., FF-22) in lieu of personal information. The code key will be kept on a separate password protected computer. Only members of the research team will have access to the code key.
APPENDIX A: IRB APPROVAL (cont.)

PART K: REGISTRY PROJECTS

26. To be considered a registry: (1) the individuals must have a common condition or demonstrate common responses to questions; (2) the individuals in the registry might be contacted in the future; and (3) the names/data of the individuals in the registry might be used by investigators other than the one maintaining the registry.

☐ Yes  ☒ No  Does this project establish a registry?

If “yes,” please provide the registry name below.

Checklist for Attachments

Listed below are the types of documents that should be submitted for IRB review. Please check and attach the documents that are applicable for your study:

☒ A copy of the informed consent document OR ☐ Letter of introduction containing the elements of consent
☐ A copy of the assent form if minors will be enrolled
☐ Letter of approval from cooperating organizations or institutions allowing you to conduct research at their facility
☐ Data-gathering instruments (including surveys)
☒ Recruitment fliers, phone scripts, or any other documents or materials participants will see or hear

The original signed copy of the application form and one set of accompanying materials should be submitted for review. Federal regulations require that one copy of the grant application or proposal be submitted for comparison with the application for approval.
APPENDIX A: IRB APPROVAL (cont.)

SECTION III: ENVIRONMENTAL HEALTH AND SAFETY INFORMATION

☐ Yes ☒ No Does this project involve human cell or tissue cultures (primary OR immortalized), or human blood components, body fluids or tissues?

PART A: HUMAN CELL LINES

☐ Yes ☒ No Does this project involve human cell or tissue cultures (primary OR immortalized cell lines/strains) that have been documented to be free of bloodborne pathogens? If the answer is “yes,” please answer question 1 below and attach copies of the documentation.

1) Please list the specific cell lines/strains to be used, their source and description of use.

<table>
<thead>
<tr>
<th>CELL LINE</th>
<th>SOURCE</th>
<th>DESCRIPTION OF USE</th>
</tr>
</thead>
</table>

Add New Row

2) Please refer to the ISU “Bloodborne Pathogens Manual,” which contains the requirements of the OSHA Bloodborne Pathogens Standard. Please list the specific precautions to be followed for this project below (e.g., retractable needles used for blood draws):

Anyone working with human cell lines/strains that have not been documented to be free of bloodborne pathogens is required to have Bloodborne Pathogen Training annually. Current Bloodborne Pathogen Training dates must be listed in Section I for all Key Personnel. Please contact Environmental Health and Safety (294-5359) if you need to sign up for training and/or to get a copy of the Bloodborne Pathogens Manual (http://www.ehs.iastate.edu/cms/default.asp?action=article&ID=214)

PART B: HUMAN BLOOD COMPONENTS, BODY FLUIDS OR TISSUES

☐ Yes ☒ No Does this project involve human blood components, body fluids or tissues? If “yes,” please answer all of the questions in the “Human Blood Components, Body Fluids or Tissues” section.

1) Please list the specific human substances used, their source, amount and description of use.

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>SOURCE</th>
<th>AMOUNT</th>
<th>DESCRIPTION OF USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.g., Blood</td>
<td>Normal healthy volunteers</td>
<td>2 ml</td>
<td>Approximate quantity, assays to be done.</td>
</tr>
</tbody>
</table>

Add New Row

2) Please refer to the ISU “Bloodborne Pathogens Manual,” which contains the requirements of the OSHA Bloodborne Pathogens Standard. Specific sections to be followed for this project are:

Office for Responsible Research
Revised: 6/30/11
APPENDIX A: IRB APPROVAL (cont.)

Anyone working with human blood components, body fluids or tissues is required to have Bloodborne Pathogen Training annually. Current Bloodborne Pathogen Training dates must be listed in Section I for all Key Personnel. Please contact Environmental Health and Safety (294-5359) if you need to sign up for training and/or to get a copy of the Bloodborne Pathogens Manual (http://www.eds.iastate.edu/cms/default.asp?action=article&ID=214).

FOR IRB USE ONLY:

Action by the Institutional Review Board (IRB):

☐ Project approved. Date: January 17, 2012
☐ Project is exempt. Date: 
☐ Project not approved. Date: 
☐ IRB approval is not required. Date:

☐ Project is not research according to the federal definition.
☐ Project does not include human subjects as defined by the federal regulations.

__________________________________________  ____________________________
IRB Approval Signature                     Date

Office for Responsible Research
Revised: 6/30/11
APPENDIX A: IRB APPROVAL (cont.)

IRB ID# 11-4885

REQUEST FOR WAIVER OF DOCUMENTATION OF CONSENT

<table>
<thead>
<tr>
<th>Principal Investigator Name:</th>
<th>Christina Sauder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Number:</td>
<td>608-921-7823</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:csauder@iastate.edu">csauder@iastate.edu</a></td>
</tr>
<tr>
<td>Title of Study:</td>
<td>Firefighters' stress response to an occupationally-relevant virtual reality stressor and a laboratory stressor</td>
</tr>
</tbody>
</table>

Iowa State University's Institutional Review Board (IRB) may waive the requirement for obtaining a signed informed consent document from each research participant if the investigator can provide specific reasons that the research meets regulatory criteria. The IRB will make the final determination as to whether or not a waiver is appropriate based on the information provided by the investigator.

Please note: A waiver of documentation of consent only means you do not need to have participants sign a document prior to their participation. Participants must still be given an opportunity to give consent to participate in the research and must be provided sufficient information upon which they can base their decision. A waiver of documentation is not a waiver of the consent process.

Please describe with details specific to your research how your research study satisfies the criteria listed in either #1 or #2 (a) and (b) below. The space will expand as you type.

1. The only record linking the subject and the research would be the consent document, and the principal risk would be potential harm resulting from a breach of confidentiality.

   Justification:

2. (a) The research presents no more than minimal risk of harm to subjects.

   Justification: Participants will come in at a 3 hour fasted state prior to participating in this study. Three hours of fasting is not a long enough time to cause risk or harm to the subject.

   (b) And, involves no procedures for which written consent is normally required outside of the research context.

   Justification: No procedures will be performed on the subject prior to signing the informed consent.

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Revised 02/10
APPENDIX B: RECRUITMENT SCRIPT

Recruitment Script

Hello ________,

I am a graduate student in the Department of Kinesiology at Iowa State University working on a research project with Dr. Franke (Department of Kinesiology) and Dr. Keren (Department of Agricultural & Biosystems Engineering). We are conducting a study at Iowa State University looking at two different stressor scenarios and firefighters’ stress responses to these scenarios. One stressor scenario will be an occupationally-relevant stressor in a virtual reality environment (VRE). The other stressor scenario will be a series of standard laboratory stressors also carried out in a VRE. The purpose of the study is to assess the stress responses in each of these scenarios and determine whether the occupationally-relevant stressor is appropriate for research assessing work stress and the potentially negative cardiovascular affects it has on firefighters. Additionally, this research will be used to improve research assessing decision making under stress. The stressor scenarios will be conducted in the C6, the highest resolution virtual reality room in the world. Participation in an experiment may be as long as 2 hours.

In this study, you will be asked to participate in a series of standard laboratory stressors in the VRE including the Color Word Stroop Test, mental arithmetic, and an anagram task, as well as interact with the VRE during fire scene simulations.

It is Important that you DO NOT discuss or share your experience with anyone of your firefighter colleagues for at least two years after you completed your participation. Failing to maintain this confidentiality process will significantly jeopardize the success of the experiments. We appreciate your understanding this sensitive issue.

Your participation is completely voluntary; you may refuse to answer any question, or you may choose to not participate at all. All of the information you will be providing will be kept strictly confidential. There is no monetary compensation for participating in the study.

Attached is an informed consent form that describes the study in further detail. Please review this document. If you are interested in participating e-mail your response to Christina Sauder: cjsauder@iastate.edu. Use Acute Stressor Experiment in the subject line. If you decide to participate, we will go over the information in the informed consent document and ask you to sign it at the beginning the study.

Participants must be over age 18, and not have any photosensitive epilepsy, epileptic seizure, or other seizure disorders, and not feel nausea or dizziness when exposed to flashing lights or while playing video games. In addition, you should not participate if
APPENDIX B: RECRUITMENT SCRIPT (CONT.)

you have a history of cardiovascular disease, endocrine disease, or are color-blind. If you meet these criteria, and are interested in taking part in the study, please provide us with the following contact information: name, preferred e-mail address, and phone number (optional). Include this information in your response e-mail.

Thanks for your consideration to participate in this study.

Sincerely,
Christina Sauder
APPENDIX C: INFORMED CONSENT

INFORMED CONSENT DOCUMENT

Title of Study: Stress Response to Acute Stressors in Emergency Responders

Investigators: Christina Sauder, Dr. Warren Franke, Dr. Nir Keren, Kevin Godby, Shawn Bayouth,

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to assess the stress response in firefighters when presented with two different forms of acute stressor scenarios. One scenario will be an occupationally relevant stressor in the context of a virtual reality environment (VRE). The second stressor will be a series of validated laboratory stressors carried out on a computer monitor. This study is a means to validate the occupationally relevant VRE scenario as an acute stressor. This information will be used in future studies assessing work stress and the cardiovascular effects it may have on firefighters while on duty. You are being invited to participate in this study because you are a firefighter in the Ames, IA area. Participants must be over age 18, and not have any photosensitive epilepsy, epileptic seizure, or other seizure disorders, and not feel nauseas or dizziness when exposed to flashing lights or while playing video games. In addition, you should not participate if you have a history of cardiovascular disease or endocrine disease.

DESCRIPTION OF PROCEDURES

If you agree to participate, you will be asked to come to the Virtual Reality Applications Center (VRAC) in a fasted state. You will be asked to abstain from eating and drinking three hours prior to arrival at the VRAC except for water. In addition, you will be asked to refrain from exercise, alcohol, and tobacco for 12 hours before coming to the VRAC. Upon your arrival, you will be asked to complete a medical history and a global measure of chronic stress and will be asked whether or not you are color-blind. The medical history will ask for information on family history, personal medical history, medications, physician visits, orthopedic/musculoskeletal injuries, activity history, dietary history, and vocational history. The global measure of chronic stress will assess stressors in your life and your stress responses in the past month.

Also upon arrival, your height and weight will be assessed and you will be instrumented for the continuous assessment of heart rate, blood pressure, stroke volume, respirations, and skin response. To measure heart rate, three electrodes will be placed in a triangular formation on your midsection. To measure blood pressure, a blood pressure cuff will be placed around your upper arm and a finger cuff will be placed on the ring and middle finger of your non-dominant hand. To measure stroke volume, 4 electrodes will be placed along your neck and 4 additional electrodes will be placed on your midsection. To measure respirations, a transducer will be placed securely around your midsection. Lastly, to measure galvanic skin response, three electrodes will be placed on the palm of your hand. The electrodes, finger cuff, and the
respiration transducer will be connected to wireless transmitters. None of these devices should pose any danger or discomfort to the wearer.

After you are instrumented, you will undergo two separate acute stressor scenarios. In one scenario, you will be asked to interact with a virtual reality environment that stimulates stressful fire scenes. In the second scenario, you will also be asked to partake in a computerized experiment that involves standard laboratory stressors. The lab stressors consist of the Color Word Stroop Test (CWST), mental arithmetic, mirror tracing, and anagrams. The CWST consists of naming the ink-color of color words under conditions where word meanings and ink colors either mismatch or are incongruent (e.g., the word red printed in green ink). The arithmetic task will consist of counting backwards from a four-digit number in steps of a two-digit number. The mirror tracing task consists of tracing, with a computer mouse, a series of complex star-burst shaped figures, which will be placed one at a time on the screen. Hand movement of the computer mouse will cause a red dot on the screen to move in the opposite direction and you must keep this red dot within the lines of the figure on the screen. Lastly, for the anagram task, you will rearrange scrambled letters to form a word.

Prior to participating in the fire simulations, you will be trained on how to navigate the virtual reality environment. Verbal instructions will be given to you on how to complete the computerized laboratory stressors.

Your participation will require that you come in for one session. The session will last approximately two hours. Upon arrival, you will be instrumented for the continuous assessment of heart rate, stroke volume, respirations, galvanic skin response and blood pressure and will then rest for 10 minutes to allow for baseline readings. This will be followed by the stressor scenarios, which will each take approximately 15 minutes. Between scenarios you will sit and rest for 30 minutes.

RISKS
There are no emotional or psychological risks associated with this study above the ones you likely encounter on your job. However, it is important that you know that rarely, people develop neurological responses such as seizures or motion sickness when exposed to flashing lights/virtual reality, or when playing with video games. If you feel ill while performing any of the tasks, please close your eyes and alert the researchers. At least one of the research personnel will be near you during the experiments and will monitor your behavior and responses.

BENEFITS
If you decide to participate in this study there may be no direct benefit to you. It is hoped that the information gained in this study will benefit society by expanding knowledge on the use of a virtual reality environment as an occupationally relevant acute stressor for firefighters. This will allow for continued research assessing firefighters and their increased risk for cardiovascular events while on duty.
APPENDIX C: INFORMED CONSENT (cont.)

COSTS AND COMPENSATION

You will not have any costs from participating in this study, and you will not be compensated for participating in this study.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

You may choose to terminate participation in this study if feeling motion sick due to the virtual reality environment.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. We are required by Federal and University policy to keep a copy of the informed consent for three years after the close of the study.

Each firefighter will be given a code name and the data collected on each firefighter will be saved under the corresponding code name. Only the research team will have access to the code key. Files will be saved in a password-protected computer. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS

You are encouraged to ask questions at any time during this study.

- For further information about the study contact Dr. Warren Franke at wfranke@iastate.edu or Christina Sauder at cjsauder@iastate.edu.
- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.
APPENDIX C: INFORMED CONSENT (cont.)

PARTICIPANT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed) __________________________________________

(Participant’s Signature) __________________________ (Date)
APPENDIX D: MEDICAL HISTORY

MEDICAL HISTORY

Today's Date: ____/____/____

Personal Information

Age: ____ Date of Birth: ____/____/____ Sex: ____

Current Medications (include ALL medications)

<table>
<thead>
<tr>
<th>Name of Drug</th>
<th>Dosage; Times/day</th>
<th>Why are you on this drug?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Physician Visits

Please list the last three (3) times you have been ill (sick) enough to see a physician, been hospitalized or had surgery.

<table>
<thead>
<tr>
<th>When?</th>
<th>Why (flu, surgery, etc.)?</th>
<th>What was done?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Family History

Have any members of your immediate family had, or currently have, any of the following?

<table>
<thead>
<tr>
<th></th>
<th>Heart Disease</th>
<th>Stroke</th>
<th>Diabetes</th>
<th>Sudden Death</th>
<th>Pulmonary Disease</th>
<th>Age of onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sisters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brothers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aunts/Uncles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grandparents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don't know</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX D: MEDICAL HISTORY (cont.)

**Personal Medical History**

Do you have any known allergies? _____ YES _____ NO If YES, please explain: ________________________

Do you use tobacco products? _____ YES _____ NO If YES, please describe product used (cigarettes, pipe, dip, etc.), how often per day (packs, bowls, etc.) and how long you have been a tobacco user (years):

What is your cholesterol level? ________ mg/dl ________ don’t know

What is your resting blood pressure? ________ mm Hg ________ don’t know

Please check the following disease conditions that you had or currently have:

<table>
<thead>
<tr>
<th>High blood pressure</th>
<th>Anemia</th>
<th>Abnormal chest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart attack</td>
<td>Jaundice</td>
<td>Bronchitis</td>
</tr>
<tr>
<td>Heart surgery (catheter, bypass)</td>
<td>Infectious mononucleosis</td>
<td>Thyroid problems</td>
</tr>
<tr>
<td>Heart failure</td>
<td>Phlebitis</td>
<td>Hernia</td>
</tr>
<tr>
<td>Heart murmur</td>
<td>Gout</td>
<td>Cancer</td>
</tr>
</tbody>
</table>

seizures

Stroke/transient ischemia attacks

Rheumatic fever

Arteriosclerosis

Kidney stones

Urinary tract infections

Emotional disorder (depression, etc.)

Prostate problem

Osteoporosis

Eating disorder

Please provide dates and explanation to any of the above which you checked:

---

Have you experienced, or do you currently experience any of the following on a recurring basis?

<table>
<thead>
<tr>
<th>At rest: YES NO</th>
<th>During exertion: YES NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortness of breath</td>
<td></td>
</tr>
<tr>
<td>Dizziness, lightheadedness, fainting</td>
<td></td>
</tr>
<tr>
<td>Daily coughing</td>
<td></td>
</tr>
<tr>
<td>Discomfort in the chest, jaw, neck or arms (such as pressure, pain, heaviness, burning, numbness)</td>
<td></td>
</tr>
<tr>
<td>Skipped heart beats or palpitations</td>
<td></td>
</tr>
<tr>
<td>Rapid heart rate</td>
<td></td>
</tr>
<tr>
<td>Joint soreness</td>
<td></td>
</tr>
<tr>
<td>Joint swelling</td>
<td></td>
</tr>
<tr>
<td>Stuttering or loss of speech</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D: MEDICAL HISTORY (cont.)

Unusually nervous or anxious
Sudden numbness or tingling
Loss of feeling in an extremity
Blurring of vision

If YES to any of the above, please explain:

------------------------------------------------------------------------

Orthopedic/Musculoskeletal Injuries

Please check the following disease or conditions which you had or currently have:

___ Arthritis
___ Swollen joints
___ Painful feet
___ Severe muscle strain
___ Limited range of motion
___ Bursitis
___ Osteoporosis

___ Muscle weakness
___ Stiff or painful muscles
___ Fractures or dislocations
___ Tennis elbow
___ Torn ligaments
___ Pinched nerve
___ “Trick” knee/knee injury
___ ANY OTHER condition which affects your mobility

___ Head injury
___ Shoulder injury
___ Ankle injury
___ Whiplash or neck injury
___ Slipped disc
___ Curvature of spine

Do any of the above limit your ability to exercise? _____ YES _____ NO
If YES to any of the above, please explain:

------------------------------------------------------------------------

Activity History

Please list any physical or recreational activities that you currently do or have done on a regular basis.

Activity | Frequency (days/week) | Time (min/session) | How long (years)
---------------------------------------------------------------

Diet History

What do you consider a “good” weight for you? _________ Lbs. When did you weigh this?
APPENDIX D: MEDICAL HISTORY (cont.)

What is the most you have ever weighed? __________ Lbs. When did you weigh this?

_________

In the past 5 years, how often have you attempted to lose weight? __________ What diets did you use?

__________________________

—

How many meals do you usually eat per day? __________

How many cups of coffee or caffeinated beverages do you drink per day? __________

How many servings (1 shot, glass of wine, 12 oz of beer) do you drink per week? ___________

On average, how often do you eat the following foods per week?

_____ cheeses (cheddar, American, etc.) _____ eggs (alone or in foods) _____ poultry

_____ fast foods (McDonalds, etc.) _____ fried foods (non fast foods) _____ non diet pop

_____ snack foods (chips, cookies, desserts, “junk” food, etc)

__________________________

Vocational History

What is your present occupation? _________________________________________________

Years at present occupation: ____________________________________

Hours worked per day: __________ Days per week: ___________ Shift: ________________

How would you perceive the average physical demands of your job (check one):

_____ light _____ fairly light _____ somewhat hard _____ hard _____ very hard

Briefly describe what your job involves:

__________________________

Approximately what percentage of your day is spent:

_____ sitting _____ standing _____ walking _____ carrying objects _____ lifting objects

Please describe any objects you must lift and/or carry at your job:

__________________________

How many hours of your work day are spent: _____ indoors _____ outdoors

Are you exposed to excessive heat, cold, air pollution, or other environmental hazards at your job?

_____ YES _____ NO If YES, please describe:

__________________________

__________________________
APPENDIX D: MEDICAL HISTORY (cont.)

How would you perceive the average psychological demands or stressfulness of your job?

Severity of stress:

- none
- fairly light
- moderate
- severe
- very severe

Frequency of stress:

- almost never
- occasionally
- frequently
- very frequently
- constantly
# APPENDIX E: GLOBAL MEASURE OF CHRONIC STRESS

**Global Measure of Chronic Stress**

For each question, please mark the answer that is most true for you. There are no "right" or "wrong" answers.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Never</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Fairly Often</th>
<th>Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In the last month, how often have you been upset because of something that happened unexpectedly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>In the last month, how often have you felt that you were unable to control the important things in your life?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>In the last month, how often have you felt nervous and &quot;stressed&quot;?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>In the last month, how often have you dealt successfully with irritating life hassles?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>In the last month, how often have you felt confident about your ability to handle your personal problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>In the last month, how often have you felt that things were going your way?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>In the last month, how often have you found you could not cope with all the things that you had to do?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>In the last month, how often have you been able to control irritations in your life?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>In the last month, how often have you felt that you were on top of things?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>In the last month, how often have you been angered because of things that happened that were outside of your control?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>In the last month, how often have you found yourself thinking about the things that you have to accomplish?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>In the last month, how often have you been able to control the way you spend your time?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX F: SIMPLE ARITHMETIC

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 + 1 =$</td>
<td>$3 + 9 =$</td>
<td>$1 + 11 =$</td>
</tr>
<tr>
<td>$1 + 2 =$</td>
<td>$4 + 4 =$</td>
<td>$1 + 12 =$</td>
</tr>
<tr>
<td>$1 + 3 =$</td>
<td>$4 + 5 =$</td>
<td>$1 + 13 =$</td>
</tr>
<tr>
<td>$1 + 4 =$</td>
<td>$4 + 6 =$</td>
<td>$1 + 14 =$</td>
</tr>
<tr>
<td>$1 + 5 =$</td>
<td>$4 + 7 =$</td>
<td>$1 + 15 =$</td>
</tr>
<tr>
<td>$1 + 6 =$</td>
<td>$4 + 8 =$</td>
<td>$1 + 16 =$</td>
</tr>
<tr>
<td>$1 + 7 =$</td>
<td>$4 + 9 =$</td>
<td>$1 + 17 =$</td>
</tr>
<tr>
<td>$1 + 8 =$</td>
<td>$5 + 5 =$</td>
<td>$1 + 18 =$</td>
</tr>
<tr>
<td>$1 + 9 =$</td>
<td>$5 + 6 =$</td>
<td>$1 + 19 =$</td>
</tr>
<tr>
<td>$2 + 2 =$</td>
<td>$5 + 7 =$</td>
<td>$1 + 20 =$</td>
</tr>
<tr>
<td>$2 + 3 =$</td>
<td>$5 + 8 =$</td>
<td>$2 + 10 =$</td>
</tr>
<tr>
<td>$2 + 4 =$</td>
<td>$5 + 9 =$</td>
<td>$2 + 11 =$</td>
</tr>
<tr>
<td>$2 + 5 =$</td>
<td>$6 + 6 =$</td>
<td>$2 + 12 =$</td>
</tr>
<tr>
<td>$2 + 6 =$</td>
<td>$6 + 7 =$</td>
<td>$2 + 13 =$</td>
</tr>
<tr>
<td>$2 + 7 =$</td>
<td>$6 + 8 =$</td>
<td>$2 + 14 =$</td>
</tr>
<tr>
<td>$2 + 8 =$</td>
<td>$6 + 9 =$</td>
<td>$2 + 15 =$</td>
</tr>
<tr>
<td>$2 + 9 =$</td>
<td>$7 + 7 =$</td>
<td>$2 + 16 =$</td>
</tr>
<tr>
<td>$3 + 3 =$</td>
<td>$7 + 8 =$</td>
<td>$2 + 17 =$</td>
</tr>
<tr>
<td>$3 + 4 =$</td>
<td>$7 + 9 =$</td>
<td>$2 + 18 =$</td>
</tr>
<tr>
<td>$3 + 5 =$</td>
<td>$8 + 8 =$</td>
<td>$2 + 19 =$</td>
</tr>
<tr>
<td>$3 + 6 =$</td>
<td>$8 + 9 =$</td>
<td>$2 + 20 =$</td>
</tr>
<tr>
<td>$3 + 7 =$</td>
<td>$9 + 9 =$</td>
<td>$3 + 10 =$</td>
</tr>
<tr>
<td>$3 + 8 =$</td>
<td>$1 + 10 =$</td>
<td>$3 + 11 =$</td>
</tr>
</tbody>
</table>
APPENDIX F: SIMPLE ARITHMETIC (cont.)

\[
\begin{array}{ccc}
3 + 13 &=& 5 + 14 &=& 7 + 15 \\
3 + 14 &=& 5 + 15 &=& 7 + 16 \\
3 + 15 &=& 5 + 16 &=& 7 + 17 \\
3 + 16 &=& 5 + 17 &=& 7 + 18 \\
3 + 17 &=& 5 + 18 &=& 7 + 19 \\
3 + 18 &=& 5 + 19 &=& 7 + 20 \\
3 + 19 &=& 5 + 20 &=& 8 + 10 \\
3 + 20 &=& 6 + 10 &=& 8 + 11 \\
4 + 10 &=& 6 + 11 &=& 8 + 12 \\
4 + 11 &=& 6 + 12 &=& 8 + 13 \\
4 + 12 &=& 6 + 13 &=& 8 + 14 \\
4 + 13 &=& 6 + 14 &=& 8 + 15 \\
4 + 14 &=& 6 + 15 &=& 8 + 16 \\
4 + 15 &=& 6 + 16 &=& 8 + 17 \\
4 + 16 &=& 6 + 17 &=& 8 + 18 \\
4 + 17 &=& 6 + 18 &=& 8 + 19 \\
4 + 18 &=& 6 + 19 &=& 8 + 20 \\
4 + 19 &=& 6 + 20 &=& 9 + 10 \\
4 + 20 &=& 7 + 10 &=& 9 + 11 \\
5 + 10 &=& 7 + 11 &=& 9 + 12 \\
5 + 11 &=& 7 + 12 &=& 9 + 13 \\
5 + 12 &=& 7 + 13 &=& 9 + 14 \\
\end{array}
\]
APPENDIX G: AFFECT GRID
APPENDIX H: NASA-TLX

Figure 8.6

NASA Task Load Index

Hart and Staveland’s NASA Task Load Index (TLX) method assesses workload on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

<table>
<thead>
<tr>
<th>Name</th>
<th>Task</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Demand</td>
<td>How mentally demanding was the task?</td>
<td>Very Low</td>
</tr>
<tr>
<td>Physical Demand</td>
<td>How physically demanding was the task?</td>
<td>Very Low</td>
</tr>
<tr>
<td>Temporal Demand</td>
<td>How hurried or rushed was the pace of the task?</td>
<td>Very Low</td>
</tr>
<tr>
<td>Performance</td>
<td>How successful were you in accomplishing what you were asked to do?</td>
<td>Perfect</td>
</tr>
<tr>
<td>Effort</td>
<td>How hard did you have to work to accomplish your level of performance?</td>
<td>Very Low</td>
</tr>
<tr>
<td>Frustration</td>
<td>How insecure, discouraged, irritated, stressed, and annoyed were you?</td>
<td>Very Low</td>
</tr>
</tbody>
</table>
# APPENDIX I: NASA-TLX RATING SCALE DEFINITIONS

<table>
<thead>
<tr>
<th>Title</th>
<th>Endpoints</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENTAL DEMAND</td>
<td>Low/High</td>
<td>How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?</td>
</tr>
<tr>
<td>PHYSICAL DEMAND</td>
<td>Low/High</td>
<td>How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?</td>
</tr>
<tr>
<td>TEMPORAL DEMAND</td>
<td>Low/High</td>
<td>How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td>Good/Poor</td>
<td>How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?</td>
</tr>
<tr>
<td>EFFORT</td>
<td>Low/High</td>
<td>How hard did you have to work (mentally and physically) to accomplish your level of performance?</td>
</tr>
<tr>
<td>FRUSTRATION LEVEL</td>
<td>Low/High</td>
<td>How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?</td>
</tr>
</tbody>
</table>
APPENDIX J: NASA-TLX COMPARISON CARDS
APPENDIX J: NASA-TLX COMPARISON CARDS (cont.)
# APPENDIX K: ANAGRAMS

<table>
<thead>
<tr>
<th>Solution Words</th>
<th>Anagrams</th>
<th>Solution Times (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>brawl</td>
<td>awrlb</td>
<td>10.0</td>
</tr>
<tr>
<td>sugar</td>
<td>ugars</td>
<td>10.5</td>
</tr>
<tr>
<td>brook</td>
<td>rkobo</td>
<td>10.5</td>
</tr>
<tr>
<td>cramp</td>
<td>rmcap</td>
<td>12.0</td>
</tr>
<tr>
<td>peony</td>
<td>ypeon</td>
<td>12.0</td>
</tr>
<tr>
<td>chair</td>
<td>cihra</td>
<td>12.5</td>
</tr>
<tr>
<td>month</td>
<td>ohtnm</td>
<td>13.0</td>
</tr>
<tr>
<td>paint</td>
<td>iptna</td>
<td>13.0</td>
</tr>
<tr>
<td>smell</td>
<td>lmlse</td>
<td>13.5</td>
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<td>slush</td>
<td>lssuh</td>
<td>14.0</td>
</tr>
<tr>
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<td>nrtde</td>
<td>14.0</td>
</tr>
<tr>
<td>party</td>
<td>rtypa</td>
<td>14.0</td>
</tr>
<tr>
<td>fruit</td>
<td>iufrtr</td>
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</tr>
<tr>
<td>human</td>
<td>mhnua</td>
<td>15.0</td>
</tr>
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<td>batch</td>
<td>cahtb</td>
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</tr>
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<td>17.0</td>
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<tr>
<td>clerk</td>
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</tr>
<tr>
<td>youth</td>
<td>ohytu</td>
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<tr>
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<td>hocra</td>
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</tr>
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<td>vital</td>
<td>ltvia</td>
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<td>oulgh</td>
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<tr>
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<td>rbscu</td>
<td>21.0</td>
</tr>
<tr>
<td>clerk</td>
<td>klrce</td>
<td>22.0</td>
</tr>
<tr>
<td>power</td>
<td>oewrp</td>
<td>22.0</td>
</tr>
<tr>
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APPENDIX L: PHOTO OF ANAGRAM STRESSOR
APPENDIX M: PHOTO OF COLOR WORD STROOP TEST STRESSOR
APPENDIX N: PHOTO OF ARITHMETIC STRESSOR

6726 - 16 = 6710
APPENDIX O: PHOTO OF PREPPED FIREFIGHTER
APPENDIX P: PHOTO OF FIREFIGHTER IN OCCUPATIONALLY-RELEVANT STRESSOR
**APPENDIX Q: MEAN PHYSIOLOGICAL RESPONSES OF FIREFIGHTERS IN BASELINE, LS AND ORS**

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