THE EFFECTS OF FLUORESCENT VERSUS LED LIGHTING ON SOLIDERS IN MILITARY SHELTERS

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ABSTRACT

The current study examines the effects of fluorescent versus LED lighting on Soldiers in military shelters. To ensure a naturalistic setting, 23 enrolled U.S. Army infantry Soldiers performed a series of tasks in a Tent Expandable Modular Personnel (TEMPER) military shelter. The tasks included: visual acuity task, military map task, tent attractiveness questionnaire, mood assessment and conflict resolution scales. These tasks were chosen based on a stressors paradigm that highlights the typical stressors of military members (e.g. interpersonal conflict, psychological distress, high workload, and worries about living environment quality). Results show that overall lighting color temperature and illuminance levels do not play a role in Soldier performance and behavior, yet the study elucidates a number of limitations such as short lighting exposure time which may contribute to the results. The current study adds to the limited research on LED lighting and proposes several new areas of exploration such as determining time thresholds for the effects of lighting on humans.

BIOGRAPHICAL SKETCH

Breanne Hawes grew up in Natick, Massachusetts. She attended Trinity College in Hartford, CT where she received her undergraduate degree in Psychology with minors in Architectural Studies and French Language. Before her senior year at Trinity College she worked as an intern at the Natick Soldier Research Engineering and Development Center (NSRDEC) for the Cognitive Science Team and accepted a full-time position on the team after graduation. She combines her interests in psychology, space design, and research to bring new ideas to NSRDEC to benefit Soldier performance and well-being. In 2014 she graduated from Cornell University with a Master's Degree in Environmental Psychology in hopes to further her interests in environmental research and design and bring new ideas to the military research community.

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LIST OF ABBREVIATIONS

DOD	Department of Defense
FL	Fluorescent
IRB	International Review Board
JOCOTAS	Joint Committee of Tactical Shelters
K	Kelvin
LED	Light Emitting Diode
Lx	Lux
MCPS	Modular Command Post System
MOS	Military Occupation Specialty
NSRDEC	Natick Army Research Engineering and Development Center
NSSC	Natick Soldier Systems Center
OPTEMPO	Operations Tempo
POMS	Profile of Mood States
R&D	Research and Design
RT	Reaction Time
SAD	Seasonal Affect Disorder
SCN	Supraciasmatic Nucleus
TEMPER	Tent Extendable Modular Personnel

I. INTRODUCTION

Any environment, built or natural, can have an effect on the way people think, feel, and behave. This is the case in military settings and should be taken into account during research and design (R&D) for military products and technologies. In 2013, the United States Department of Defense (DOD) spent approximately $64 billion on R&D to develop the "best" technologies for the military (Comptroller, 2014). These technologies are often considered in terms of effectiveness, energy use, and cost, but the impacts of the technologies on user cognition and well-being can be overlooked. This is especially the case in R&D of Army Soldier living environments.

Deployed Army Soldiers can live in a wide variety of settings ranging in size and operational goals. Deployment is a period of time in which a Soldier is relocated, typically overseas, to fulfill their duties. These locations can be a place of peace or war (Goarmy.com, *Deployment*, 2014). The living environments during deployment are called base camps. Base camps have been defined in many ways, one well-written definition states that base camps are:

> "…an evolving military facility that supports the military operations of a deployed unit and provides the necessary support and services for sustained operations." (Davis & Ezell, 2001, pp.14)

Base camps are typically categorized into three sizes: main base camp, forward operating base, and outpost (RedBook, 2001) (Table 1.1). Each camp is equipped with amenities to maintain a reasonable quality of life. Larger camps have many more amenities than smaller camps, as smaller camps prioritize missions (Redbook, 2001).

Table 1.1 Properties of Base Camps (RedBook, 2001)

Base Camp Category	Number of Soldiers	Goals	Amenities
Main Base Camp	~500+	Continuously operated camps with command, staff, and logistic functions	Housing, office, post office, PX, laundry, fitness center, chapel, etc.
Forward Operating Base	~100-500	Operated on a continuous basis	Housing, supply room, dining facilities, kitchen, fitness center (no post office, barber shop, chapel, etc.)
Outpost	Less than 100	For operationally defined missions (e.g. checkpoints and observation posts),	Will not have the level of services the main base camps and forward operations bases. Outposts are authorized the following primary services (i.e. living and working tents)

Figure 1.1. 550-man base camp (Product Manager Force Sustainment Systems, 2013)

As previously stated, a great deal of R&D is invested in providing optimal safety, operational effectiveness, and quality of life of the Soldiers at each camp (RedBook, 2001). One of the key areas of R&D is for the shelters that house all of the functions at each base. The Joint Committee of Tactical Shelters (JOCOTAS) is a research group that focuses on R&D for these shelters. One of the goals of this group is to standardize the shelter systems; in 1995, the group reduced the number of shelter types from over 100 to 21 (NSRDEC, 2012). Shelters can be categorized into three types: rigid wall, soft wall and hybrid. All types can be easily transported. Each type of shelter has been designated for different usages according to JOCOTAS. For example, the TEMPER air supported tent is recommended for dining, sleeping, and medical facilities while a modular command post system (MCPS) is recommended as a command post (Figure 1.2). The shelter design goals are to be state of the art and cost effective while still keeping high quality of life of Soldiers. Also, there is currently a large energy reduction effort by the military. For base camps, the goal is to create net zero camps that are energy dependent by using renewable power and proper power management (Kauchak, 2011).

Figure 1.2. MCPS shelter (Killan, 2014)

To achieve this net zero goal, the DoD is considering many new technologies. One of these technologies is light emitting diode (LED) lighting systems for the shelters. Each shelter is typically equipped with a lighting system, currently a fluorescent technology (Figure 1.3). These systems (fluorescent and LED) have been evaluated and compared based on set-up time, efficiency, and cost but it is also important to consider how the lighting impacts Soldier cognition and well-being. As discussed below, there is already a large knowledgebase about the effects of lighting on human health, cognition, and behavior. Yet, very little research has looked specifically at the effects of military shelter lighting systems on Soldiers. Soldiers perform most of their daily tasks (will be discussed further below) in shelters, thus it is important to understand how the lighting surrounding them affects their performance. This is especially important considering that military members face many challenges. They are affected by the same stressors as civilians, such as occupational workload, but they also experience military-specific stressors such as safety concerns. (Adler, McGurk, Stetz, & Bliese, 2003). If lighting may play a role in alleviating military stressors it is important to understand this relationship.

Figure 1.3. TEMPER tent equipped with fluorescent lighting (Copybook, 2014)

Artificial Lighting

Properties of Artificial Light

There are several properties of light. Some of which are important to understand for the current research. Light coming from a source can be measured by color

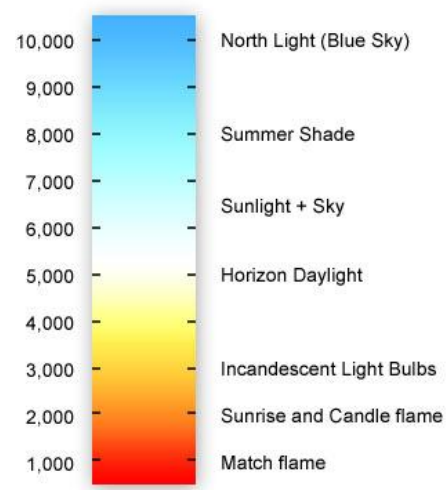

Figure 1.4. Kelvin Scale (Prokopenko, 2014)

temperature. Color temperate is measured in Kelvin, lower measurements are reddish (warm) while higher measurements are bluish (cool) in appearance (Figure 1.4). Illumination is the amount of light striking a surface within a sphere and is measured in luminous flux (rate of energy emitted from a source) per unit area (Sanders & McCormick, 1993). The units are called footcandles (fc) or lux (lx).

Mechanism of Light Perception

Light perception is a process that was originally understood to involve two photoreceptors in the eye (rods and cones) that receive on or off signals based on the presence of light. These signals cause a chemical reaction that reaches the visual cortex of the brain. Eventually, a third photoreceptor was described; a photosensitive retinal ganglion cell connected to the supraciasmatic nucleus (SCN) (Berson, Dunn & Motoharu, 2002). The light signals that reach these cells cause chemical reactions in the SCN in the brain which controls the biological clock and signals the pineal gland.

A large body of research has focused on the effects of light on functions of the SCN, especially the effects of different light intensities on melatonin suppression. Melatonin is produced in the pineal gland and mediates human adaptations to different parts of the day (Boyce & Kennaway, 1987). Melatonin is released during the parts of the day when most humans feel tired (night). A review of the biological and visual effects of lighting cited several articles examining similar effects of light on melatonin and cortisol suppression, concluding that higher luminance levels reduce stress and raise alertness (Van Bommel & Van Beld, 2004). One specific study exposed ten participants to a tungsten filament lamp with conditions of 1000, 1500, 2000 or 2500 lx during the hours of midnight to 2 am (Boyce & Kennaway, 1987). They found that all light conditions suppressed melatonin, with the highest lux levels having the strongest (but not significant) effect (Boyce & Kennaway, 1987). A controlled overnight study exposed ten young males to two hours of 460nm light or 550nm light (by a monochomatic Xenon lamp) (Cajochen et al., 2004). Through saliva sampling they found that light causes melatonin suppression ($P<0.001$) and that short wavelength light (460nm, higher color temperature) is more effective than long (550nm) in reducing subjective sleepiness in the evening ($P<0.05$) (Cajochen et al., 2004).

Lighting and Health

The effects of lighting on biological processes, such as melatonin production, can also have impacts on sleep, seasonal affective disorder (SAD), Alzheimer's, and cancer (Boyce, 2010). In relation to SAD (depression-like) symptoms, one study found that in young adults, exposure to bright light from a light box comprised of six cool white fluorescent lamps (2500 lx, 6500K) reduces intensity of SAD symptoms (Partonen & Lonnqvuist, 2000). For the intervention condition, the participants were asked to sit in a certain position in front of the light for one hour a day at least five days a week. The intervention condition was two four-week periods interspersed with two four week periods of no intervention (ABAB). At baseline and after each two-week period, participants completed several questionnaires assessing SAD symptoms, such as the Symptom Distress Checklist 90 (SCL-90). As stated above, they found that light reduced SAD symptoms; for example, a reduction in depression symptoms on the SCL-90 after each light exposure week ($P<0.001$), and a rebound in depression symptoms during the non-exposure weeks ($P<0.001$) (Partonen & Lonnqvist, 2000). A review of bright-light therapy literature examined several studies on bright-light therapy and the reduction of SAD symptoms and other negative symptoms of mood disorders (e.g. bipolar depression) (Pail et al., 2011). The authors concluded that bright-light therapy is an effective treatment for these disorders and should be utilized by health care professionals.

There is a large breadth of research on lighting in healing environments. Buchanan et al.(1991) reviewed lighting literature in relation to hospitals and found that not only does lighting impact patients by reducing length of stay and depression symptoms (via mechanisms previously discussed), lighting also helps staff performance by increasing visual acuity on vital tasks such as medication distribution. The effect of lighting on visual acuity will consequently be discussed below.

Mood and Cognition

Apart from SAD specific studies, many researchers have examined the effects of lighting on general mood and mood induction. Two integral reports of the impacts of lighting on mood were implemented by Igor Knez. The first report described a series of studies in which Knez (1995) tested the effects of four lighting conditions, warm white (3000 K; dim vs bright: 300 lx vs 1500 lx) and cool white (4000 K; dim vs bright: 300 lx vs 1500 lx) on mood, long-term recall, problem solving, free recall, performance appraisal, and room light evaluation. Notably, he found that the mood of males was less negative in the cool lighting condition and the mood of females was less negative in the warm condition ($P<0.01$) (Knez, 1995). In addition to this, females perform better on the problem solving ($P<0.05$) and long term recall ($P<0.05$) tasks in the warm lighting than cool, and the opposite is true for males (Knez, 1995).

In a similar study, researchers examined the effects of warm white (WW: 3000K, 487lux), cool white (CW: 4150K, 512lux), and full-spectrum (Chroma: 5000K, 526lux) lighting on: proofreading, subtracting numbers, recommending salaries, rating the confederates on attractiveness and friendliness, rating room attractiveness, and rating subjective mood (Boray, Gifford & Roseblood, 1989). They did not find any effects of the lighting on perceptions of the space, nor did they find differences of mood and cognition under each of the lighting conditions. It is important to note that the study only exposed the participants to lighting for 35 minutes and used a specific population of college students.

For some of the studies on human behavior and lighting the authors claimed that they wanted to highlight tasks and behaviors that are less vision based. For example, two studies examined the effects of lighting on interpersonal communication (Gifford, 1988; Baron, Rea & Daniels, 1992). Gifford (1988) found that participants spent more time writing personal notes ($P<0.01$) under "bright" light condition 35 watt fluorescent bulbs (90 footcandles) condition versus the "soft" light condition 100 watt bulb (6 footcandles). Baron, Rea and Daniels (1992) also examined the proclaimed non-visual effects of lighting, such as dealing with conflict situations and ratings of others' helpfulness. The first study used a 2x4 design of conditions: 150 lx or 1500 lx of white (3000K), natural white (3600k), cool white (4200K) and D50 (5000K) fluorescent lighting. The participants rated an employee, performed word categorization, and completed mood surveys. A notable result was that participants rated fake employees more positively in the lower luminance (150 lx), except in the cool white condition ($P<0.05$ in all cases) (Baron et al., 1992). In the second study, the researchers used a 2x2 design of low and high luminance (150 lx, 1500 lx) and warm white and cool white (3000k, 4200K) conditions. The participants completed mood surveys, MODE surveys (how they deal with conflict), a coding task, and rated their reactions to a conflict situation. Results showed that in the warm white condition participants were more likely to resolve conflict with collaboration than with avoidance versus the cool white condition ($P<0.02$). Their third study involved induced mood with gift giving and participants willingness to help, which is less applicable to the purposes of this review.

A recent 2X2 study design investigated the effects of blue (40 lx LED 470nm light) versus white light (100 lx) with caffeine or placebo on mood (Ekstrom & Beaven, 2013). Mood was measured by the Swedish Core Affect Scale. Results showed that there was a main effect of light on mood, specifically, global mood and arousal were higher in the blue-light caffeine-placebo condition than in the white-light caffeine-placebo condition ($P=.009$).

Thus far, I have discussed the effects of lighting on biological processes and health such that certain levels of artificial lighting can suppress melatonin (reduce sleepiness), reduce depression symptoms, and boost general mood and arousal. Other studies have shown that humans have preferences toward certain types of artificial lighting and that lighting can affect our perception of a room, a space, or a person.

Lighting Preference

Research by Butler and Biner (1987) found that it is possible to measure general preference for lighting based on activity. Using a previously developed questionnaire (Butler et al., 1986) they researched preferences for lighting levels (very dark to very bright) and importance of lighting levels for certain tasks (not important to very important). In two studies they found that more extreme preference ratings predict (toward very dark or very bright) higher importance for lighting levels ($P<.01$).

Another study examined workers' preferences for combinations of daylight and artificial lighting in offices (Begemann, Beld & Tenner, 1997). They also attempted to examine human behavior such as performance and mood. They set up four identical offices in an office building in the Netherlands with a combination of windows and artificial lighting (each luminarie comprised of 2700 K plus 6500 K fluorescent lamps). 170 participants were asked to work in this office for one day under their normal routine. The experimenters took continuous sensor readings for lighting measurements. The main findings showed that people preferred artificial lighting (an average of 800 lx) in addition to any daylight level (Begemann, Beld & Tenner, 1997).

Visual Effects of Lighting

Visual Acuity. Light also affects visual processes. Specifically, lighting influences visual acuity and perception. One noteworthy paper on this topic purported that a greater amount of light leads to smaller pupil size, thus better visual acuity (Berman, 1992). Several studies examined these effects, and these studies were reviewed by Veitch and McColl (2001). They cite several studies in line with Berman's theory. They purport that carefully controlled studies match the theory, while more naturalistic theories do not (Veitch & McColl, 2001). One study in line with the theory examined two male and seven female participants' pupil size and performance on word-reading (Berman et al., 1996). The participants were exposed to six lighting conditions: task luminance of 20, 50 and 80 cd/m2 (24W incandescent lamps) and surround luminance of 5 and 50 cd/m2 F213 (fluorescent lamps). They found that pupil size decreased as background luminance increased from 5 to 50 cd/m2 (P<0.0001) and surround luminance had a significant effect on reading score (P=0.014.). Although, they did not find a correlation between pupil size and reading accuracy when luminance increased from 5 to 50 cd/m2 (P=0.09).

Visual Perception. In addition to effects on visual acuity, lighting can influence the perception of spaces and other people. Houser et al.(2002) reported two studies, the second of which employed questionnaires on subjective room brightness, visual comfort, uniformity of lighting, spaciousness of rooms, and lighting preferences. In this study, an experimental room was set up with direct and indirect triphosphor fluorescent lamps of 3500 K and CRI of 75. The participants were exposed to 11 settings of the lighting (different combinations of direct and indirect lighting), while their work surface area illuminance was kept constant at 538 lux. Results showed strong correlations between wall and room-brightness scores (r=0.74) and between ceiling and room-brightness scores (r=0.68), but weaker correlations between work surface and room-brightness scores (r=0.49). They concluded that perception of brightness is a combination of illuminance of work plane as well as wall and ceiling appearance (Houser et al., 2002). In another study looking at lighting's impact on space appearance, Berman et al. (1990) found that 12 young adults perceived and reported an illuminated wall in a test chamber as brighter when lit by a fluorescent lamps of 52 cd m^2 as when lit by a fluorescent lamps of 40 cd m^2 (P=0.002).

One study examined the effects of lighting on perceptions of space such as clarity, spaciousness, relaxation, privacy (intimacy), pleasantness, and order (Manav & Yener, 2014). The room was equipped with two ceiling mounted fluorescent lamps (40W), two cove lights (40W and 20W, 6200K) and two tungsten halogenated torchiere for uplighting (300W, 3000K). The participants entered a dark room (free of natural daylight) and were instructed to turn on the light systems and eventually choose one system to leave on. Once they chose the system they filled out several questionnaires. Notable results found that those that filled out the questionnaires in cove lighting rated the room as more spacious while those that chose the tungsten-halogenated lamps rated the room as more relaxing, privacy-enhancing and pleasing (Manav & Yener, 2014).

In relation to perception of faces, Hill and Bruce (1996) found that the ability recognize face recognition based on shape information, is affected by lighting direction. The authors (Hill & Bruce, 1996) placed participants in a windowless room with one fluorescent light source; the participants viewed images of co-workers. The authors found that top lighting lead to more accurate determinations of likeness for both male ($P<<0.05$) and female faces ($P<<0.05$).

Office Productivity and Wellbeing

Many of the previously discussed papers describe studies that take place in carefully controlled laboratory-type settings. Several studies have looked specifically at human performance and behavior under artificial lighting in real-life settings. The majority of this lighting research has examined lighting in office settings. Many of these studies examine the effects of lighting on wellbeing and productivity of the workers.

For example, one study tested an intervention of high color temperature lighting system on a call center in the UK (Mills, Tomkins & Schlangen, 2007). The study used two identically set-up floors of the call center, one floor was the control floor with the baseline of 2900 K fluorescent lights, while the other floor was exposed to the baseline and then fluorescent lighting of 17000K. Using questionnaires to assess alertness, memory, fatigue, wellbeing, and job performance the authors found improvements in the ability to concentrate ($P<0.01$ after correction for type 1 errors) on the floor with the 17000K intervention lighting system (Mills et al., 2007).

Gaps and LED lighting

As discussed above, there are a variety of ways in which lighting affects humans. Lighting affects humans physiologically by suppressing sleepiness, reducing cortisol and reducing depression symptoms. In some settings people have a preference for the lighting they would like to experience. Lighting can also affect visual acuity, and perceptions of people and spaces. Lighting can also affect how we behave. It can affect our memory, productivity, intimate note-writing, and collaboration behaviors. The studies discussed above use a very wide variety of methodologies, settings and light sources. Some even omit useful details about the lighting systems. Therefore, it is difficult to extrapolate the past results to various settings, especially lighting in military shelters. Very little research has looked specifically at the effects of military shelter lighting systems on Soldiers.

Before discussing the current proposed application of this past research, it is important to discuss one of the main gaps in the research: light emitting diode (LED) technologies. LEDs are a new form of lighting that use semiconductor technology and are highly efficient and durable (Herkelrath, Laksberg & Woods, 2005). Very few studies have examined the effects of LED lighting on human vision or behavior. One recent study by did attempt to do so, but only preliminary results are available (Varkeviesser, Raymann & Keyson, 2011). For this study, 37 college-aged students were tested under fluorescent lighting combined with different LED conditions labeled: Red-Green (RG), Red-Blue (RB), Green-Blue (GB) and Red-Green-Blue (RGB). They preliminarily reported that lighting does not cause significant differences in wellbeing (measured by their own wellbeing Likert survey). Although, they did find that the low illuminance group (RD and RGB) reported more negative emotions than the high luminance group (GB) (no statistics reported) (Varkeviesser et al., 2011). This effort to test humans under LED conditions is appreciated, yet the results are unclear and preliminary, as are the exact measures of the experimental lighting conditions. Of the other publications that exist on LEDs and human behavior, most examined LEDs in the treatment of SAD symptoms (see: Glickman et al., 2006; Desan et al., 2007; Levitt, Joffe & King, 1994).

Lighting and the Military

Soldier Schedule

One of the main reasons it is very important to understand the effects of lighting on Soldiers is because they spend a large portion of their time in the artificially-lighted tents. Operations tempo (OPTEMPO) refers to work schedule for deployed Soldiers (Huffman et al., 2005). OPTEMPO within a day consists of several rotations: hours on security, in briefings (meetings), hours on patrol (off base), and some leisure hours for eating, resting, and exercise; an average work day for a Soldier is 11.66 hours (Huffman et al., 2005). OPTEMPO can range from high to low. Typically, forward operating camps such as the outposts or FOBs will have higher OPTEMPOs. Several studies have examined sleep deprivation and found that Soldiers at high OPTEMPO base camps sleep an average of 3.9 hours a night, while Soldiers at low OPTEMPO camps sleep an average of 7.8 hours a night (Miller, Shattuck, & Matsangas, 2011; LaBash et al., 2009). Daily rotations will range based on rank and military occupation specialty (MOS: job) (Joint Chiefs of Staff, 2014). Although there is a great deal of variation on work schedules, it is clear that deployed Soldiers spend a lot of time in shelters, especially to escape hot temperatures. Since Soldiers face many stressors it is important to understand how the artificial lighting in the shelters may affect behavior.

Stressors in the Military

Several articles have discussed and modeled the many stressors Soldiers face (Table 1.2). In one review, the authors explain that military members face similar stressors to civilians, such as occupational workload, but they also experience military-specific stressors such as safety concerns (Adler et al., 2003). For example, Adler et al. (2003) discuss Soldier work hours, which are often ambiguous; unpredictability can cause stress. Other military specific stressors include interpersonal conflict within the unit during training and deployment. While this can be an issue, Brusher (2007) explained that unit cohesion and morale can be the primary motivation for Soldiers in combat. Stressors for deployed Soldiers also include worries about food and living conditions, uncertainty about mission objectives, and safety concerns (Adler et al., 2003).

The military stressors defined in Table 1.2 guided the selection of tasks under investigation in the current study. One study so far has examined the effects of lighting on Soldiers. In a controlled experiment, Hawes et al. (2012) tested four different technologies (one fluorescent, three LED) that were controlled for illuminance but varied in color temperature, and found that higher color temperature lighting (when compared to lower color temperatures) elicit and faster reaction times on cognitive tasks and lower depression ratings in Soldiers (e.g. $P<0.01$ for a linear relationship between reaction time and color temperature). Yet, that study used specific cognitive tasks adapted for military applications. The current study will examine the two extreme color temperature lighting technologies: current fluorescent (FL) (~3300 K) versus frontrunner LED (~6000 K) effects on Soldier performance on closer-to-real-life tasks. The illuminance at the work stations will not be controlled to create a more naturalistic setting, but the measurements are carefully recorded (see Methods) and comparable between technologies. The tasks were chosen based on military stressor literature.

Table 1.2 Military versus Civilian Stressors

Phases	Civilian	Military
Occupational	Workload	Workload
	Long hours	Long hours
		Unpredictable hours
	Not enough training for job	Not enough training for job
	Interpersonal conflict	Interpersonal conflict
Training	Physical stress (job dependent)	Physical stress
		Interpersonal conflict in unit
Deployment		Quality of living conditions
		Confusion over mission objective
		Safety
		Sleep quality
		Pay disbursement
		Family separation (psychological distress)
		Harassment (psychological distress)
		Witnessing injury and death (psychological distress)

Hypotheses

First, the current study examines the effect of lighting on subjective mood ratings. This can show whether Soldiers feel more alert under certain lighting which can lead to better work quality. It also addresses the stressors of sleep deprivation and psychological distress. If lighting can provide a boost in mood it may mediate the effects of family separation, safety concerns, and any other psychological distress. The first hypothesis is that:

(H1) Soldiers will self report more positive and alert mood under LED than FL lighting.

This is based on past research that high color temperature can suppress melatonin and reduce depression symptoms (Boyce & Kennaway, 1987; Knez, 1995; Pail, 2011). Also, blue light increases arousal, or wakefulness, more than white light (Ekström, 2014), especially for males (Knez, 1995). (Note: the majority of the participants are male, in line with the Army population, see Method.)

Second, the current study examines the effect of lighting on visual acuity and a military map task. The map task closely represents a typical work related project involving near vision. The map task also involves color contrasts. This task will show how lighting can affect efficiency on work tasks to alleviate the stressor of Soldier workload. The second hypothesis is that:

(H2a) Soldiers will have better visual acuity at any work station with higher illuminance.

(H2b) Soldiers will perform better (more correct answers) and more efficiently (faster reaction times) on the task under LED than FL lighting.

This is based on the past research that higher illuminance and color temperature lead to better visual acuity and faster reactions times (Berman, 1992; Hawes et al., 2012). And blue wavelength light leads to higher arousal than white light which can lead to higher productivity (Cajochen et al., 2004; Ekström, 2014; Hawes et al., 2012; Mills et al., 2007).

Third, the current study examines the effects of lighting on interpersonal conflict coping styles. As discussed above interpersonal conflict can be a stressor for Soldiers, but avoiding these conflicts and creating Soldier cohesion is one of the best ways to cope with stressful situations (Brusher, 2007). The third hypothesis is that:

(H3) Soldier will rate their interpersonal conflict style as more collaborative in the FL than LED lighting.

Although past research shows that cool lighting encourages communication more than warm lighting (Gifford, 1988), this is based on past research that participants were more likely to resolve conflict with collaboration than with avoidance in warm white versus the cool white lighting ($P<0.02$) (Baron et al., 1992).

Lastly, the current study examines the effect of lighting on perceived tent attractiveness. The adapted questionnaire will determine how the lighting affects the interior tent appearance. Living condition quality can be a stressor of deployed Soldiers, and tent attractiveness can contribute to perceived quality. The fourth hypothesis is that:

(H4) Soldiers will rate the tent as more pleasant and attractive under the FL than LED lighting.

There is less research in the area of room perception and lighting, but a well established study purported that lower color temperature elicits higher ratings of spaciousness and pleasantness (Manav & Yener, 2014).

As discussed from the past literature, lighting can influence several human behaviors, including productivity (e.g. Mills et al., 2007), mood (e.g. Knez, 1995), interpersonal relationships (e.g. Baron et al., 1992) and perception of spaces (e.g. Houser et al., 2002). Yet, there are few consistencies between the experimental light sources, settings, and participant demographics. Some studies even found inconclusive results (see, Boray et al., 1989; Knez & Kers, 2000). Additionally, there has been very little research connecting the newer LED technologies and human behavior. Therefore, in order to make an informed decision between specific FL and LED technologies in military shelters it would be beneficial to run a study comparing the effects of the two on military personnel. As discussed, one such study has been run so far, but focused on cognitive tasks. Now, based on the stressors paradigm (Adler et al., 2003), it is important to examine lighting effects in such areas as conflict resolution to ease interpersonal stress, and the appearance of living space to ease living condition stress. The results of this work can guide the down selection of lighting in military shelters in hopes to increase wellbeing, quality of life, and mission effectiveness of Soldiers.

II. METHOD

Participants

A total of 23 subjects (20 male: 87% and 3 female: 13%) voluntarily participated in the experiment. All participants were enrolled United States Army infantry members stationed at the

Natick Soldier Systems Center (NSSC) as research volunteers. The age of the participants ranged from 19 to 29 years old (Mean: 21.70 and sd: 2.75). All testing procedures were approved by the ethics committee at the U. S. Army Natick Soldier Research, Development and Engineering Center as well as the IRB at Cornell University. The uneven number of males and females is acknowledged; the numbers represent the typical available infantry members stationed at NSSC. Additionally, it should be noted that the percentages closely represent the current gender enrollment in the Army: 85% male, 15% female (Simons, 2014).

Design

A within-participants repeated-measures design was used, requiring each participant to visit the laboratory on two consecutive days. To control for circadian rhythm, each participant visited the laboratory at the same time each day, but overall testing times ranged from 0900-1400. As research volunteers, each participant adhered to the same controlled normal work schedule outside of the laboratory. To control for carry-over effects between lighting conditions, the order was counterbalanced across days, yet due to scheduling conflicts nine participants experienced LED on day one and fourteen participants experienced florescent on day one. Two lighting technologies covered extremes of the spectrum of color temperature, including FL (3345K) and LED (6029K). The dependent variables included two questionnaires (a conflict resolution instrument and a room attractiveness scale), an Army-based map search-and-locate task, a visual acuity test (Landolt C) and a self-report mood instrument (POMS). The battery of tasks took approximately 30 minutes to complete.

Setting

The experimental environment was a climate-controlled Tent Expandable Modular Personnel (TEMPER) 32' L x 20' 6" W military shelter (640 sq. ft.). The tent is insulated for complete darkness (no daylight). The interior liner of the tent was the white Thinsulate Camel Extreme Weather Liner. For each session the tent comprised of the same set-up and layout of desks and chairs (see Figure 2.1). The desks are numbered for future reference. The experimenter sat at table 4.

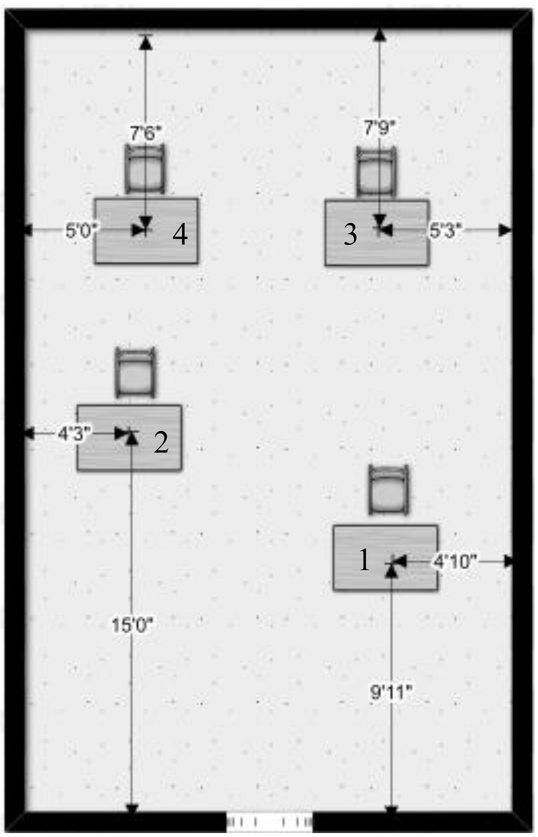

Figure 2.1 . Tent seating layout

The four tables were Alulite, Mardi Gras iDesign and Southern Picnik Aluminum (48x30x30 inches). The chairs at each table were Meco Gray Dream folding chairs (seat height: 16 inches; back height: 30 inches). Each day the tent was rigged with the appropriate lighting technology based on the counterbalancing scheme. The shelter was rigged with a heating and cooling system to keep the tent at a constant interior temperature of approximately 70deg F.

Lighting

Two lighting technologies were chosen due to their representation of the extremes of the range of color temperatures. These two technologies represent the traditional military tent lighting and the new possible replacement technology. The traditional FL lighting had an average color temperature of 3345K (tested range 3320-3370K), and provided a general shelter illumination of 20.3 foot candles, with a color rendering index (CRI) of approximately 80. The LED lighting had an average color temperature of 6029K (tested range 5996-6062K), and provided a general shelter illumination of 32.6 foot candles, with a CRI of approximately 90. The lighting placement was based on the built-in light hanging straps of the TEMPER tent (Figure 2.2 and 2.3). Based on the lighting configuration and placement of the tables, illumination measurements varied on each work surface of the tent (Table 2.1). Each participant sat at the same table in both sessions. The table number was noted.

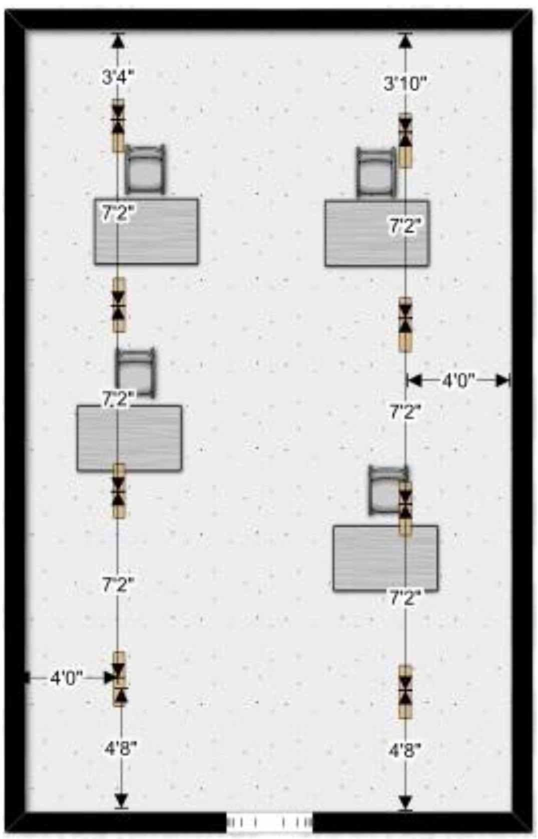

Figure 2.2. Tent layout with FL lighting

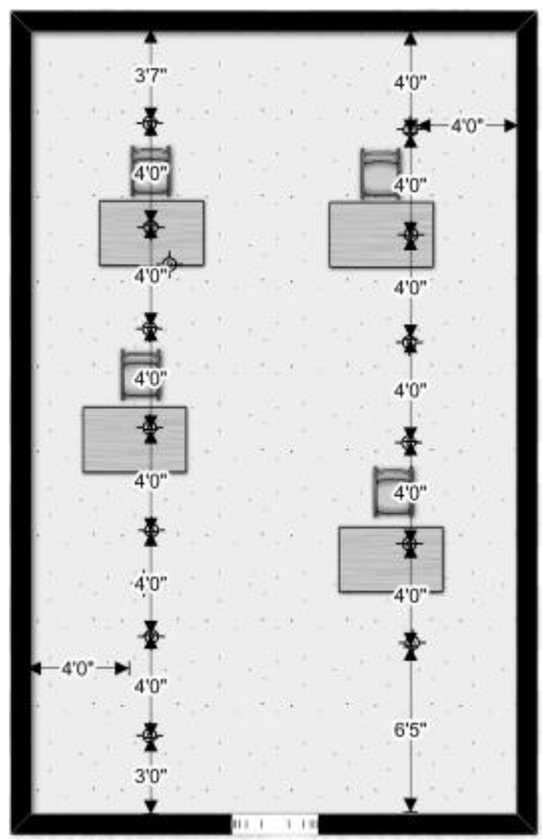

Figure 2.3. Tent layout with LED lighting

Table 2.1. Illuminance measures under FL lighting

Fluorescent		Day 1			Day 2			
		Table Top	Paper	Map	Table Top	Paper	Map	Average
Table 1	LUX	274	279	298	310	307	309	296.2
	FC	25.7	25.9	27.7	28.2	28	28.7	27.4
Table 2	LUX	163	164	169	170	172	176	169.0
	FC	15.1	15.7	15.6	15.3	15.9	16.3	15.7
Table 3	LUX	236	240	146	245	246	262	229.2
	FC	21.6	22.4	22.8	22.6	22.9	24.7	22.8
Table 4	LUX	265	255	268	266	258	273	264.2
	FC	24.7	23.9	24.9	24.7	23.9	25.5	24.6

Table 2.2. Illuminance measures under LED lighting

LED		Day 1			Day 2			
		Table Top	Paper	Map	Table Top	Paper	Map	Average
Table 1	LUX	289	289	294	295	300	302	294.8
	FC	26.9	26.8	27.2	27.6	27.9	28.0	27.4
Table 2	LUX	327	328	331	330	332	334	330.3
	FC	30.5	30,5	30.6	30.6	30.7	31.0	30.7
Table 3	LUX	314	313	322	320	320	320	318.2
	FC	29.2	29.1	29.8	29.7	29.8	29.7	29.6
Table 4	LUX	255	259	253	249	236	245	249.5
	FC	23.7	24.0	23.3	23.2	22.0	22.7	23.2

Experimental Tasks

During each session the participants performed a battery of tasks designed to measure visual acuity, conflict resolution style, visual search ability, color recognition, subjective room appearance and self-reported mood state.

Military Map Task. The Military Map task tested both visual search ability and color distinction. This task is adapted from actual military tasks. Soldiers typically use tranverse maps in mission planning and during tactical operations. They are used to locate friendly versus foe zones, friendly resupply areas, fire support areas, as well as enemy targets. After speaking with former military consultants at NSRDEC, it was determined that Soldiers typically study these maps by standing over them as they are laid out on a table or work surface. For this study, the participants were asked to stand over the map at an arms distance from the table surface. The participant is required to locate a total of nine points on an 18x27in map. The maps were obtained from the United States Geological Survey (USGS) online database of topographical maps (Appendix A and B). Since each participant completed two sessions, two maps were required for this task. Participants were exposed to the maps based on the counterbalancing system. The two map sections chosen were Jackson, NH and North Conway, NH based on the similar spatial densities of landmarks (towns, street, mountains, rivers, etc.) (Tables 2.3 and 2.4). In order to analyze the maps, they were broken into three sections (upper, middle and lower) representing an exact third of the area of the entire map.

Table 2.3. Characteristics of Jackson map

Section	Road	Landmark	Significant Landmark	Water Body
Upper	1	1	2	6
Middle	10	5	1	6
Lower	18	7	5	7
Sum	29	13	8	19

Table 2.4. Characteristics of North Conway map

Section	Road	Landmark	Significant Landmark	Water Body
Upper	21	4	4	8
Middle	11	4	1	9
Lower	9	5	0	9
Sum	41	13	5	26

Each participant was given nine coordinates. The coordinates were chosen on each map using a system that ensured three things: 1. three points were located in each section of the map (lower, middle, upper) 2. each of these three points represented a different type of location (road, landmark, water) since each type of location if written in a different color and font and 3. Each type of location was matched with a different background color (white, green or brown topography lines). The coordinates were randomized when presented to the participants. Since it is part of military training all participants had previous coordinate search training. For this study, the instructions for the task were based on the Department of the Army (DOA) Soldier's manual of common tasks: skill level 1 (1987). They were also given a practice coordinate search. (For instructions and practice example see Appendix C). The participants were timed on the iphone 4S using the stopwatch section of the standard clock utility application. Each coordinate was presented at the top of a blank page, the experimenter began the timer as soon as the participant flipped the page and stopped the timer when they pointed at the location, saying “coordinate found”. They next wrote the name of the location on their paper and flipped to the next page. In addition to time, the task was also scored based on correctness of the recorded location.

Visual Acuity Task. The Landolt C Eye chart is a standard visual acuity test which consists of 8 lines of 7 block letter C at various orientations, top row is large font and the size of the letters progressively decreases by each row. The participant is instructed to indentify the location of the opening of the letter C (up, down, left, right) beginning at the top row and progressively working their way down to smaller font sizes. The participant would attempt to read the entire chart, and the experimenter would record any errors. (recording sheet: Appendix D).

Conflict Resolution. In each session the participants were given the Thomas-Kilmann (1974) Conflict Mode Instrument. The PDF was obtained from VISTA Tours since it was printed in a clear and concise manner (Appendix E). According to the directions the participant is required to read each question and select from two options (A/B) which they are more likely to do in a conflict situation. The task was presented as a paper and pencil task. The scoring procedure adhered to the Thomas-Kilmann methodology (Appendix F).

Tent Attractiveness Scale. In order to assess subjective aesthetics we used the adapted Room Attractiveness Scale (Chronbach alpha= 0.89) (Boray, Gifford & Rosenblood, 1989). This is a 9-

point bipolar scale rating room appearance from Comfortable-Uncomfortable, Like-Dislike, Pleasant-Unpleasant and Beautiful-Ugly. The scale was adapted to rate the tent interior appearance (Appendix G).

Mood Assessment. The Profile of Mood States (POMS; McNair et al., 1971) standard form was administered at the beginning and end of each experimental session to measure the initial and final mood state of the participant. The POMS questionnaire consists of 65 items rated by the participant on a 5-point scale from 0 "not at all" to 4 "extremely”. The participants were instructed to rate the items based on how they were feeling “RIGHT NOW,” a common procedure for repeated-measures pre-post mood testing (see also, Berger & Owen, 1983; Schotte, Cools, & McNally, 1990). The POMS questionnaire was administered on 11.4 inch Samsung 700T Slate 7 Notebooks.

Procedure

Each participant completed two sessions for this study. During each of the test sessions, the shelter was equipped with one of the two lighting technologies in correspondence with the counterbalancing scheme. As explained above, based on scheduling issues, nine participants were exposed to FL first and 14 were exposed to LED first. Each session occurred on separate consecutive days and a given participant would always begin and end at the same time and be seated in the same position in the shelter. The tasks were not counterbalanced because the nature of the tasks does not lead us to think that there will be an order effect, thus for every participant the order was: POMS, conflict resolution, map task, TAS, Landolt C and POMS.

III. RESULTS

Using IBM SPSS Statistics 22 we performed a series of mixed model ANOVAs to analyze the results. Task performance was analyzed to understand the effects of the two lighting technologies, analyses also controlled for seat location since each seat had carefully-recorded, slightly different illumination measurements, session number, session time of day and participant characteristics (gender, age, MOS).

Mood Assessment

The Profile of Mood States is scored into subscales of Tension-Anxiety, Depression, Anger, Confusion, and Vigor (McNair et al., 1971). It should be noted that the program for the POMS scale had a glitch that randomly omitted the answers to two questions. Therefore, for each participant the average of the subscale with a missing answer would be recalculated based on the answers provided. This ensures that the missing answers did not count as a 0 ("not at all") answer. A mixed model analysis of overall mood (both pre and post session) controlling for order, lighting and seating shows: no effects of lighting for all subscales except Vigor (Tension-Anxiety: lighting $F(1,47)=.057$, $P=.812$, seating $F(2,13)=.936$, $P=.417$; Depression: lighting $F(1,47)=.019$, $P=.891$, seating: $F(2,13)=1.509$, $P=.257$; Anger: lighting $F(1,47)=1.419$, $P=.240$, seating: $F(2,13)=1.365$, $P=.290$; Confusion: lighting: $F(1,47)=.815$, $P=.371$, seating: $F(2,13)=1.701$, $P=.221$) (Table 3.1). For Vigor there was a significant lighting effect ($F(1,47)=9.437$ $P=.004$), showing that on average participants report higher Vigor scores under fluorescent lighting than LED lighting (seating: $F(2,13)=1.442$, $P=.251$) (Figure 3.1).

Table 3.1 POMS overall self rating by subscales.

Scale	Fluorescent	LED	P Value Lighting	P Value Seating
Tension-Anxiety	4.186	4.091	.812	.417
Depression	1.183	1.227	.891	.257
Anger	1.782	2.341	.240	.290
Confusion	3.193	3.455	.371	.221
Vigor	17.594	15.385	.004*	.251

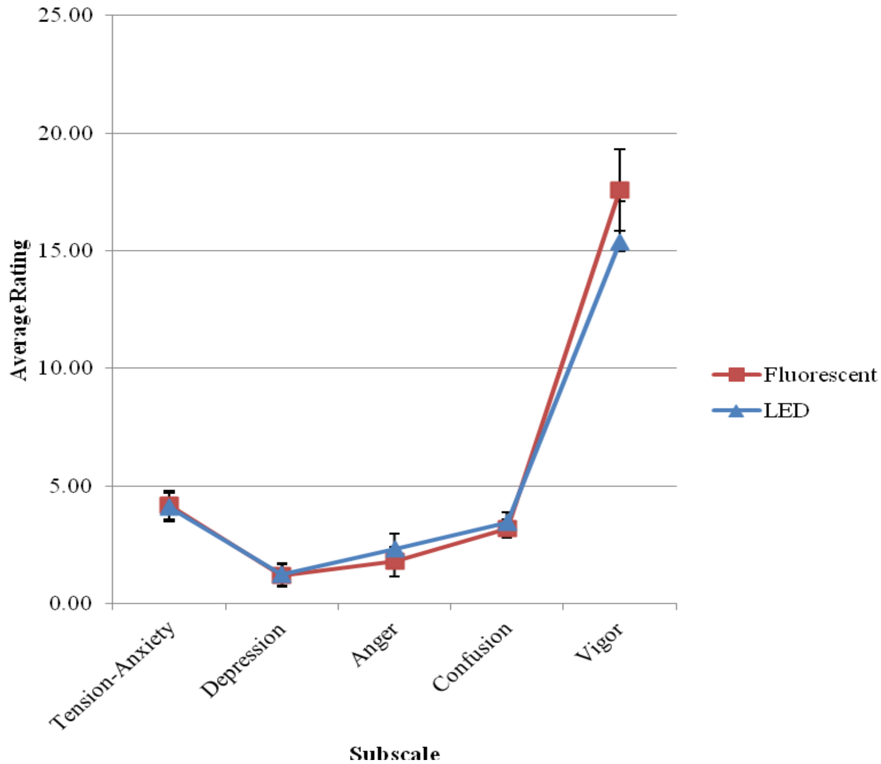

Figure 3.1 POMS overall self rating by subscales.

There is also an interaction showing that the mean vigor score is only reported as higher in LED lighting than in FL lighting at seat two (F(2,47)=4.229, P=.02) (Figure 3.2). Yet, when individual variables are considered: gender, time of day and age (gender F(1,10)=.528, P=.484; age F(1,10)=.014, P=.907; time of day F(7,10)=.449, P=.850) are controlled this interaction is no longer significant (F(2,10)=.538, P=.600).

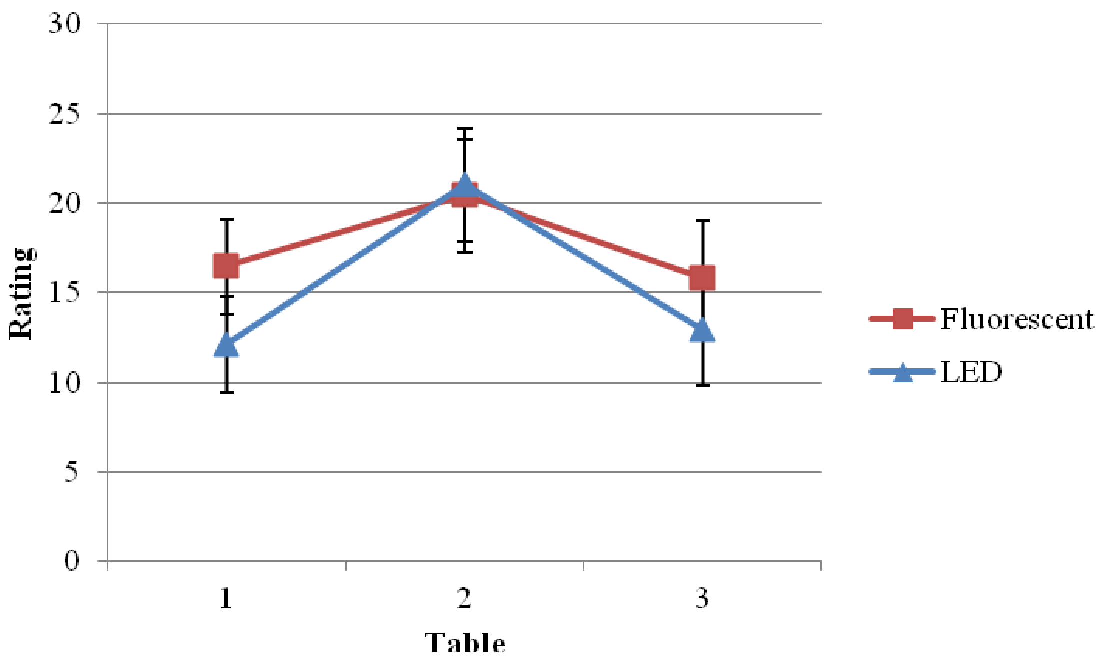

Figure 3.2 POMS Vigor scores by lighting condition and table

The same analyses were performed to include the difference in mood ratings for pre versus post session answers. This shows how the lighting affected change in mood over time in the lighting. There are no significant results for any of the subscales: Tension-Anxiety ((F(1,59.470)=.969, P=.329), Depression (F(1,59.874)=.748, P=.391), Vigor (F(1,59.224)=.985, P=.772), Confusion (F(1,59.728)=2.808, P=.099), and Anger (F(1,59.346)=.017, P=.896). Seating location does not play a role in the effects of lighting over time (Table 3.2).

Table 3.2 POMS ratings by lighting over time

Subscale	Lighting	Pre/Post	Mean	Std. Error	P Value	P Value for seating
Tension-Anxiety	FL	Post	3.532	.620	.229	.198
		Pre	4.416	.600		
	LED	Post	4.077	.613		
		Pre	4.262	.603		
Depression	FL	Post	.743	.494	.391	.391
		Pre	1.662	.471		
	LED	Post	1.490	.487		
		Pre	1.817	.475		
Vigor	FL	Post	15.195	1.552	.985	.524
		Pre	16.190	1.522		
	LED	Post	13.094	1.542		
		Pre	13.686	1.527		
Confusion	FL	Post	2.766	.428	.099	.220
		Pre	3.509	.409		
	LED	Post	3.849	.422		
		Pre	3.627	.413		
Anger	FL	Post	2.291	1.031	.896	.974
		Pre	2.901	1.007		
	LED	Post	2.910	1.023		
		Pre	3.652	1.011		

Visual Acuity Task

Landolt C data used only the errors on the last line of the tool because it was the only line in which there were errors. Results showed that under fluorescent lighting participants incorrectly identified 0.907 out of 8 locations on the last line (sd=.236), while under LED lighting participants incorrectly identified an average of 1.007 out of 8 locations (sd= 0.236).

There were no significant differences of visual acuity under each lighting condition (F(1,21)=.150, P=.702) (Figure 3.3). Table did not play a significant role in visual acuity in general (F(2,19)=.629, P=.545) or under each lighting condition (F(2,19)=1.413, P=.268) (Figure 3.4).

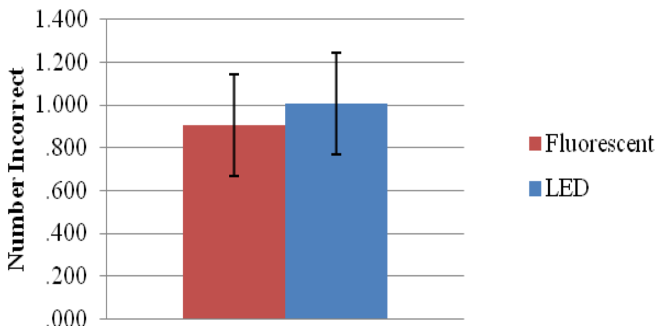

Figure 3.3 Visual Acuity Errors by Lighting

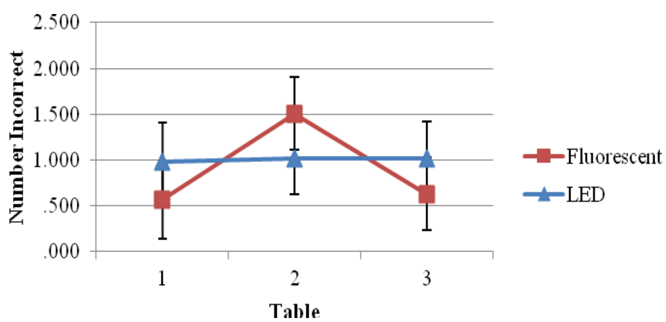

Figure 3.4 Visual Acuity errors by lighting and seating location

Map Task

The variables of interest in the map task were time to completion of finding each data point (will be called reaction time) and correctness. Measures of correctness show that under fluorescent lighting participants identified the correct location of the coordinates an average of 91.2% of the time, while under LED lighting participants identified the correct location 92.6% of the time. There were two different maps, although the maps were controlled for spatial and color density, results showed that reaction time (RT) was faster for map 1 (M=13.628 sec, sd=1.106) than map 2 (M=15.762, sd=1.112). This difference was statistically significant (F(1,371)=12.025, P=.001). Additionally, there was an order effect showing that overall RT was significantly (F(1,375.361)=65.408, P<.001) faster during the second session (M=12.224 sec, sd=1.108) than during the first session (M=17.165 sec, sd=1.108). A mixed model ANOVA looked at the difference of RT between coordinates, as coordinate sets were developed with different color discriminations. The results showed that there were no significant differences in RT for each coordinate under each session light (FL or LED) (F(1,368)=2.238 P=.135) (Figure 3.5).

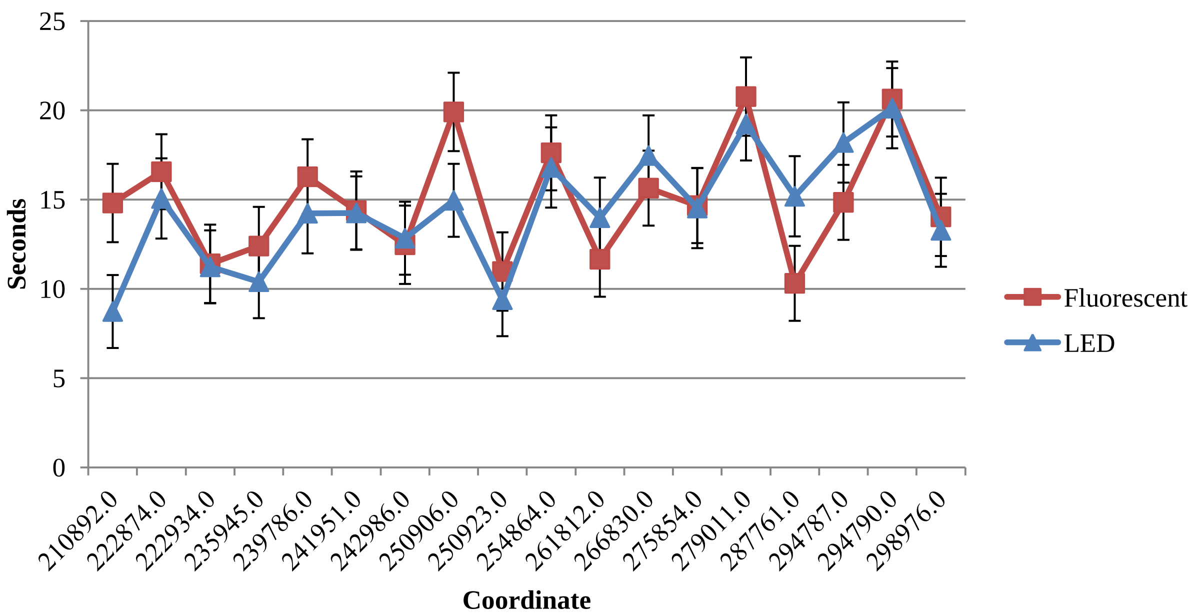

Figure 3.5 Map Task coordinate reaction time by lighting condition

Seat location of each participant had an effect on their performance of the task under each lighting condition. Results show that task performance overall (FL and LED combined) was the fastest at table 1 (M=10.048 sec, sd=1.597) (table 2: M=17.836, sd=1.494, table 3: M=15.744, sd=1.383). This difference is statistically significant (F(2,16)=6.721, P=.008). Results show that there was a significant interaction under each lighting condition, RT is moderated by seat location (F(2, 368)=3.189, P=.042). Specifically, RT was faster under FL at table two and faster under LED at table 1 and 3 (Figure 3.6).

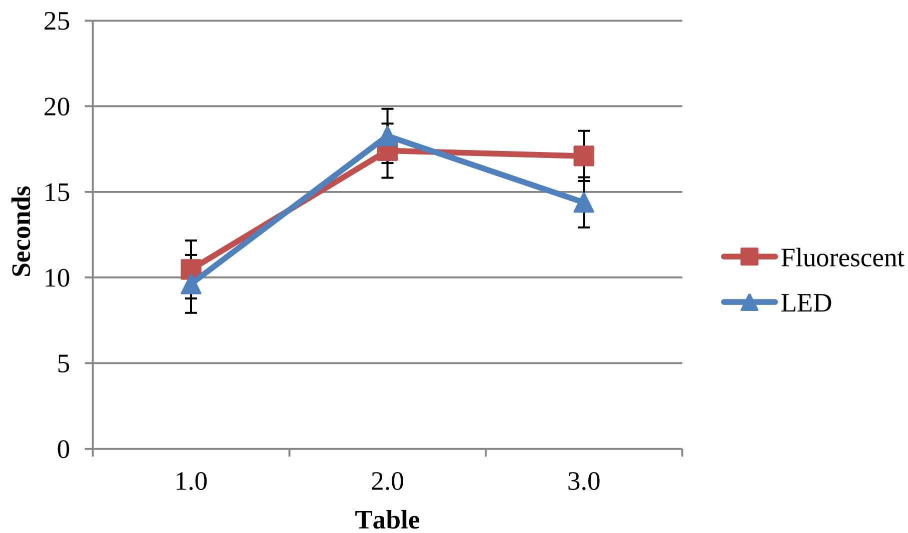

Figure 3.6 Map Task RT by lighting and table

Analyses show that individual characteristics did not play a role in differences between performance under each lighting condition and at each table (MOS: F(4,10)=2.386, P=.121; gender: F(1,10)=1.769, P=.213; age: F(1,10)=.081, P=.781, time: F(5,5)=1.513, P=.273.) When controlling for these variables the interaction is still significant (F(2,10)=6.371, P=.016).

Conflict Resolution Scale

The conflict resolution scale was scored according to the developed scoring system (Thomas & Kilmann, 1974) When controlling for session, lighting and table there was no effect of lighting or table on all subscales expect competing (collaborating lighting: F(1,17)=3.534, P=.077 seating: F(2,17)=1.557, P=.239; compromising lighting: F(1,17)=.255, P=.620 seating: F(2,17)=2.035, P=.161; avoiding lighting: F(1,17)=.004, P=.949 seating: F(2,17)=1.139, P=.343; accommodating lighting: F(1,17)=.487, P=.495 seating: F(2,17)=.102, P=.903). For competing there was an effect of lighting ratings (F(1,17)=5.468, P=.033) but not an effect of seating (F(2,17)=1.916,P=.178). Participants rated themselves as less competitive in the FL lighting than LED lighting (Table 3.3 and Figure 3.7).

Table 3.3 Conflict Resolution Scale self-report means by lighting

Scale	Fluorescent	LED	P Value Lighting	P Value Seating
Collaborating	5.486	5.186	.077	.239
Compromising	7.061	6.794	.620	.161
Avoiding	6.711	6.725	.949	.343
Accommodating	5.808	6.072	.495	.903
Competing	4.789	5.367	.033*	.178

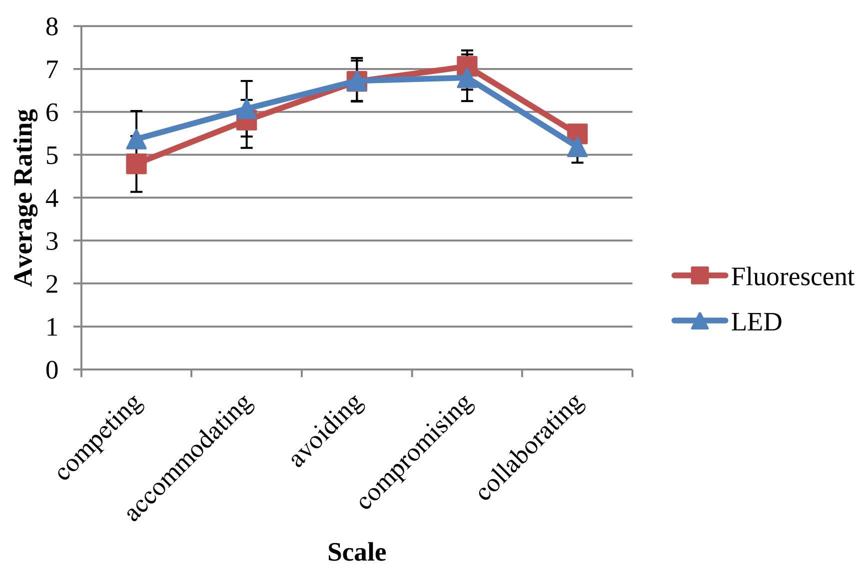

Figure 3.7 Conflict Resolution Scale self-report means by lighting

Tent Attractiveness Questionnaire

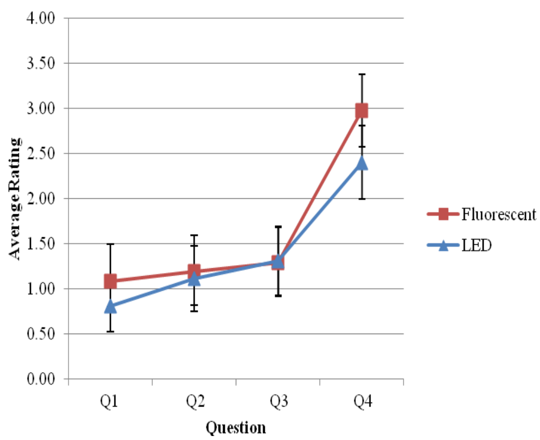

Figure 3.8 TAQ average answers by lighting

For the TAQ there were no differences in rating under each lighting condition for three of the scales (Q1: F(1,17)=.975, P=0.302; Q2: (F(1,17)=.001, P=.979; Q3: (F(1,17)=.002,P=0.967), but for Q4 (Beautiful-Ugly) there was an effect of lighting condition on rating (F(1,17)=5.359, P=.033). Specifically, participants rated the tent less beautiful in the FL lighting than the LED lighting (Figure 3.8).

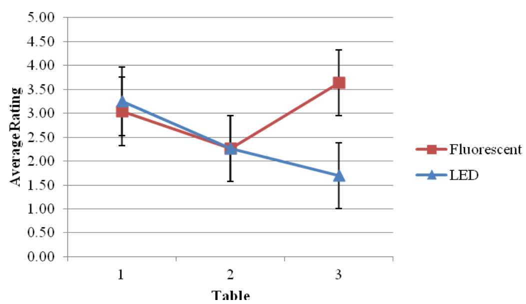

Figure 3.9 TAQ Q4 by lighting by table

Additionally, there was an interaction showing that if seated at table three the tent was rated much less ugly under the FL lighting than the LED while at the other seats the ratings were similar ((F2,17)=7.620,P=.004) (Figure 3.9). But when controlling for the characteristics of the participants at each table (MOS, age, gender and time of day) results show that they did not play a role in the significant differences for question 4 (MOS F(4,11)=1.630, P=.236; gender: F(1,11)=.032, P=.861; age: F(1,11)=.022, P=.280; time of day F(6,5)=.184, P=.969).

IV. DISCUSSION

In order to ensure a more naturalistic study the illuminance of each lighting technology was not controlled to match at each testing station. These measures were carefully recorded, thus when considering the effect of the two technologies it is important to consider factors of color temperature and illuminance. Illuminance is considered in the analyses by examining the effects at each table.

Hypotheses

Hypothesis I

(H1) Soldiers will self report more positive and alert mood under LED than FL lighting.

The mood analyses showed two significant relationships: higher vigor scores under fluorescent lighting and an interaction showing that the effect of lighting on vigor scores is moderated by seat. However, neither of these findings is significant when controlling for individual characteristic variables (gender, time of day and age) and none of these variables explain the relationship. Additionally, analyses showed that change in mood under each lighting condition was not significant for any of the subscales. Therefore, the hypothesis was not supported, showing that there is no difference in mood under each lighting condition. This finding may be due to the short lighting exposure time of the current study. The participants in the current study were exposed the each lighting condition for approximately 35 minutes during each session. Several other studies that have found significant differences in lighting effects exposed the participants to at least one hour of artificial lighting (Ekstrom & Beaven, 2013; Hawes et al., 2012; Partonen & Lonnqvist, 2000). Some of the naturalistic studies examined effects after a full work day of exposure (Begemann, Beld & Tenner, 1997). One study that did not find significant differences noted that the 35 minute exposure time of their study may not have been enough (Boray, Gifford & Roseblood, 1989).

Hypothesis II

(H2a) Soldiers will have better visual acuity at any work station with higher illuminance.

Overall, participants performed well on the Landolt C task, on average only misidentifying one of the eight positions on the last line of the instrument. There were no significant differences of performance under each lighting condition or at each table, therefore the hypothesis was not supported. Interestingly, the highest number of errors was at table two under the fluorescent lighting which was by far the lowest illuminated testing station (169 lux), but as stated, this difference is not significant. This may be due to the timing of the tasks. The participants performed the task after they had experienced each lighting condition for approximately 25 minutes. It is possibly due to eye fatigue, it takes longer for visual acuity to change under different lighting.

(H2b) Soldiers will perform better (more correct answers) and more efficiently (faster reaction times) on the task under LED than FL lighting.

On the map task, there was a significant finding of an interaction between lighting and reaction time. Specifically, reaction time under each lighting condition is moderated by seat location. For table 1 and 3 reaction time was faster in LED lighting which is in line with hypothesis 2b. There is also a greater difference (between FL and LED lighting) in reaction time at table 3 (2.711 sec) than table 1 (0.844 sec) which matched the differences in illuminance at each table. Specifically, there is a greater difference of lux at table 3 under each lighting condition than at table 1 (Table 4.1). This is in line with the idea that higher illuminance and higher color temperature creates faster reaction times (Berman, 1992; Hawes et al., 2012). Yet, at table 2, reaction time is faster under FL (169.0 lux) than under LED (330.3 lux) which is the opposite of what would be expected. These differences are not explained by the characteristics of the participants at each table.

Table 4.1 Map Task RT by lighting and table compared to table illuminance

Session Light	Table	Mean	Std. Error	Table (Lux)
Fluorescent	1.0	10.470	1.691	296.2
	2.0	17.406	1.582	169.0
	3.0	17.099	1.465	229.2
LED	1.0	9.626	1.691	294.8
	2.0	18.266	1.582	330.3
	3.0	14.388	1.465	318.2

It is important to note that the unexpected findings may be due to the development of the map task. The map task had an order effect, meaning that there was a learning effect: task performance improved the second time it was performed. Additionally, one map was slightly easier than the other. Although these variables such as map number and session number were counterbalanced during the application of the study and controlled in the analyses; still this shows that more careful development of the tasks would benefit future studies.

Issues aside, these results lean toward the idea that when examining the effects of lighting on humans, illuminance may be more effective than color temperature, especially for visual tasks. This idea is supported by a previous study that only examined the effects of fluorescent lighting of various color temperature on several tasks (Boray et al., 1989). They claimed that illuminance differences were small and did not factor illuminance into their analyses. Yet, they did not find any significant results and explained that they may have found significant differences if illuminance differences were considered. Additionally, in a study that did examine color temperature and illuminance, the main findings in relation to color temperature found interactions with gender (Knez, 1995), which relates to a limitations of the current study, discussed below.

In the discussion of the map task it is also important to acknowledge the issue of color rendering. The analyses of the RT for each coordinate addressed whether CRI played a role in reaction time on a task that involved color contrasts. Results showed that reaction time under each lighting condition did not have a significant effect on RT for individual coordinates. Considering the two lighting technologies were relatively close in CRI measurements (FL:~80; LED:~90) these results can be expected. These results are also important because they add another aspect of comparison for the two lighting technologies. In this case, the color rendering differences do not play a role in Soldier performance, determining the two technologies equal in this sense.

Hypothesis III

(H3) Soldier will rate their interpersonal conflict style as more collaborative in FL than LED lighting.

The only significant difference for the conflict resolution scale was that participants rated themselves as more competitive under LED lighting than FL lighting. This is in line with hypothesis 3, yet the relationship is no longer significant when controlling for age, gender, and time of day. One of the limitations pertaining to this task is the scale instrument. The Conflict Resolution Scale (Thomas & Kilmannn, 1974) is more suited to address the *trait* conflict style of a participant than the *state* conflict style. Meaning, that it was addressing how the individuals "typically" deal with conflict situations, it may have been beneficial for the purposes of this study to adapt the questionnaire to address how the participants would address a conflict situation "at this moment".

Hypotheses IV

(H4) Soldiers will rate the tent as more pleasant and attractive under the FL than LED lighting.

On the surface, it seems as though participants rated the tent as more beautiful under the LED lighting than the FL lighting which does not support hypotheses 4 but this is no longer significant when controlling for age, gender and time of day. It is possible that this is because most studies on room appearance test home-like rooms while military tents are a sterile setting. The interior of tents are entirely one color and the furniture is provided for function with neutral colors and industrial surfaces. The effects of lighting may not make as large of an impact on a sterile environment as a home-like setting.

Limitations and Suggestions for Future Work

As discussed, the only relationship that remains significant when controlling for all variables of each participant is the interaction of seating and map task RT, which cannot be easily explained by past literature. All other relationships are insignificant and are not explained by individual characteristics of the participants. Five considerations are discussed based on the findings of the current study. First, as mentioned above, time of exposure to lighting conditions can play a large role in the effects of the lighting on humans. One of the methodological differences of the current study to most lighting literature is the short exposure time to the lighting conditions (35 minutes). This finding elucidates an interesting area of future research: determining thresholds of lighting effects. As shown in the current study there were slight differences on visual tasks and emotional ratings, so it would be interesting to see if there are different exposure thresholds based on the task. As discussed by previous authors (Gifford, 1988; Baron, Rea & Daniels, 1992) visual tasks may be affected differently by lighting than non visual tasks. For example, does it take longer for lighting to affect visual performance than it does to induce mood changes? Also, it would be interesting to examine the effects of lighting over time, and how the effects change if the participant is given short exposure to sunlight or other sources.

Second, one of the limitations for the current study is external validity. While we attempted to create a naturalistic environment by not controlling for illuminance around the tent and by employing real Army tasks and shelters, Soldiers were performing the tasks in peaceful settings on U.S. soil, as opposed to warzones. This opens an area of future research: it may be beneficial to send surveys overseas to deployed Soldiers. It will likely take a long time to switch to a new lighting technology from the current FL so the researcher could target base camps with old and newer lighting technologies. At the same time, it is possible that the lack of significant results can be explained by the naturalistic setting. In a review, Veitch and McCool (2001) point out that carefully control studies found significant results about the effects of light on visual acuity, while naturalistic studies do not. Except in the case of studies on office productivity and lighting are naturalistic settings and show significant differences (Mills, Tomkins & Schlangen, 2007).

Third, the current study adds to the research on LED lighting. LED lighting has been called the future of lighting (Herkelrath et al., 2005), yet very little research has attempted to learn more about what it does to humans in non-healthcare settings. The current study and the past study on lighting in military shelters (Hawes et al., 2012), both add to the sparse research on LED lighting in terms of cognitive tasks, self-reported mood and visual acuity. Not only do they add to the literature, they show that humans under LED lighting perform equally well on visual tasks and work more efficiently.

Fourth, the current study examines a majority of males. While the proportion of participant gender nearly matches Army enrollment numbers, there were still only three women. Our analyses included gender as a variable to detect differences but three is a low representation of a trait group. The effects of color temperatures may have changes with an equal number of men and women. It would be beneficial for follow up studies to consider gender differences more carefully.

Lastly, can lighting affect stressors on the deployed military members? When answering this question it is important to consider the results of the current study addition to the previous military lighting study (Hawes et al., 2012). The areas of stressors addressed in this study were: workload, quality of living conditions, interpersonal conflict, and general well-being.

Workload. Thus far, two studies have looked at military shelter lighting and the effects on Soldiers. For work-related tasks, the first study found that on controlled computer based cognitive tasks (e.g. procedural memory, working memory), Soldiers performed more efficiently (faster reaction times) under higher color temperatures. The current study found that on close to real, paper-based search and locate military tasks there are no significant effects of illuminance or color temperature. The lighting exposure time of the first study was approximately two hours while the exposure time for the current study was approximately 30 minutes. It may be possible that higher color temperature lighting can aid Soldier work efficiency on memory based tasks and only if the Soldier will be working in the lighted environment for a period of time longer than 30 minutes. As mentioned in OPTEMPO discussions above, Soldiers typically are in lighted shelters for a great deal of their 12 hour day, therefore the 2-hour exposure results may more closely represent actual lighting effects.

Quality of Living Conditions. Due to the sterile nature of military shelters it is possible that lighting does make a significant enough impact on tent environment to improve perceptions of living qualities. There are other issues in shelters such as heat and crowding that may play a bigger role in quality of life conditions than lighting (Stone Lombardi, 2004).

Interpersonal Conflict. In this study lighting may not have played a role in interpersonal conflict style, but possibility of higher color temperature raising competitiveness and feelings of vigor remains. Interestingly, these feelings could be beneficial or not depending on the situation. In a tent where Soldiers are resting and socializing these states could cause frictions, but in a location where they are planning and strategizing it may be beneficial. This raises an interesting point: all shelters (which are used for many different activities) are typically equipped with the same lighting technology which may have different effects on different situations.

General Well-Being. In both the current study and past study on military shelters the only subscale of mood that is affected is vigor, this should be taken into account when selecting the lighting, this will be good for the sleep deprived Soldiers such as high OPTEMPO Soldiers getting 3.9 hours of sleep a night (Miller et al., 2011) but may not be best for Soldiers who need to calm down and de-stress after a day on patrol.

Conclusions

The current study can help guide the down-selection of lighting for use in military shelters (FL versus LED). It is already known that there are several pros and cons to each type of lighting (Sullivan, 2011). FL lighting is heavier, bulkier, and less durable than LED lighting. FL lighting is difficult to repair and contains of hazardous materials. FL lighting is not efficient and lasts approximately 10,000-12,000 hours while LED lighting uses less power and lasts approximately 50,000-100,000 hours. FL lighting is already utilized in all military shelters and the switch to LED lighting will be expensive, but the technological advantages of LEDs are clear and the current research adds more positive evidence for LED lighting. The current research adds evidence for LED lighting in a previously unchartered area of military lighting research: the effects of lighting on Soldier behavior. Based on the current study and previous work on lighting in military shelters (Hawes et al., 2012) data reveals that visual acuity and color discrimination is similar under the two conditions and that the strongest relationship between lighting and Soldier performance is that: higher color temperature induces greater self reported vigor and greater efficiency on memory based tasks. Therefore, depending on the goals of the DOD decision makers this research adds to the list of LED advantages and supports the switch to the new technology. The switch will save costs and energy for the DOD while inducing more alert and efficient mood states.

Another important take-away of the current study is that it is always beneficial to explore the effects of technologies on human behavior. While technological specifications of technologies are important, especially with so many beneficial, energy-reducing technologies, it would behoove researchers and designers not to forget the human user.

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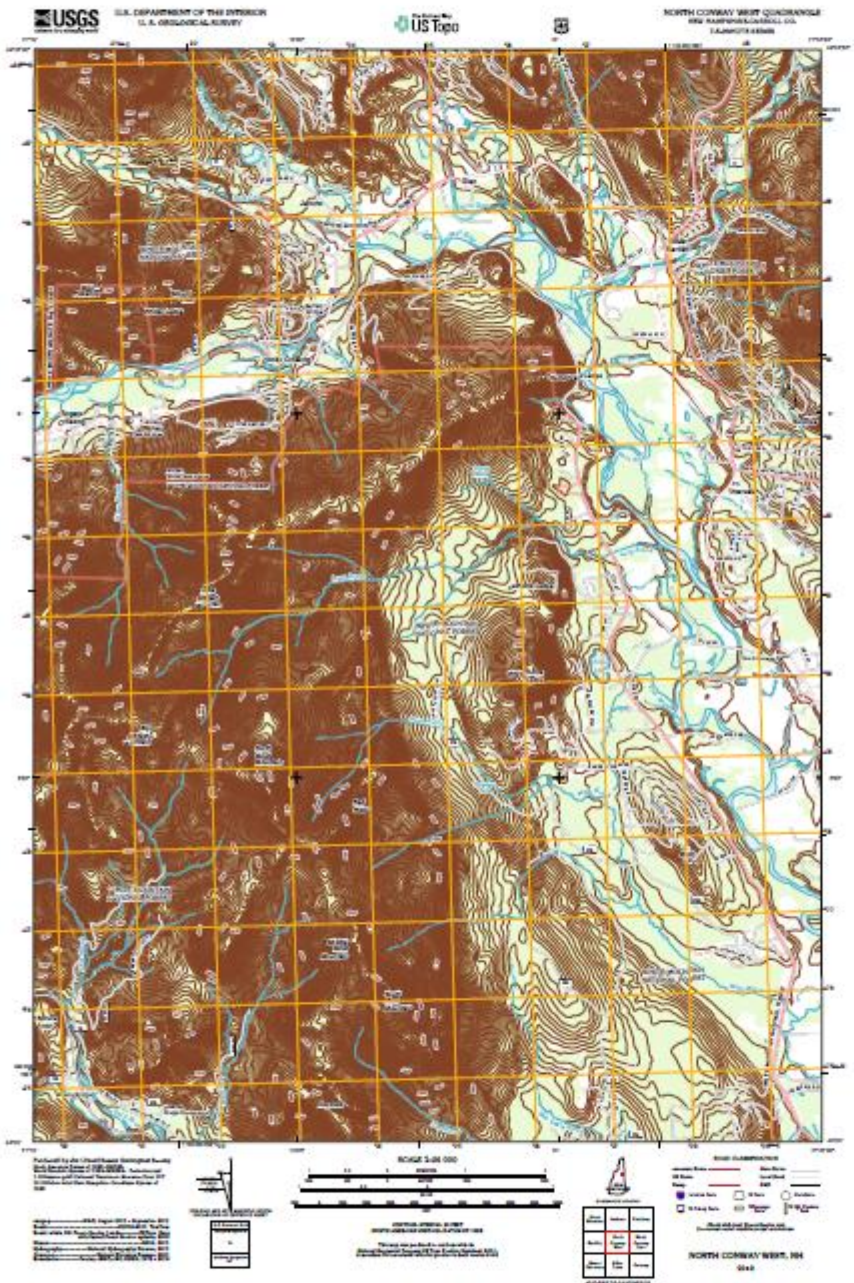
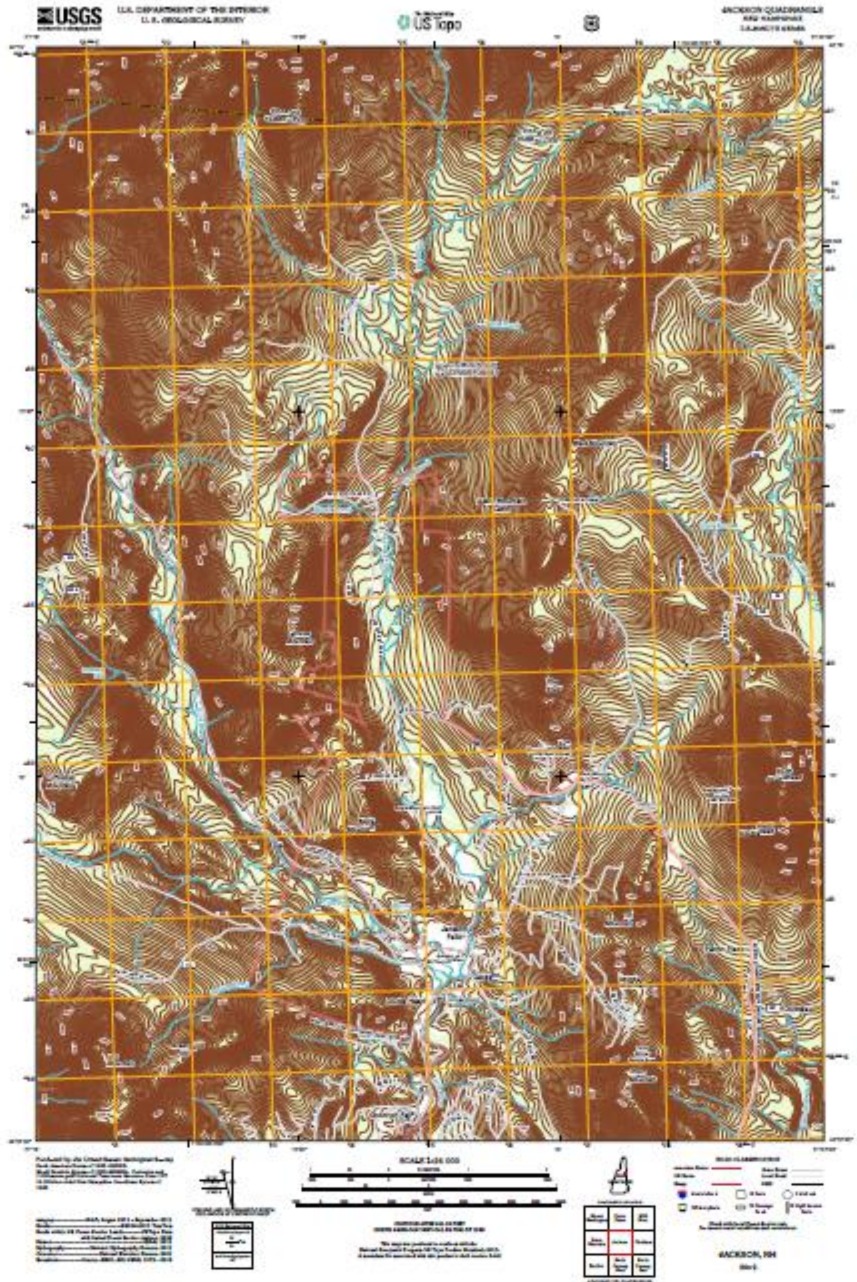
Appendix A


USGS
U.S. DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY
US Topo
NORTH CONWAY WEST QUADRANGLE
NORTH CONWAY WEST, NH

Appendix B

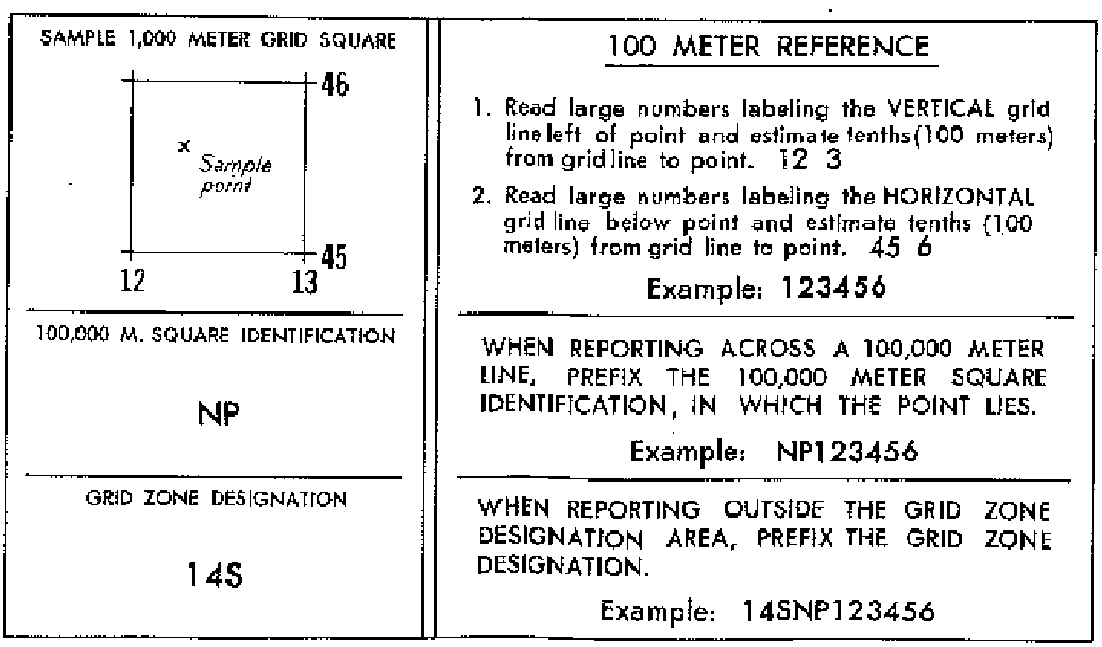


Appendix C

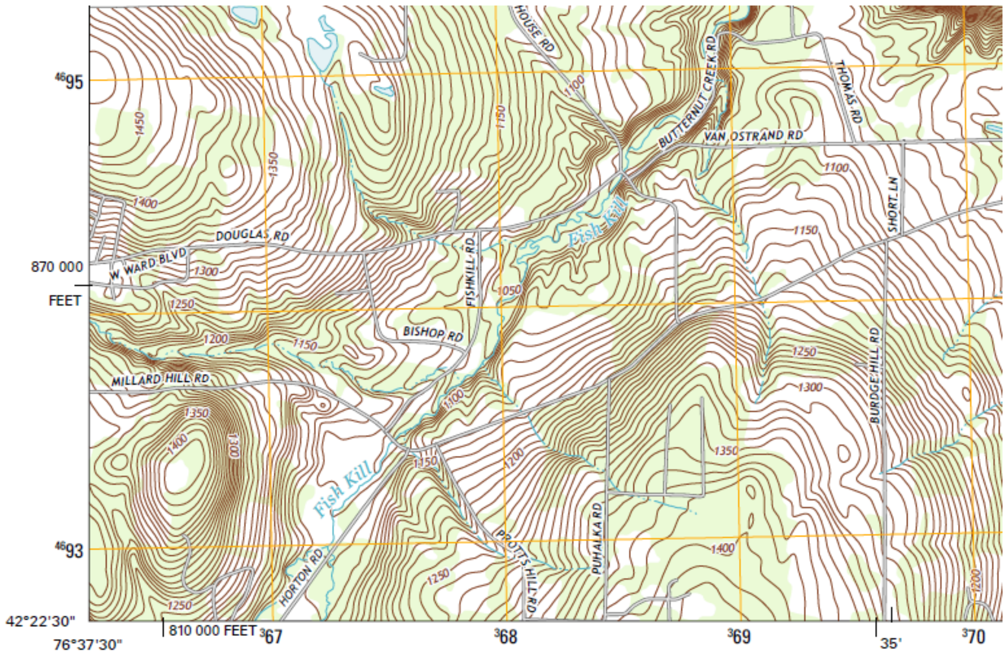
Map Task:

For this task you will be asked to identify points of interest on a map. The experimenter will provide you a large map. You will also have a packet. On each sheet there will be a large set of coordinates at the top you will read the coordinates then locate the point on the map. The coordinate should lead you to the middle of a word written on the map. This is your point, write it on the paper. Once you are ready for the next set, say “coordinate found” and flip the page.

First you will practice using coordinates to find points of interest using the method below:



See Practice on the next page.



Find: **695949**

Which point did you find?

Please let the experimenter know when you are ready to flip the page and begin.

Appendix D

Line								
1	left	right						
2	right	down	left					
3	down	left	up	right				
4	left	up	down	right	up			
5	right	left	down	up	left			
6	down	right	up	left	right	down		
7	left	down	left	right	down	left		
8	right	left	up	down	right	up	right	
9	up	down	left	right	up	left	down	
10	right	left	up	left	down	right	up	left
11	left	up	down	right	down	up	left	down
12	up	left	up	down	right	left	down	right

Appendix E

CONFLICT RESOLUTION

Instructions

Consider situations in which you find your wishes differing from those of another person. How do you usually respond to such situations?

On the following pages are several pairs of statements describing possible behavioral responses. For each pair, please circle the "A" or "B" statement which is most characteristic of your own behavior. In many cases, neither the "A" nor the "B" statement may be very typical of your behavior; but please select the response which you would be more likely to use.

Thomas-Kilman Conflict Mode Instrument

1. A. There are times when I let others take responsibility for solving the problem.
   B. Rather than negotiate the things on which we disagree, I try to stress those things upon which we both agree.

2. A. I try to find a compromise solution.
   B. I attempt to deal with all of his/her and my concerns.

3. A. I am usually firm in pursuing my goals.
   B. I might try to soothe the other's feelings and preserve the relationship.

4. A. I try to find a compromise solution.
   B. I sometimes sacrifice my own wishes for the wishes of the other person.

5. A. I consistently seek the other's help in working out a solution.
   B. I try to do what is necessary to avoid useless tensions.

6. A. I try to avoid creating unpleasantness for myself.
   B. I try to win my position.

7. A. I try to postpone the issue until I have had some time to think it over.
   B. I give up some points in exchange for others.

8. A. I am usually firm in pursuing my goals.
   B. I attempt to get all concerns and issues immediately out in the open.

Thomas-Kilman
Conflict Mode Instrument

9. A. I feel that differences are not always worth worrying about.
B. I make some effort to get my way.

10. A. I am firm in pursuing my goals.
B. I try to find a compromise solution.

11. A. I attempt to get all concerns and issues immediately out in the open.
B. I might try to soothe the other's feelings and preserve our relationship.

12. A. I sometimes avoid taking positions which would create controversy.
B. I will let the other person have some of his/her positions if he/she lets me have some of mine.

13. A. I propose a middle ground.
B. I press to get my points made.

14. A. I tell the other person my ideas and ask for his/hers.
B. I try to show the other person the logic and benefits to my position.

15. A. I might try to soothe the other's feelings and preserve our relationship.
B. I try to do what is necessary to avoid tensions.

16. A. I try not to hurt the other's feelings.
B. I try to convince the other person of the merits of my position.

17. A. I am usually firm in pursuing my goals.
B. I try to do what is necessary to avoid useless tensions.

18. A. If it makes other people happy, I might let them maintain their views.
B. I will let other people have some of their positions if they let me have some of mine.

19. A. I attempt to get all concerns and issues immediately out in the open.
B. I try to postpone the issue until I have had some time to think it over.

20. A. I attempt to immediately work through our differences.
B. I try to find a fair combination of gains and losses for both of us.

Thomas-Kilman
Conflict Mode Instrument

21. A. In approaching negotiations, I try to be considerate of the other person's wishes.
    B. I always lean toward a direct discussion of the problem.

22. A. I try to find a position that is intermediate between his/hers and mine.
    B. I assert my wishes.

23. A. I am very often concerned with satisfying all our wishes.
    B. There are times when I let others take responsibility for solving the problem.

24. A. If the other's position seems very important to him/her, I would try to meet his/her wishes.
    B. I try to get the other person to settle for a compromise.

25. A. I try to show the other person the logic and benefits of my position.
    B. In approaching negotiations, I try to be considerate of the other person's wishes.

26. A. I propose a middle ground.
    B. I am nearly always concerned with satisfying all our wishes.

27. A. I sometimes avoid taking positions that would create controversy.
    B. If it makes other people happy, I might let them maintain their views.

28. A. I am usually firm in pursuing my goals.
    B. I usually seek the other's help in working out a solution.

29. A. I propose a middle ground.
    B. I feel that differences are not always worth worrying about.

30. A. I try not to hurt the other's feelings.
    B. I always share the problem with the other person so that we can work it out.

Appendix F

SCORING

Circle the letters below that you circled on each item of the questionnaire.

	Competing	Collaborating	Compromising	Avoiding	Accommodating
1.				A	B
2.		B	A		
3.	A				B
4.			A		B
5.		A		B	
6.	B			A	
7.			B	A	
8.	A	B			
9.	B			A	
10.	A		B		
11.		A			B
12.			B	A	
13.	B		A		
14.	B	A			
15.				B	A
16.	B				A
17.	A			B	
18.			B		A
19.		A		B	
20.		A	B		
21.		B			A
22.	B		A		
23.		A		B	
24.			B		A
25.	A				B
26.		B	A		
27.				A	B
28.	A	B			
29.			A	B	
30.		B			A

Total the number of items circled in each column:

______	______	______	______	______
Competing (forcing)	Collaborating (problem-solving)	Compromising (sharing)	Avoiding (withdrawal)	Accommodating (smoothing)

Appendix G

Tent Attractiveness Questionnaire

Instructions: This questionnaire will help evaluate the aesthetic condition of this tent. Please **circle the number** that **BEST** corresponds as your answer to each question.
Quintessentially

Please circle how you would evaluate the environmental conditions in this tent.

Comfortable   Uncomfortable
0 -------- 1 -------- 2 -------- 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 -------- 9

Like   Dislike
0 -------- 1 -------- 2 -------- 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 -------- 9

Pleasant   Unpleasant
0 -------- 1 -------- 2 -------- 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 -------- 9

Beautiful   Ugly
0 -------- 1 -------- 2 -------- 3 -------- 4 -------- 5 -------- 6 -------- 7 -------- 8 -------- 9