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Altering The Environment: The Effects Of Light And Music On Vigilance Performance And Affective State

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ALTERING THE ENVIRONMENT: THE EFFECTS OF LIGHT AND MUSIC ON VIGILANCE PERFORMANCE AND AFFECTIVE STATE

By

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Author Contribution Statement

This research was conducted under the supervision of Dr. Samantha Smith. She has reviewed this manuscript and provided much needed guidance and support throughout its production. Dr. Samantha Smith initially provided the base laboratory procedure adapted in Chapters 2 and 3 and portions of the scientific background used to justify Chapter 2's contributions. Elizabeth Sunblad assisted with data collection in Chapter 2.

Both studies have been revised and updated for this thesis, following publication in peer reviewed conference proceedings. The experiment in Chapter 2 can be found in

> Monroe, L. E., & Smith, S. L. (2021, September). If you're happy and you know it stay alert: The effects of lighting on vigilance performance and affective State. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 65, No. 1, pp. 854-858). Sage CA: Los Angeles, CA: SAGE Publications.,

and the experiment in Chapter 3 can be found in,

> Monroe, L., & Smith, S. (2022, September). The effects of varying music tempo on vigilance performance and affective state. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 66, No. 1, pp. 888-892). Sage CA: Los Angeles, CA: SAGE Publications.

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List of Abbreviations

BMIS – Brief Mood Introspection Scale

SSSQ – Short Stress State Questionnaire

SSS – Stanford Sleepiness Scale

NASA-TLX – NASA Task Load Index

SDT – Signal Detection Theory

CRT – Cognitive Resource Theory

PVT – Psychomotor Vigilance Task

SART – Sustained attention Response Task

TVT – True Vigilance Task

Abstract

Vigilance, otherwise known as a state of alert watchfulness, is a phenomenon that occurs when someone is sustaining their attention on a particular task or environment. Largely, tasks that require a state of vigilance induce negative mood outcomes, result in loss of performance over time, and cause increased disengagement from the task. These tasks involve detecting critical signals which are buried among more frequently occurring neutral signals. While little can be done to change the base nature of the vigilance task, altering the physical environment of the operator may improve working conditions to a point where there are fewer losses of engagement and declines in arousal. Previous research has found that exposure to bright short-wavelength light can improve sleepiness, alertness, and mood. In other research, music has been found to positively impact cognitive function and response times. The first study examined the efficacy of using a bright light therapy lamp during vigilance performance to minimize the decline in alertness and arousal. There were 50 participants placed into two conditions: A bright light therapy lamp and dim light. Results indicated that the therapy light did not prevent a decline in detection of critical signals over time, nor significantly impact workload, sleepiness, or subjective stress state compared to a dim light condition. However, mood questionnaire results suggest that lighting may impact separate constructs of arousal and tiredness, warranting further research. The second study determined differently tempoed music, namely fast and slow tempos, did not significantly impact operator engagement and response time. It also recruited 50 participants but had 3 conditions: fast tempo, slow tempo, and silence. Results indicated that varying music tempo did not influence the typical decline in detection of critical signals, but the fast tempo condition had a modestly positive impact on worry and engagement from pre to post task.

1 Scientific Background & Justification

During the 2nd World War (WWII), the Royal Air Force took note of the decrease in performance in the radar technicians who were scanning for German submarines, namely in situations that required constant monitoring of an environment for more than 40 minutes (Mackworth, 1948). They were completely missing some 'radar blips' that could signify an enemy submarine. Later, after the end of WWII, laboratory studies were conducted in order to determine the ideal length of operating time for a technician to be on task before that breakdown in performance occurs. The drop off in performance as time on task increases has since been coined, the vigilance decrement (Davies & Parasuraman, 1982). Vigilance, or sustained attention, involves a prolonged interaction with an environment where the operator in question is charged with monitoring said relatively unchanging environment for critical signals that are among neutral signals (Epling et al., 2016). Critical signals are those requiring a response or input of some kind and neutral signals are those not requiring a response. Vigilance is most commonly defined as the ability to maintain concentration over prolonged periods of time, but the decrement has been observed in as little as 5 minutes if the task is challenging enough (Helton & Russell, 2015).

The vigilance decrement refers to the observed decline in performance accuracy and response time as time on task increases, but the performance decline is not the only negative outcome that vigilance induces. In previous vigilance research, operators and participants report an increase in stress and negative mood outcomes post vigilance task (Warm et al., 2008). It is possible that the difficulty of these tasks pushes operator stress level higher and high stress levels are correlated with performance declines. In addition to the increase in stress and worry, vigilance and sustained attention research also has found that these tasks increase participant sleepiness as well as decreased arousal and engagement with the task (Epling et al., 2016; Matthews et al., 2010). The decline in arousal likely contributes to the decline in performance that gets observed and the sleepiness contributes to the decline in arousal and engagement. Additionally, the drop in performance can manifest as a decline in discrimination ability or sensitivity. Signal Detection Theory (SDT) is used to test one's ability to detect signals through noise. Since vigilance and sustained attention tasks involve critical signals buried in noise (neutral signals) the SDT measures of bias, the tendency to respond to stimuli, and sensitivity, the ability to discriminate between different stimuli, provide valuable information about how time affects accuracy through these measures. As time on task increases the tendency to respond depends on the frequency of critical stimuli. If there is a high probability of critical stimuli then bias will trend towards response over non-response, and if there is a low probability, then bias will trend towards non-response. With sensitivity, as time on task increases the ability to discriminate between stimuli decreases. All of these measures demonstrate that with vigilance and sustained attention there is something going on that causes this decline in performance.

There are two main types of vigilance tasks, the True Vigilance Task, (TVT) and the Sustained Attention Response Task (SART). The defining characteristic of a TVT is that there is a low probability of critical signals that the participant responds to and a high probability of neutral signals that the participant ignores. The SART is the same, but the participant responds to the neutral signals and ignores the critical ones. The TVT generally brings about an increase in response time and an increase in "misses" (a failure to respond) and causes an increase in bias indicating that the participant becomes less likely to respond. The SART generally induces increased false alarms (responding to a neutral signal) and causes a decrease in bias indicating that the participant becomes more likely to respond than not. Both types of tasks induce the vigilance decrement as well as the mood, arousal, and engagement decline.

It is unfortunate that with these types of tasks, the decline in performance seems almost an inevitable conclusion, especially since they appear in domains where error can be dangerous. Vigilance is commonly found in military surveillance work, air traffic control, and long-distance driving (Warm et al, 2008). Errors in these domains can lead to damaged equipment, increased maintenance time and costs, injury, and even loss of life in some extreme cases. Finding a way to reduce or mitigate the vigilance decrement will reduce the amount of human error seen in these types of fields.

1.1 Theoretical Frameworks

While there is no one theory that encapsulates the whole of the vigilance decrement, research has yielded two main theoretical frameworks, overload versus underload, that attempt to explain how and why the decrement occurs: Mindlessness and Mind Wandering Theory (underload), and Cognitive Resource Theory (CRT; overload). Mindlessness Theory postulates that since vigilance and sustained attention tasks are boring and monotonous, the human operator mentally disengages from the task at hand which directly affects performance (Manley et al., 1999). The Mind Wandering Theory is similar to the Mindlessness Theory in many ways. The main difference is that during the mental disengagement of the human operator, there is an increase in task unrelated thoughts and a decrease in executive control (Smallwood & Schooler, 2006). The CRT postulates that humans possess cognitive resource pools with limited depth, and since vigilance tasks are considered to be more difficult than other similar tasks these resources get drained faster than they get replenished (Thomson et al., 2016). When these pools get drained, mental performance declines until after a period of rest or time away from task.

While the majority of vigilance and related research to date has been focused on determining the validity of the underload versus overload theories, other frameworks, that set aside that debate, may also be useful in finding ways to mitigate that decrement. Vigilance tasks are often considered hard and require a lot of mental effort, resulting in decreased arousal, engagement, and mood, and increased mental workload, sleepiness and stress, therefore altering the environment of the operator may in turn improve the mental state of the operator (Al-Shargie et al., 2019; Jacobsen et al., 1987; Leichtfried et al., 2014; Warm et al., 2008).

1.2 Light

Many vigilance research studies are conducted in a dimly lit, quiet environment with little to no distractions or outside influences (Dillard et al., 2019; Epling et al., 2019; Greenlee et al., 2016). This is not reflected in the spaces that these tasks are performed in the workplace. Light exposure plays a vital role in the regulation of melatonin production through the suppression of said sleep hormone and previous research has had moderate success in enhancing information processing speeds, increasing alertness, increasing response times, and decreasing lapses in attention due to exposure to short wavelength light (Chang et al., 2013; Hershner & Chervin, 2014; Lehrl et al., 2007; Lockley et al., 2006). Since light plays an important role in the regulation of circadian rhythms, and the lighting in workplaces can have an effect on self-reported performance, alertness, and fatigue, exposure to bright light therapy may have a positive impact on those metrics during the performance of a vigilance task (Lehrl et al., 2007; Lockley et al., 2006). Although bright light has been found to decrease subjective sleepiness while improving response times as well as subjective mood in human operators, some research has found that bright light exposure did not mitigate cognitive load demands or psychomotor performance (Borragán et al., 2017; Griepentrog et al., 2018).

Previous research has demonstrated the feasibility of utilizing bright light in vigilance or sustained attention research. One research study found that night shift nurses that had been exposed to a bright light therapy lamp over the duration of their shift reported lower subjective sleepiness than the nurses who had only been exposed to typical hospital lighting (Griepentrog et al., 2018). Blue light, when compared to yellow light, was found to increase both self-reported alertness and the speed of information processing during a visual reading task after twenty seconds of exposure (Lehrl et al., 2007). Short wave-length light has also been reported to lower subjective sleepiness levels as well as improve response times and decrease attentional lapses during an auditory psychomotor vigilance task (PVT; Lockley et al., 2006). A 32-day longitudinal study found that exposure to dim light *before* task performance followed by bright light *during* task performance reduced subjective sleepiness as well as decreased the observed decrement in PVT performance (Chang et al, 2013). The reduction in sleepiness, a common side effect of vigilance task performance, as well as the positive impacts on response time and performance that exposure to bright light has induced in these studies suggest that further exploration is warranted.

From the resource theory perspective, vigilance tasks are difficult and stressful to perform as they drain mental resources faster than they can be replenished. This theoretical framework does not suggest that the vigilance decrement could be mitigated by interventions that target alertness, sleepiness, and mood directly but could be mitigated by an indirect mechanism. If bright light helps to reduce the observed decline in arousal and alertness that may in turn reduce the demands that these tasks have on cognitive resources. In addition to potential effects on performance, bright light exposure may also mitigate sleepiness and/or negative affective state outcomes associated with vigilance tasks. Both bright, broad-spectrum light, as well as specific narrow-band blue light, have been found to have positive effects on not only energy and cognitive performance, but also mood (Jacobsen et al., 1987; Knapen et al., 2014; Meesters et al., 2016). Because of this, the application of bright light in a true vigilance domain (which tends to negatively affect performance, sleepiness, and mood) is an important gap in the literature to address.

1.3 Music

Vigilance research is also often performed in a quiet environment which does not reflect real world working environments. In order to sustain attention in situations where the potential for error is high, the operator must be able to work alongside distractions like sound. This presents an opportunity for determining how best to structure the vigilance performance environment. If the operator was listening to music while performing a vigilance task, they would be shielded from external noise while giving the operator an opportunity to enhance their performance because of the music. Music has been found to have a positive effect on cognitive performance due to increased limbic system activation (Mammarella et al., 2007). This leads to increased processing speed and enhanced memory, specifically when music is being listened to while the operator is focused on a separate task that does not involve verbal processing (Bottiroli et al., 2014). Additionally, music has been found to increase activation in multiple cortical areas working cooperatively as well as regions that are physically distant. This is due to the increased activation effect that music has on the cortical regions of the brain, as even passive exposure to music can induce positive neuronal changes that lead to reduced wiring costs (Pantev & Herholz, 2011; Sloboda et al., 2001). These reduced costs lead to improved brain organization which decreases cognitive effort. This decrease in cognitive effort may help reduce the perceived high workload of vigilance tasks, and may also mitigate the vigilance decrement as cognitive resources may not be depleted as quickly as they would without the addition of music. From the Mindlessness and Mind Wandering Theory perspective, music would also be expected to aid performance because familiar music has been shown to increase arousal, motivation, the perception of energy, as well as concentration level (Al-Shargie et al., 2019). Increased arousal and energy could then decrease operator disengagement and mitigate task unrelated thoughts and mind wandering.

Previous research has examined the effect of different music tempos on performance in visual attention tasks and found a positive effect on response times from music with a fast tempo (Amezcua et al., 2005). Past findings suggest that slow tempo music (approximately 60 bpm) will result in a poorer performance, while fast tempo music (approximately 140 bpm or above) does not have the same decline (Mayfield & Moss, 1989). In addition, previous research has also determined that the introduction of music can substantially improve the detection accuracy of critical signals when compared to silence and white noise conditions (Davies et al., 1974). However, there is a trade-off when involving music that contains lyrics. Music with lyrics increased distractions, reduced worker attention and performance, and led to negative effects on their ability to sustain concentration but does improve concentration, attention level, and induced a positive mood when it was familiar and preferred (Al-Shargie et al., 2019). Another research study found that when older adults are exposed to classical music, they experience positive improvements in episodic memory, semantic memory, processing speed and post-task mood (Bottiroli et al., 2014). These results suggest that music as an intervention may improve vigilance performance through improved response time and detection accuracy as well as improve the negative mood outcomes often seen post vigilance task performance.

1.4 Present Research

The two following studies alter one aspect of the vigilance environment each: one with bright light and the other with varying tempos of music. Study 1 was designed to explore the effects of bright light exposure on both performance and various self-reported state factors as participants complete a laboratory vigilance task. In a between-subjects design, participants completed the task in either the dim or bright light condition. From the resource theory perspective, it was predicted that neither the vigilance decrement nor self-reported workload would be significantly affected by lighting condition. However, it was hypothesized that the bright light condition would mitigate some negative post-task mood outcomes compared to the dim light condition.

Study 2 was designed to explore the effects of different tempo music without lyrics on both performance metrics and self- reported state factors as participants complete a visuospatial vigilance task. The between-subjects design used in Study 2 had participants complete a visual detection task while listening to fast tempo music, slow tempo music, or silence. I predicted that participants in both music tempo conditions would report a lower task-induced negative affect and lower global workload. I predicted that the music intervention would mitigate the decline in detection accuracy, regardless of overload versus underload theoretical perspective. I also predicted that the fast tempo condition would show less of a negative impact on participant affective state when compared to the slow music and control conditions.

2 Study 1

2.1 Methods

2.1.1 Participants

Fifty undergraduate students (19 women) served as participants and were compensated with psychology research credit through the SONA participant system. Sixty participants were recruited but ten of those participants were excluded from analysis due to failure to meet the performance check during the training portion (N = 6), failure to follow instructions (N = 2), and technical issues (N = 2). Half of the participants (N = 25) were randomly assigned to the bright light condition and the other half (N = 25) were assigned to the dim light condition. All participants abstained from alcohol, caffeine, nicotine, and other psychoactive drugs for 12 hours prior to their participation and had 20/20 or corrected to 20/20 vision. The study was approved by Michigan Technological University's IRB and each participant gave informed consent. The testing sessions lasted approximately one hour, started no later than 1:00 PM, and were conducted between the months of October 2020 and February 2021.

2.1.2 Materials

All participants were tested individually in a laboratory at Michigan Technological University while seated at a large desk facing the back wall of the lab. All data were collected from participants using a Dell Intel® Core™ i7-9700k CPU with a 64-bit operating system and a Dell NVIDIA Quadro P620 monitor with a 60 Hz refresh rate and a RGB color format. For the bright light condition, A Carex Day-Light Classic Plus light therapy lamp on the 10,000 lumens setting was placed approximately 14 inches away from the participants eyes, angled down by 15 degrees was used for the bright light condition. The lamp was centered behind and above the participant monitor and had a wavelength spectrum of 400-700 nm. The dim light condition utilized a Mainstays™ desk lamp with a 4-watt LED bulb on the researcher desk in the opposite corner of the room and approximately 10 feet behind the participant. Custom software, developed by the Air Force Research Laboratory, presented the vigilance task stimuli (adapted from Hitchcock et al., 2003) and recorded participant responses, accuracy, and timing data. All surveys were conducted using the Qualtrics survey software.

2.1.2.1 Stanford Sleepiness Scale

The Stanford Sleepiness Scale (SSS) is a seven-statement questionnaire that quantifies increasing degrees of sleepiness from 1, "feeling active and vital; alert; wide awake" to, 7, "no longer fighting sleep, sleep onset soon; having dream-like thoughts." The scale has been validated to measure sleepiness as quantified by the decline in mental performance following sleep deprivation and has been found to be correlated with task performance changes due to sleep loss (Hoddes et al., 1973). It is being utilized in present research as a way to quantify any changes in self-reported sleepiness pre- post-task performance.

2.1.2.2 Short Stress State Questionnaire

The Short Stress State Questionnaire (SSSQ) is an adaptation of the Dundee Stress State Questionnaire (DSSQ), a survey designed to quantify the different levels of subjective affect changes to stressful environments (Matthews et al., 2002). It has narrowed the different stress state factors into three categories: engagement, distress, and worry through a 24 item questionnaire (see Appendix A; Helton, 2004). It has also been validated as a measure that is sensitive to task stressors. It is being utilized in the present research as a means to measure the changes in stress factors pre- and post-vigilance task performance.

2.1.2.3 Brief Mood Introspection Scale

The Brief Mood Introspection Scale (BMIS) is a questionnaire that has been validated to quantify the pre- and post- task changes in 16 different mood states (Mayer & Gaschke, 1988). These 16 mood states (see Appendix A) are sorted into 8 categories (happy, loving, calm, energetic, fearful/anxious, angry, tired, and sad) to report on changes in mood on 4 scales: pleasant to unpleasant, arousal to calm, positive to tired, and negative to relaxed. Higher scores indicate a state more aligned with the first item in scale name. It is being utilized in the present research to explore pre- and post-task changes in mood states that are affected by vigilance (i.e., arousal, stress, and negative mood; Warm et al., 2008).

2.1.2.4 NASA-Task Load Index

The NASA-Task Load Index (NASA-TLX) is a validated post task self-report measure of global workload across 6 factors: mental demand, physical demand, temporal demand, performance, effort, and frustration (Hart & Staveland, 1988). It is being utilized in the present research to determine differences in global workload between the different conditions laid out below in Study 1 and Study 2.

2.1.3 Procedure

Special procedures aimed at reducing the spread of COVID-19 were approved by the university's Human Subjects Research COVID-19 Committee. These precautions included screening participants for symptoms, recent travel, and recent exposure to the virus; washing or sanitizing hands upon arrival to the lab; wearing masks; maintaining at least six feet of distance between the researcher and participant; and sanitization of all laboratory touchpoints between participants.

After giving informed consent, participants were asked to silence cell phones and other electronic devices as well as remove all time keeping devices and place them in their bag or out of sight. Participants then completed the pre-task surveys, including demographic information, the SSS, the SSSQ, and the BMIS.

Participants then launched the vigilance program and progressed through the task training slides. Participants were instructed to monitor stimuli for the occurrence of potential collision events between two remotely piloted aircraft (RPA). As seen in Figure 1, the participants were shown the 10 possible stimuli in the training slides, each consisting of a static image containing a solid red circle surrounded by three concentric white circles, with two gray lines representing RPA flight paths. Participants only saw one of the 10 possible stimuli at a time and were instructed to press the spacebar to send a warning when the RPA were on a collision course (critical signals) and to withhold a response to the neutral stimuli representing safe flight paths. Responses made to critical signals were analyzed as correct detections; a failure to respond to a critical signal before the onset of the next signal was a miss. Pressing the spacebar in response to a neutral signal was considered a false alarm. The display updated 40 times per minute (one stimulus event every 1500 ms), with each signal being displayed for 80 ms followed by a blank screen for 1420 ms. Each participant's vigil utilized a pseudo-random stimulus presentation, with each minute including 38 neutral signals and 2 critical signals (critical signal probability = 5%). The experimental vigil lasted a total of 28 minutes.

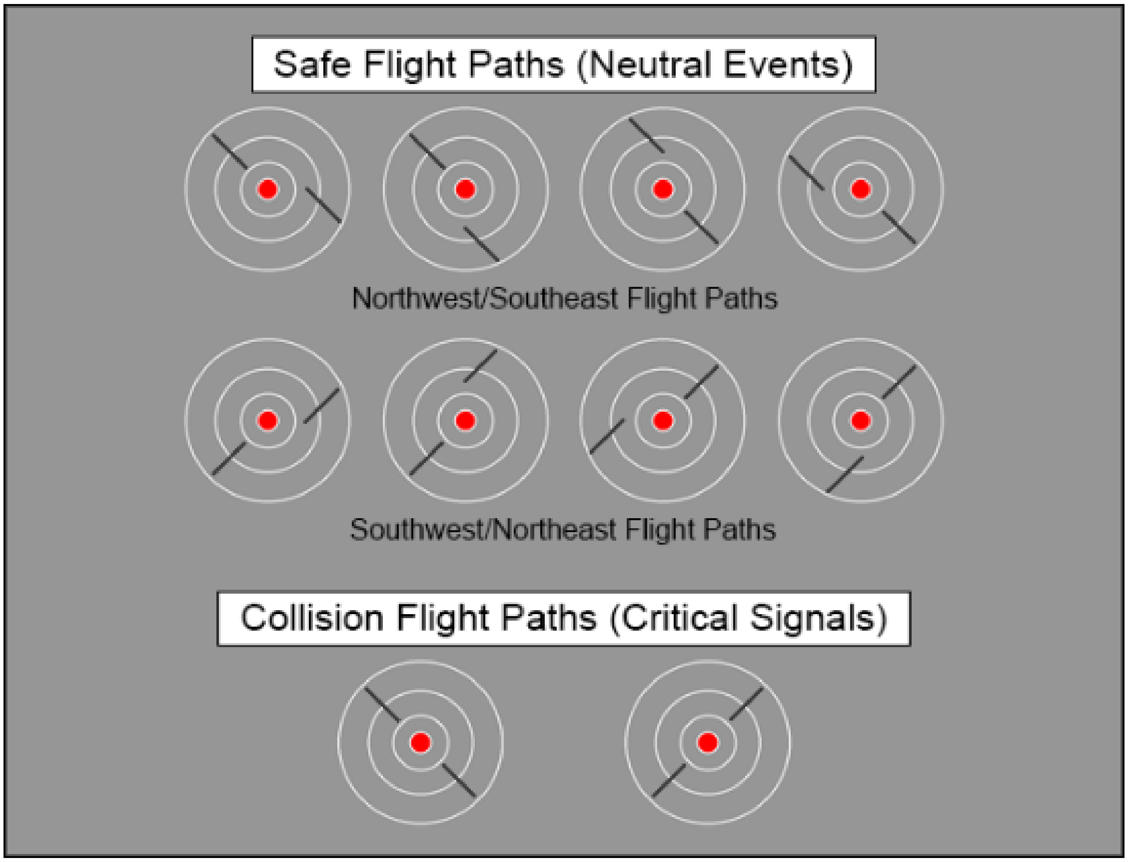

Figure 1.1. Examples of critical and neutral signals in the task display.

After reading the training slides and being given the opportunity to ask questions, participants completed the first of two, five-minute training trials. Participants were told that they must achieve at least a 70% correct detection rate and make no more than 7% false alarms in at least one of the two training trials in order to participate in the full experimental vigil. Participants received real-time pre-recorded audio feedback for each correct detection, miss, and false alarm, and were also given performance feedback by the researcher and the opportunity to ask questions after each training trial.

Up to this point, the laboratory was lit by overhead fluorescent light. If the participant met the performance criteria, the researcher then turned on the lamp commensurate with the participant's assigned lighting condition and turned off the overhead light. The researcher did not say anything to draw attention to this change. Participants were then told to rest for two minutes before starting the experimental vigil. This allowed participants' eyes to adjust, without going over the maximum recommended exposure to the therapy lamp (30 minutes). Upon completion of the vigil, the overhead light was turned on and the lamp turned off.

Participants were then directed to complete the post-task surveys, which included the SSS, the SSSQ, the BMIS, and the NASA-TLX. Upon completion, the researcher debriefed participants regarding the nature of the experimental manipulation, answered any questions, granted research credit, and then released the participant.

2.2 Results

2.2.1 Vigilance Performance

Performance was calculated in terms of the proportion of correct detections, false alarms, and response time across four continuous seven-minute periods of watch. I employed a 2 (conditions) × 4 (periods of watch) repeated measures analysis of variance (ANOVA), with lighting condition being the between-subjects factor and periods of watch the within-subjects factor. For correct detections, there was a significant main effect for condition, $F(1,48) = 10.12$, $p < .01$, $\eta p^2 = .17$. As seen in Figure 2.1, participants in the dim light condition performed better, on average, than participants in the bright light condition. There was also a significant main effect for period, $F(3,144) = 24.27$, $p < .01$, $\eta p^2 = .34$, whereby participants detected fewer critical signals over time. The period by condition interaction was nonsignificant, $F(3,144) = .14$, $p = .71$, $\eta p^2 < .01$.

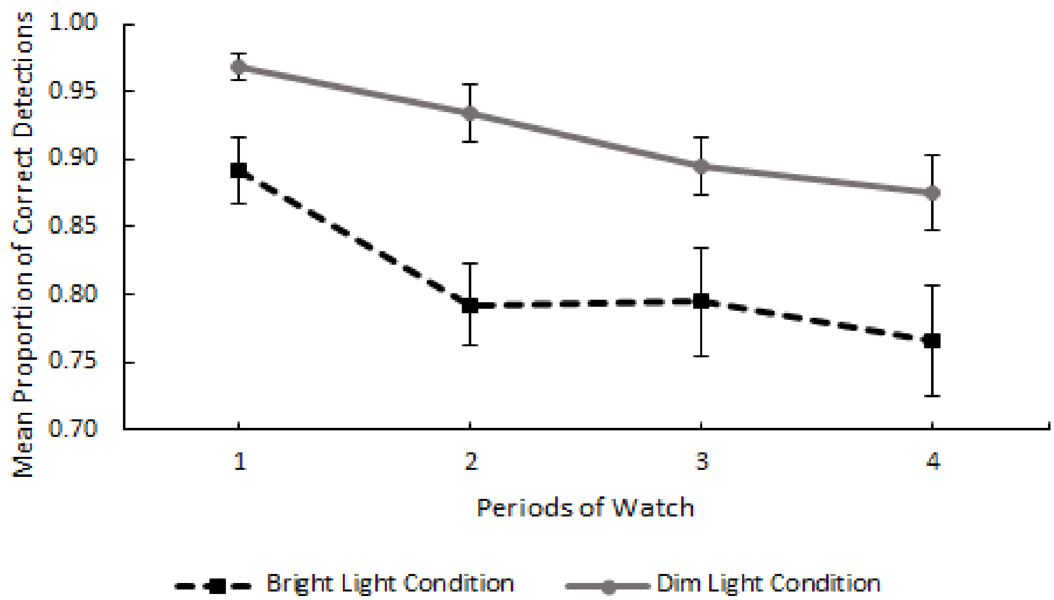

Figure 2.1. Mean proportion of correct detections in bright and dim light conditions across periods of watch. Error bars are standard error of the mean.

For false alarms, there was a nonsignificant main effect for both condition, $F(1,48) = 2.20$, $p = .14$, $\eta p^2 = .04$, and period, $F(3,144) = 1.23$, $p = .30$, $\eta p^2 = .03$. However, the period by condition interaction was significant, $F(3,144) = 7.48$, $p < .01$, $\eta p^2 < .14$. As seen in Figure 2.2, participants in the bright light condition tended to commit more false alarms in period one than participants in the dim light condition, but they converged to a similar rate of false alarms by period four.

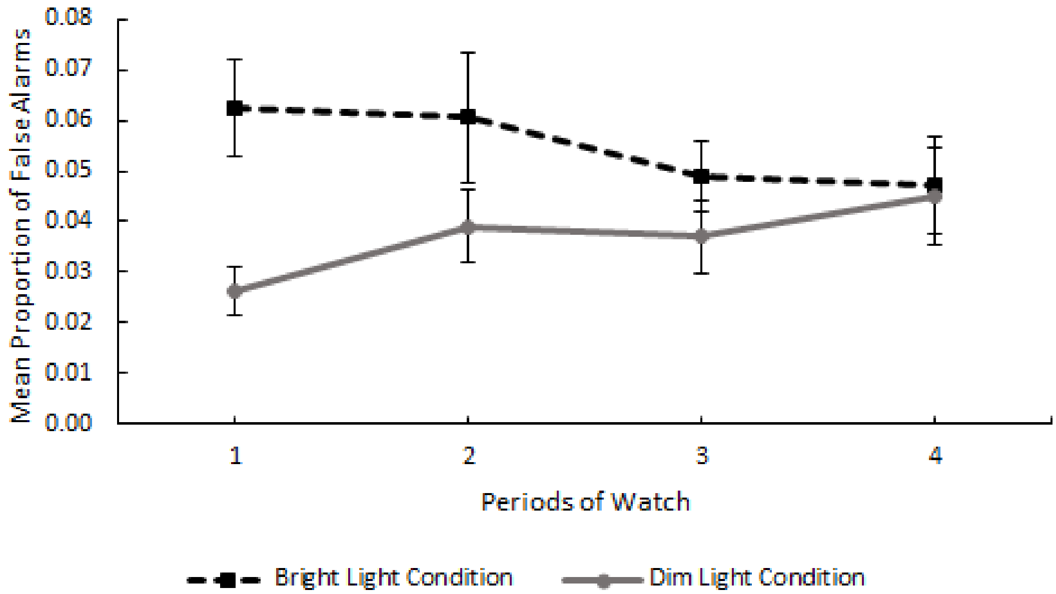

Figure 2.2. Mean proportion of false alarms in bright and dim light conditions across periods of watch. Error bars are standard error of the mean.

For correct detection response time, there was a significant main effect for condition, $F(1,48) = 8.54$, $p < .01$, $\eta p^2 = .15$. As seen in Figure 2.3, participants in the dim light condition responded faster than participants in the bright light condition. There was also a significant main effect for period, $F(3,144) = 29.59$, $p < .01$, $\eta p^2 = .38$, whereby participants responded to critical signals more slowly over time. The period by condition interaction was nonsignificant, $F(3,144) = .17$, $p = .92$, $\eta p^2 < .01$.

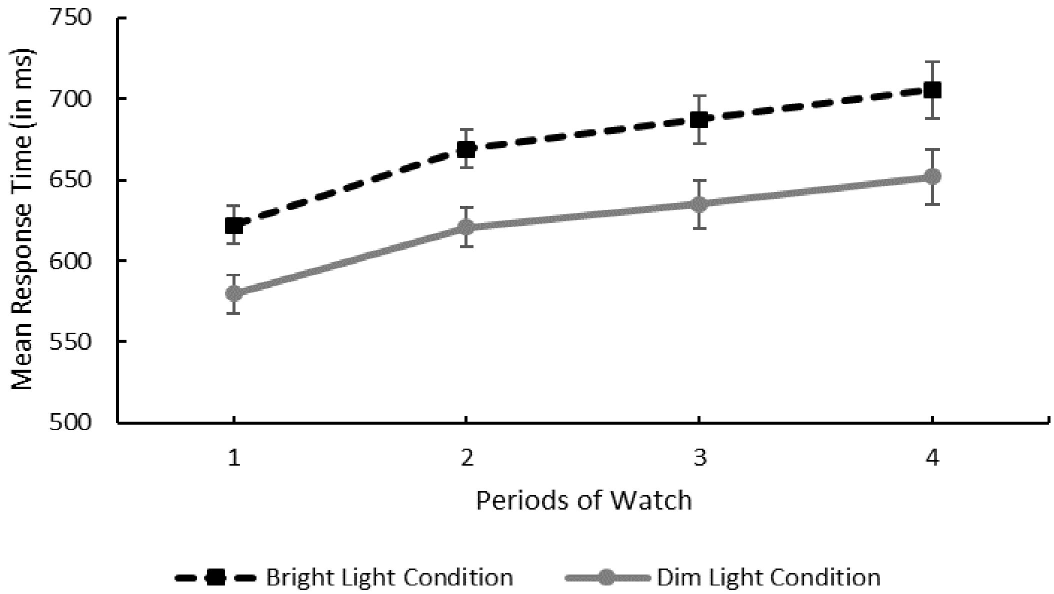

Figure 2.3. Mean response time in bright and dim light conditions across periods of watch. Error bars are standard error of the mean.

I then utilized some Signal Detection Theory metrics to further analyze the performance trends across time for the different conditions. As there were some participants who had full watch periods with no error, the Log Linear correction was used to reduce data bias (Hautus, 1995). For the SDT measure of sensitivity (*d*), there was a significant main effect for period, $F(3,48) = 6.75$, $p < .01$, $\eta p^2 = .02$, as participants became less able to discriminate between a neutral stimulus and a critical stimulus as time on task continued. This is consistent with previous research in this domain as the task utilized in this experiment has images of low salience to increase task difficulty. There was also a significant main effect for period by condition, $F(3,48) = 2.97$, $p < .05$, $\eta p^2 = .06$, shown in Figure 2.4. Participants in the dim light condition were more able to distinguish between critical and neutral stimuli overall demonstrated by the significant condition effect, $F(1,48) = 10.57$, $p < .01$, $\eta p^2 = .18$.

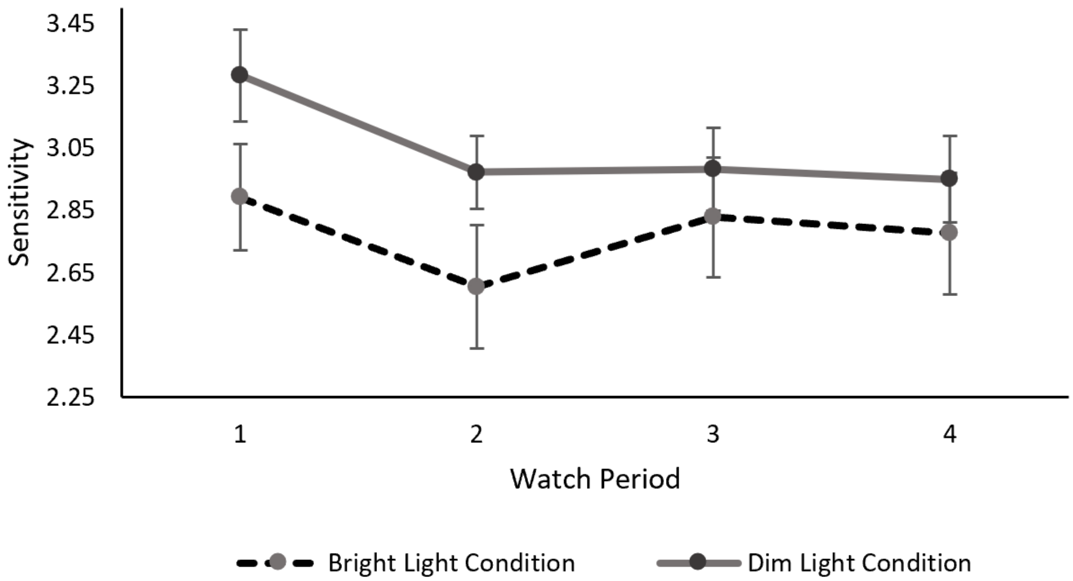

Figure 2.4. Changes in participant sensitivity in bright and dim light conditions across periods of watch. Error bars are standard error of the mean.

For the STD measure of bias (*c*), there was a significant period main effect, $F(3,48) = 10.07$, $p < 0.1$, $\eta p^2 = .17$, as participants in both conditions became less likely to respond to a stimulus as time on task continued. This is also consistent with previous research in this domain as there was a low frequency of critical stimuli compared to neutral stimuli. There was also a significant period by condition main effect, $F(3,48) = 3.17$, $p < .05$, $\eta p^2 = .06$, with participants in the bright light condition being more likely to respond to a stimulus than not. There was a non-significant condition effect, $F(1,48) = 1.73$, $p = .19$, $\eta p^2 = .04$.

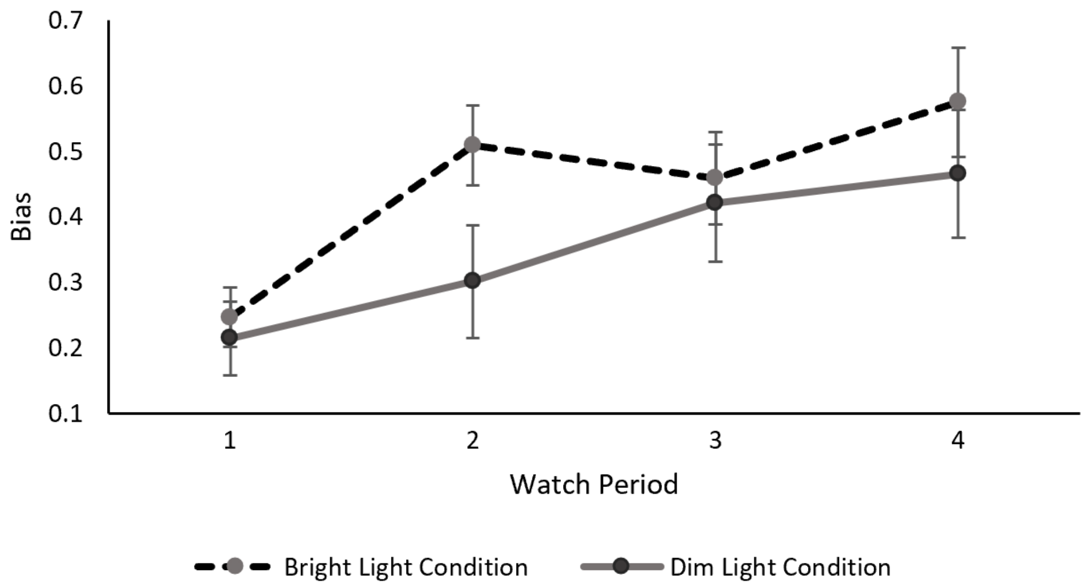

Figure 2.5. Changes in participant bias in bright and dim light conditions across periods of watch. Error bars are standard error of the mean.

2.2.2 SSS

A 2 (condition) × 2 (pre- versus post-task administration) repeated measures ANOVA revealed a nonsignificant main effect for condition, $F(1,48) = .26$, $p = .61$, $\eta p^2 = .01$, and a nonsignificant condition by administration interaction, $F(1,48) = .09$, $p = .77$, $\eta p^2 < .01$. The main effect for administration was significant, $F(1,48) = 22.87$, $p < .01$, $\eta p^2 = .32$, with participants reporting greater sleepiness post-task (M = 3.08, SD = 1.45) compared to pre-task (M = 2.10, SD = .86).

2.2.3 SSSQ

The state factors of engagement, distress, and worry, computed from the 24 survey items with engagement being the mean of items 2, 5, 11, 12, 13, 17, 21, and 22, distress being the mean of items 1, 3, 4, 6, 7, 8, 9, and 10, and worry being the mean of items 14, 15, 16, 18, 19, 20, 23, and 24. These three factors were then analyzed in the present research using a 2 (condition) × 2 (pre- versus post-task administration) repeated measures ANOVA. The main effect of administration was significant for each factor, whereby engagement decreased, $F(1,48) = 9.54$, $p < .001$, $\eta p^2 = .44$, distress increased, $F(1,48) = 34.51$, $p < .01$, $\eta p^2 = .42$, and worry increased, $F(1,48) = 9.63$, $p < .01$, $\eta p^2 = .17$, from pre- to post-task, as seen in Figure 2.5. There were non-significant condition main effects for engagement, $F(1,48) = .23$, $p = .92$, $\eta p^2 = .02$, worry, $F(1,48) = 0.98$, $p = .43$, $\eta p^2 = .08$, and distress, $F(1,48) = 1.17$, $p = .34$, $\eta p^2 = .09$. There were non-significant condition by administration effects for engagement, $F(1,48) = 1.38$, $p = .25$, $\eta p^2 = .03$, worry, $F(1,48) = .88$, $p = .35$, $\eta p^2 = .03$, and distress, $F(1,48) = .04$, $p = .99$, $\eta p^2 = .03$.

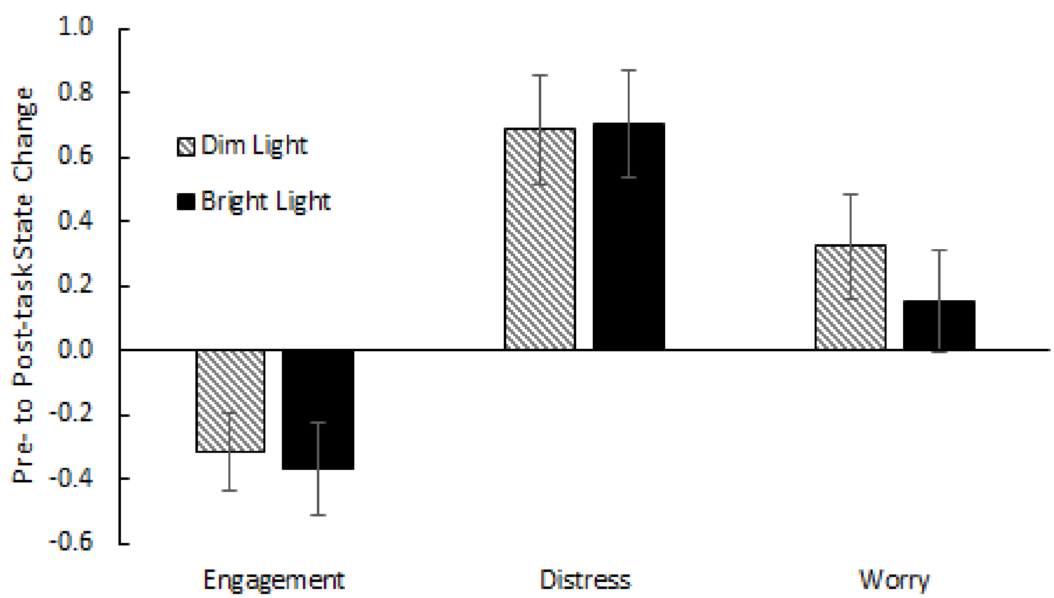

Figure 2.5. Change scores for SSSQ state factors from pre- to post-task in bright and dim light conditions. Error bars are standard error of the mean.

2.2.4 BMIS

The state factors of pleasant-unpleasant were calculated from the sum of items 1, 2, 5, 6, 11, 13, 14, and 16, plus reverse-scored items 3, 4, 8, 9, 10, 12, and 15. The state factors of arousal-calm were calculated from the sum of items 1, 3, 5, 7, 8, 11, 12, 15, 15, 16, and reverse scored items 13 and 14. The state factors of positive-tired were calculated from the sum of items 1, 5, 11, 14, and 15 with reverse scored items 4 and 9. The state factors of negative-relaxed were calculated from the sum of items 3, 7, 8, 12, 15, added to reversed scored item 13. The repeated measures ANOVA administration by condition interaction for the arousal-calm factor, $F(1,48) = 2.69$, $p = .11$, $\eta p^2 = .05$, was non-significant, as was the administration main effect, $F(1,48) = 1.27$, $p = .27$, $\eta p^2 = .03$, and the condition main effect, $F(1,48) = .47$, $p = .50$, $\eta p^2 = .01$. While the bright light group did not noticeably change on this factor from pre- to post-task, the dim lighting group appeared to report being less aroused post-task compared to pre-task. There was a significant administration by condition interaction for the positive-tired factor, $F(1,48) = 8.44$, $p = .01$, $\eta p^2 = .15$, as well as a significant administration main effect, $F(1,48) = 75.94$, $p < .01$, $\eta p^2 = .61$. Though both groups reported similar values post-task, the dim light condition had a higher rating pre-task (i.e., less tired) and thereby had a steeper increase in tired feelings from pre- to post-task. The condition main effect was non-significant, $F(1,48) = 1.79$, $p = .19$, $\eta p^2 = .04$. There was a significant administration main effect for the pleasant-unpleasant factor, $F(1,48) = 53.15$, $p < .01$, $\eta p^2 = .53$ with an increase in self-reported unpleasant feeling pre- to post-task, though the administration by condition interaction was non-significant, $F(1,48) = 1.85$, $p = .18$, $\eta p^2 = .04$, as was the condition main effect, $F(1,48) = 2.62$, $p = .11$, $\eta p^2 = .05$. The administration by condition interaction for the negative-relaxed scale was not significant, $F(1,48) = .01$, $p = .92$, $\eta p^2 < .01$, as was the condition main effect, $F(1,48) = 3.07$, $p = .09$, $\eta p^2 = .06$, but the administration interaction was significant, $F(1,48) = 11.24$, $p < .01$, $\eta p^2 = .19$, with an increase in relaxed feelings across both conditions from pre- to post-task administration.

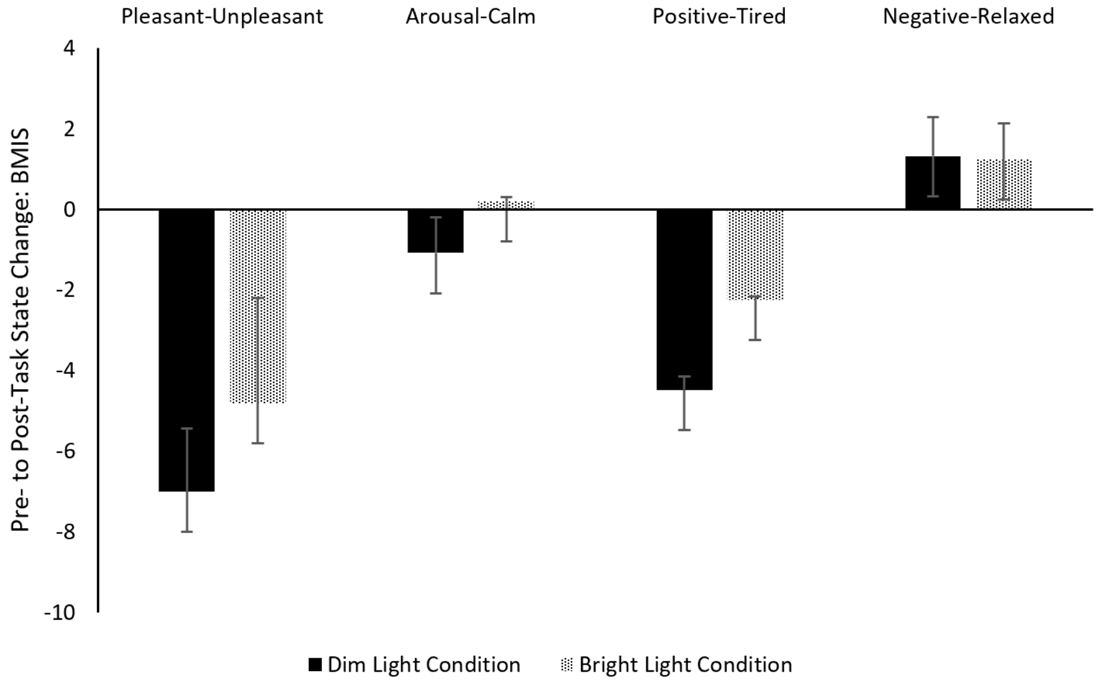

Figure 2.6. Change scores for BMIS state factors from pre- to post-task. Error bars are standard error of the mean. Positive y indicates the first item in the pair, and vice versa.

2.2.5 NASA-TLX

Each participant's global workload score was calculated from the mean of the six unweighted subscales (Nygren, 1991). An independent-samples t-test revealed a nonsignificant difference in global workload between the bright (M = 63.97, SD = 10.54) and dim light condition (M = 61.63, SD = 9.99), $t(48) = .80$, $p = .43$, shown in Figure 2.7.

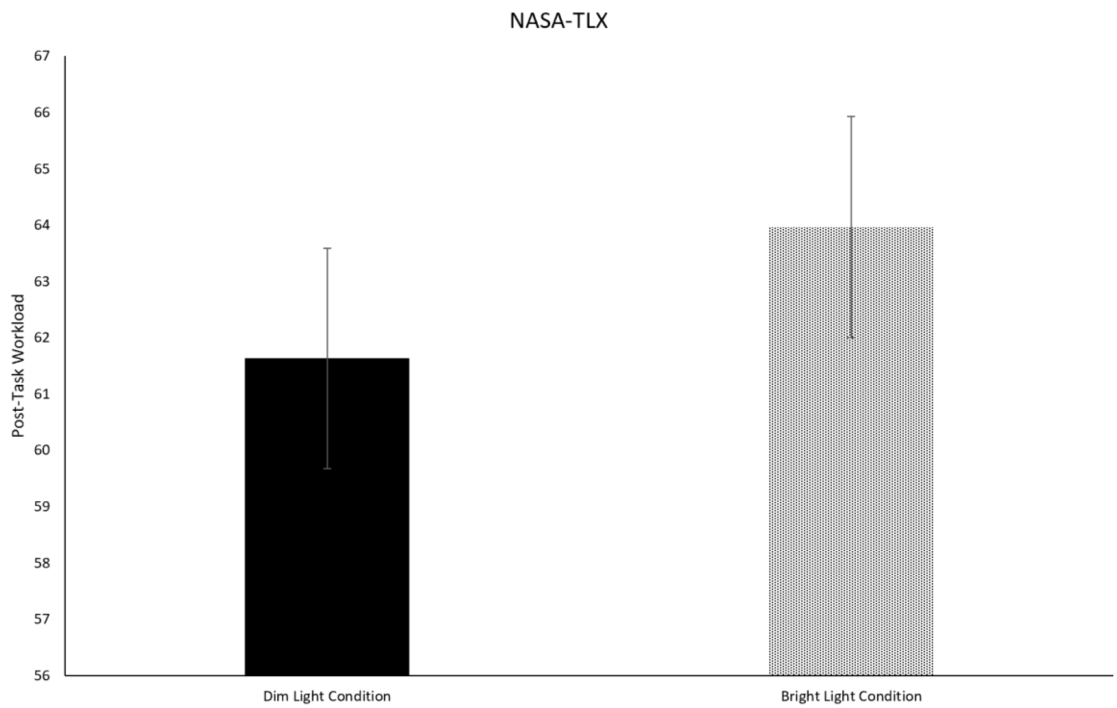

Figure 2.7. Post-task self-reported global workload in bright and dim lighting conditions. Error bars are standard error of the mean.

2.3 Discussion

The results of the present study are consistent with past vigilance research. In both conditions, participants detected fewer critical signals over time, responded more slowly to critical signals over time, and reported high workload. Participants also experienced a task-induced increase in distress, worry, and sleepiness, and decrease in engagement. As hypothesized, participants in the bright light condition still exhibited a decrease in detection of critical signals with time on task, and there was also a nonsignificant difference between conditions in participants' reports of workload. Unexpectedly, critical signal detection and response time were better in the dim light condition. While I did not find evidence that bright light impacted workload or resource utilization (due to similar decrements in both groups), the bright light may have made it more difficult to perceptually discriminate between critical and neutral stimuli. Despite pilot testing to ensure that the lighting and stimuli contrast parameters made for an appropriately difficult task, there were several anecdotal reports that participants found it difficult to see the screen while the bright light was on. This likely contributed to the unexpected finding. The fact that the light made it difficult to perceptually distinguish between the task stimuli suggests that future research should have the light and the task be consecutive rather than concurrent, or that stimuli with greater salience be used. Additionally, previous research in this domain is typically performed in a dim laboratory. There could have been a limitation introduced with having participants practice in a lit laboratory and then test in a darkened laboratory.

Interestingly, the false alarms committed by each group trended in opposite directions over time. Thus, as an exploratory follow-up analysis, I computed the Signal Detection Theory metric of sensitivity, or d′, bias or *c*. Though sensitivity was better overall in the dim light condition, where the dim light yielded a decline in sensitivity across the vigil, participants in the bright light condition exhibited relatively stable (though lower) sensitivity. For other vigilance tasks that are easier to visually distinguish between critical and neutral signals (i.e., tasks where the bright light would not be expected to impair baseline levels of performance), this stability in sensitivity over time could be a promising result and calls for follow-up research with different task stimuli. The bright light likely contributed to participant's ability to discriminate between critical stimuli and neutral stimuli meaning the participant's in this condition had trouble visually interacting with the items on the screen. This would be an explanation for the finding that participants in the dim light condition had an overall higher sensitivity score across all four periods.

Though I did not find evidence from SSS and SSSQ outcomes that the bright light mitigated sleepiness or negative outcomes in engagement, worry, or distress, BMIS results suggest that participants in the bright light condition experienced more stable levels of arousal, and did not increase in tiredness by as much as participants did in the dim light condition. However, it should be noted that participants in the dim light condition began the task with a higher value on the positive-tired scale, which perhaps limits my ability to call this a noteworthy finding. Sleepiness, as measured by the SSS is the urge to sleep. Tiredness as measured in the BMIS coincides with declines in mental performance and increases in mental fatigue. From the resource theory perspective, a reduction in tiredness may suggest a reduction in the cognitive resources needed to perform this vigilance task. The findings support the hypothesis that environmental lighting may indeed affect participants' mood states.

3 Study 2

3.1 Methods

3.1.1 Participants

Fifty participants (18 women) with a mean age of 20.5 years (SD = 3.81) either enrolled in an introductory psychology course at Michigan Technological University or members of the Keweenaw Peninsula community at large served as participants and were compensated with course research credit or a check for $15. Eighteen additional consenting participants were excluded from analysis due to failure to pass training performance criteria (N = 11) or experimental task performance being outside an acceptable range (N = 7). Participants were randomly assigned to the fast tempo music (N = 15), slow tempo music (N = 19), or a no music condition (N = 16). All participants had 20/20 or corrected to 20/20 vision and had abstained from alcohol, caffeine, nicotine, and other psychoactive drugs for 12 hours prior to participation. The study was approved by Michigan Technological University's IRB and informed consent was gained from each participant. Each testing session lasted approximately one hour, began between 8:00 am and 2:00 pm, and was conducted between the months of May and November of 2021.

3.1.2 Materials

Participants were tested individually in a windowless laboratory at Michigan Technological University. Participants sat at a large desk facing the back wall of the lab. All participant activities were done using a Dell Intel® Core™ i7-9700k CPU with a 64-bit operating system and a Dell NVIDIA Quadro P620 monitor with a refresh rate of 60 Hz and a RGB color format. All three conditions utilized Audio- Technica© ATH-M30x circumaural headphones that connected to the headphone jack of the participant workstation. Music selections were tempo adjusted using Adobe Audition© software. For the fast tempo music condition, I chose Beethoven's 5th Symphony and for the slow tempo music condition, Beethoven's Moonlight Sonata. Both pieces were tempo adjusted across all movements to match the target condition tempo. These pieces were chosen because they were already relatively close to my target tempo before adjustment, and because of their recognizability. Custom software displayed the vigilance task stimuli (adapted from Hitchcock et al., 2003) and recorded participant responses and accuracy data. The software was developed by the Air Force Research Laboratory and has been employed in prior research (e.g., Dillard et al., 2019; Monroe & Smith, 2021). All questionnaires were given electronically using Qualtrics survey software. All audio files were played using VLC Media Player.

3.1.3 Procedure

After giving informed consent, participants were asked to silence cell phones and other electronic devices. Participants then completed the pre-task surveys, including demographic information, the SSSQ, and the BMIS. Prior to the participant arriving in the lab, the current condition's music selection was loaded and prepped.

Participants then launched the vigilance program and progressed through the task training slides. Participants were instructed to monitor stimuli for the occurrence of potential collision events between two remotely piloted aircraft (RPA). As seen in Figure 1, there were ten possible stimuli, each consisting of a static image containing a solid red circle surrounded by three concentric white circles, with two gray lines representing RPA flight paths. Participants only saw one of the 10 possible stimuli at a time, and were instructed to press the spacebar to send a warning when the RPA were on a collision course (critical signals) and to withhold a response to the neutral stimuli representing safe flight paths. Responses made to critical signals were analyzed as correct detections; a failure to respond to a critical signal before the onset of the next signal was a miss. Pressing the spacebar in response to a neutral signal was considered a false alarm. The display updated 40 times per minute (one stimulus event every 1500 ms), with each signal being displayed for 80 ms followed by a blank screen for 1420 ms. Each participant's vigil utilized a pseudo-random stimulus presentation, with each minute including 38 neutral signals and 2 critical signals (critical signal probability = 5%). The experimental vigil lasted a total of 28 minutes.

After reading the training slides and being given the opportunity to ask questions, participants completed the first of two, five-minute training trials. Participants were told that they must achieve at least a 70% correct detection rate and make no more than 7% false alarms in at least one of the two training trials in order to participate in the full experimental vigil. Participants received real-time pre-recorded audio feedback for each correct detection, miss, and false alarm, and were also given performance feedback by the researcher and the opportunity to ask questions after each training trial.

Participants in all conditions were then fitted with circumaural headphones and then participants in the slow and fast tempo music conditions were directed to press play on the VLC audio file and then begin the vigilance task. Participants in the control condition experienced no audio but wore headphones for consistency of methodology. Upon completion of the vigil, the participants were directed to remove the headphones and close the VLC Media Player.

Participants were then directed to complete the post-task surveys, which included the NASA-TLX, SSSQ, and BMIS. Upon completion, the researcher debriefed participants regarding the nature of the experimental manipulation, answered any questions, granted research credit, and then released the participant.

3.2 Results

3.2.1 Vigilance Performance

Vigilance performance was determined from the proportion of correct detections, false alarms, and response time. I applied a 3 (conditions) x 4 (periods of watch) repeated measures analysis of variance (ANOVA) with music tempo condition being the between subjects factor and period of watch being the within subjects factor. For proportion of correct detections, there was a significant main effect for period, $F(3,144) = 17.40$, $p < .01$, $\eta p^2 = .27$, as participants detected fewer critical signals across all conditions over time, shown in Figure 3.1. The period by condition interaction was non-significant, $F(2,48) = .87$, $p = .52$, $\eta p^2 = .04$, as was the condition main effect, $F(2,48) = .29$, $p = .75$, $\eta p^2 = .01$.

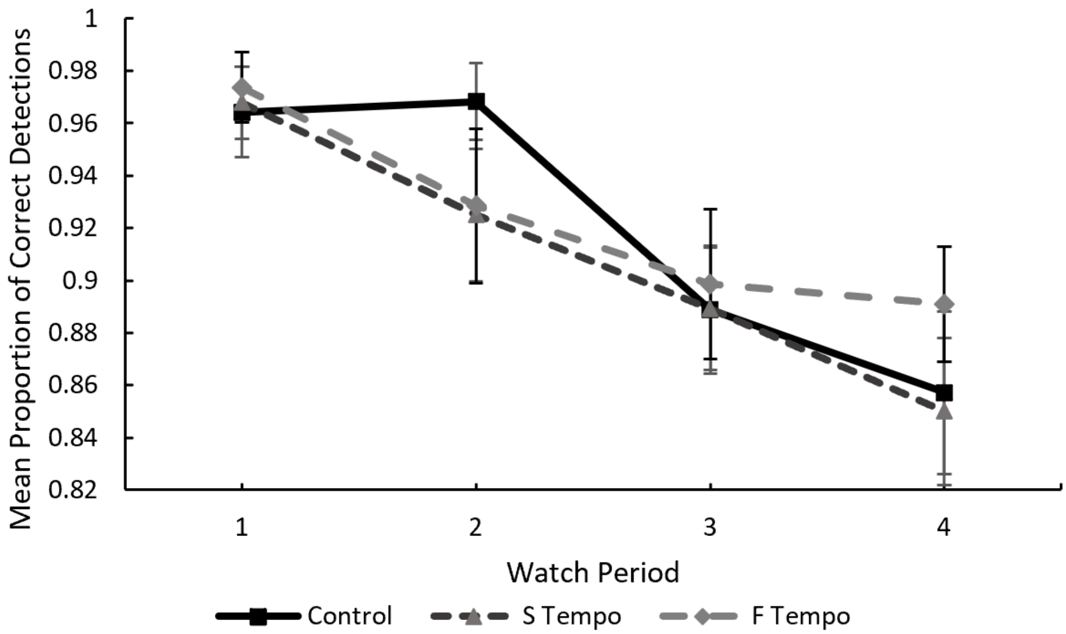

Figure 3.1. Mean proportion of correct detections in fast, slow, and no music conditions across periods of watch. Error bars are standard error of the mean.

For false alarms, there was a non-significant main effect for period, $F(3,144) = .26$, $p = .86$, $\eta p^2 < .01$, as participants had a relatively steady rate of false alarms, shown in Figure 3.2. The period by condition main effect was non-significant, $F(3,48) = .59$, $p = .74$, $\eta p^2 = .02$, as was the condition main effect, $F(2,48) = .97$, $p = .39$, $\eta p^2 = .04$.

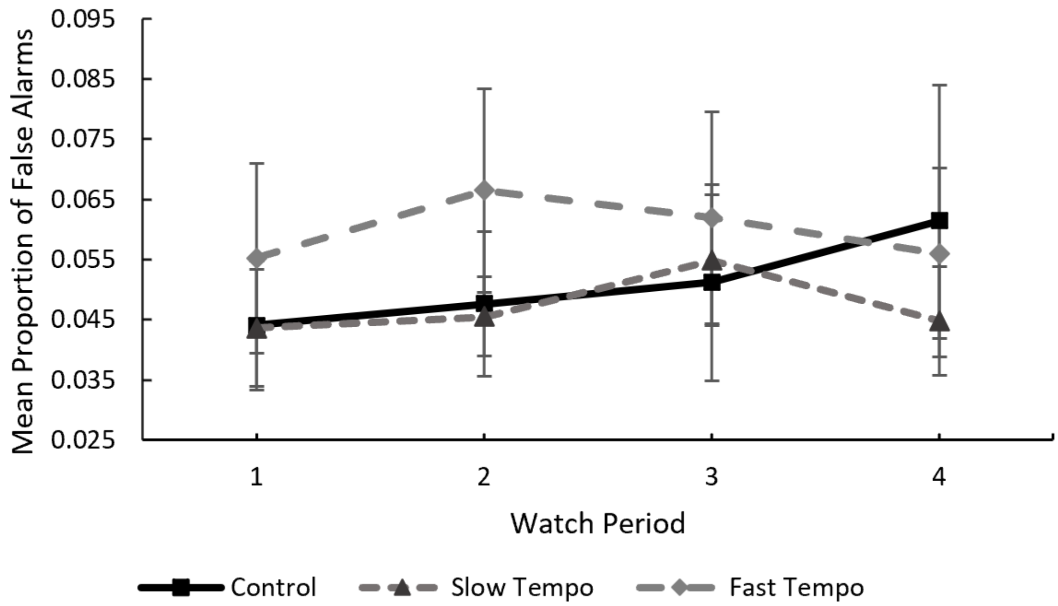

Figure 3.2. Mean proportion of false alarms in fast, slow, and no music conditions across periods of watch. Error bars are standard error of the mean.

For response time, there was a significant main effect for period, $F(3,144) = 63.32$, $p < .01$, $\eta p^2 = .57$, as participant response time increased across all four periods, shown below in Figure 3.3. There was a nonsignificant main effect for the condition by period interaction, $F(3,48) = .93$, $p = .47$, $\eta p^2 = .04$, and a non-significant main effect for condition, $F(2,48) = .65$, $p = .53$, $\eta p^2 = .03$.

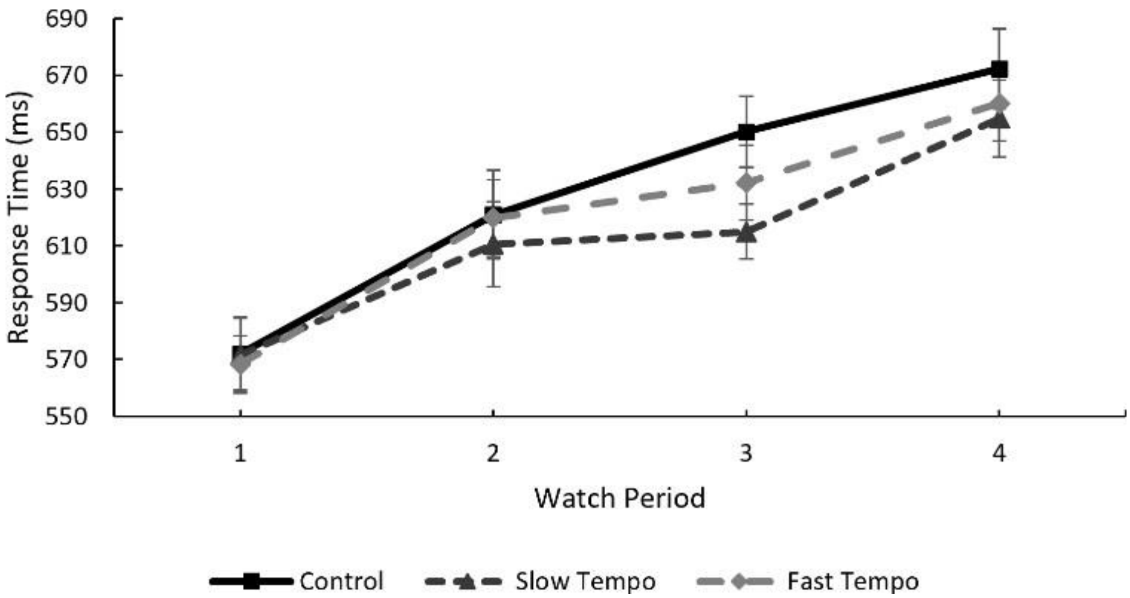

Figure 3.3. Response time in milliseconds for fast tempo, slow tempo, and control conditions across periods of watch. Error bars are standard error of the mean.

I then applied Signal Detection Theory (SDT) metrics to determine changes in participant sensitivity and bias over time. For the measure of sensitivity (d′) there was a significant main effect of period, $F(3,48) = 10.09$, $p < .01$, $\eta p^2 = .18$, meaning that participants became less discriminatory between critical signals and neutral signals over time (see Figure 3.4). The condition main effect was nonsignificant, $F(2,48) = 1.34$, $p = .27$, $\eta p^2 = .05$, as was the case with the period by condition interaction, $F(3,144) = .77$, $p = .59$, $\eta p^2 = .03$.

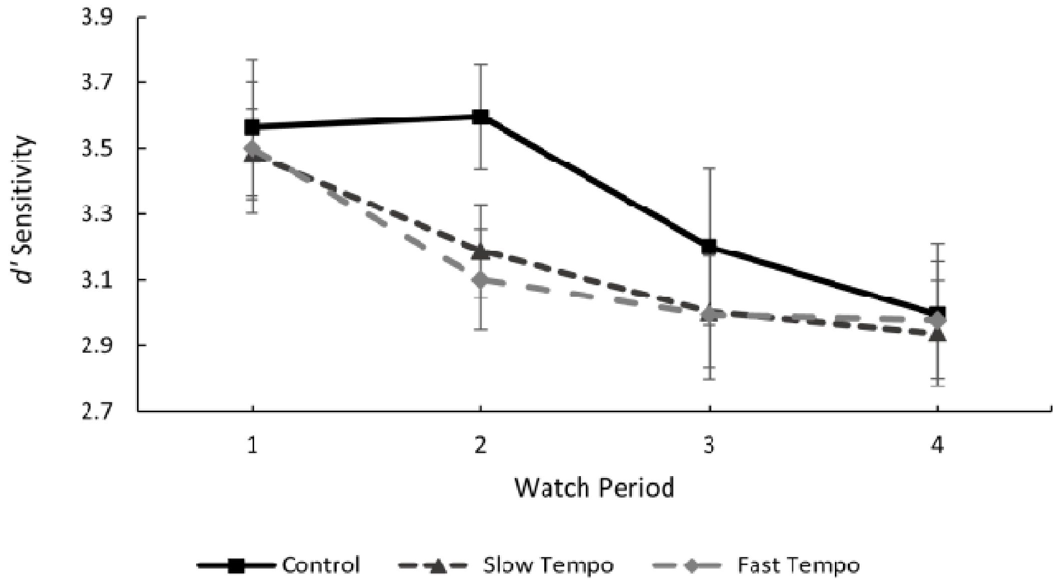

Figure 3.4. Changes in participant sensitivity in fast tempo, slow tempo and control conditions over time. Error bars are standard error of the mean.

For the measure of bias (*c*), there was a significant main effect for period, $F(3,48) = 12.2$, $p < .01$, $\eta p^2 = .21$, with participants becoming less likely to respond to a stimulus over time demonstrated in Figure 3.5 below. The period by condition interaction was nonsignificant, $F(3,48) = .43$, $p = .86$, $\eta p^2 < .02$, as well as the condition main effect $F(2,48) = .32$, $p = .73$, $\eta p^2 < .02$.

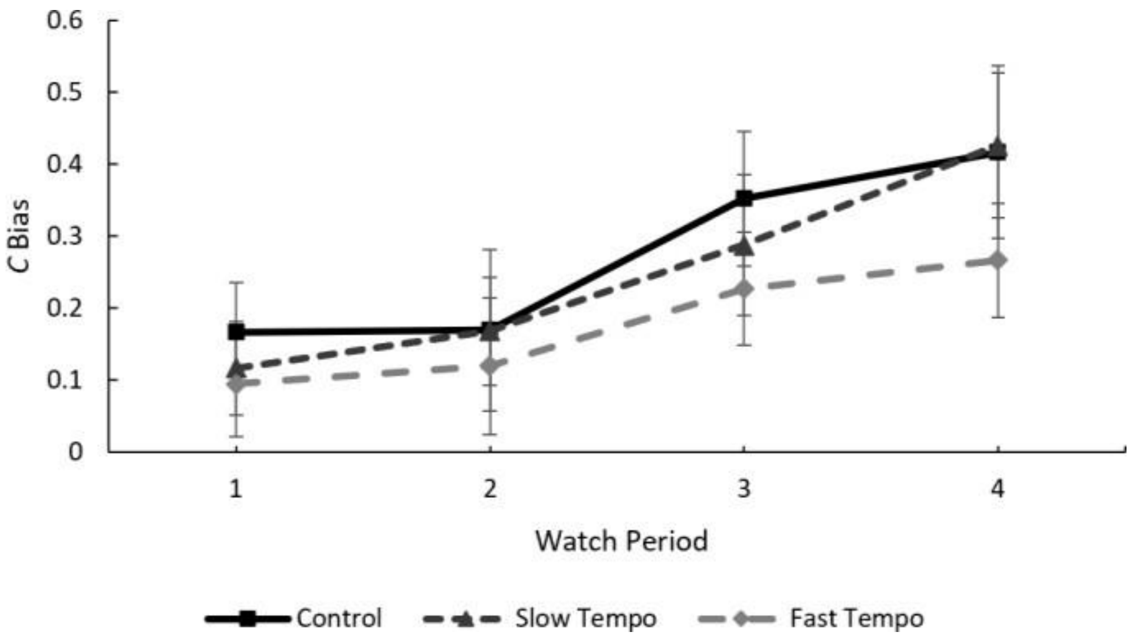

Figure 3.5. Changes in bias for fast tempo, slow tempo, and control conditions across periods of watch. Error bars are standard error of the mean.

3.2.2 SSSQ

The state factors of engagement, distress, and worry, scored from the 24 survey items, were analyzed in the present research using a 3 (condition) × 2 (pre- versus post-task administration) ANOVA. The main effect of task administration was non-significant for worry, $F(2,48) = 2.66$, $p = .11$, $\eta p^2 = .05$, and was significant for distress, $F(1,48) =50.93$ $p < .01$, $\eta p^2 = .52$, and engagement, $F(1,48) = 28.07$, $p < .01$, $\eta p^2 = .37$. Distress increased from pre- to post-task in all conditions, worry decreased in all conditions save control, and engagement decreased in all conditions save fast tempo, as seen in Figure 3.6. There was a non-significant condition by administration effect for engagement, $F(2,48) = 4.06$, $p = .11$, $\eta p^2 =0915$, distress, $F(2,48) = .51$, $p = .60$, $\eta p^2 = .02$, and worry, $F(2,48) = 1.06$, $p = .04$. There was non-significant condition main effect for engagement, $F(2,48) = .44$, $p = .65$, $\eta p^2 < .02$, distress, $F(2,48) = .17$, $p = .85$, $\eta p^2 < .01$, and worry, $F(2,48) = .57$, $p = .57$, $\eta p^2 = .04$.

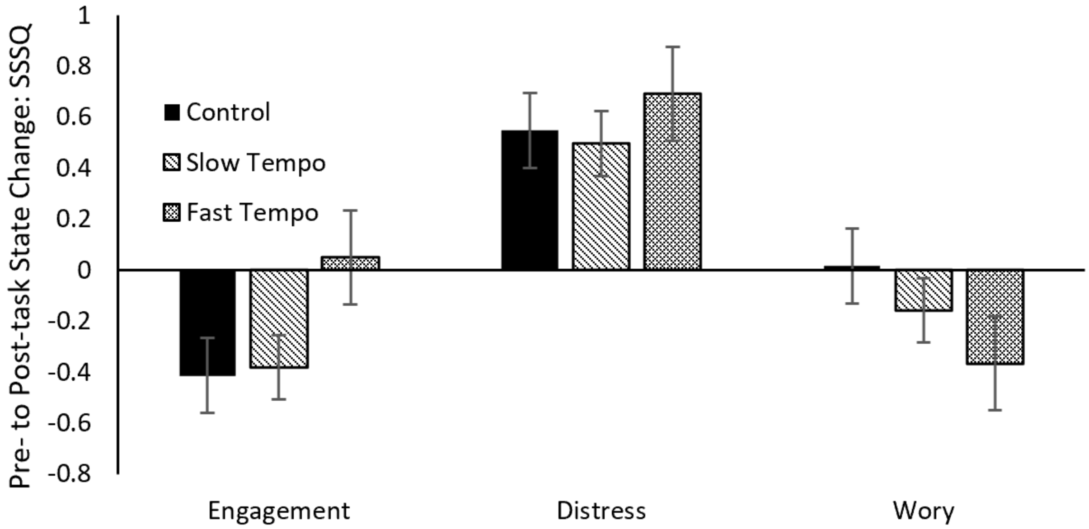

Figure 3.6. Change scores for SSSQ state factors from pre- to post-task in fast, slow, and no music conditions. Error bars are standard error of the mean. Positive y indicates the first item in the pair, and vice versa.

3.2.3 BMIS

The repeated measures ANOVA revealed an administration by condition interaction that was nonsignificant for the arousal-calm factor, $F(2,48) = 1.73$, $p = .19$, $\eta p^2 =.08$, but the period main effect approached significance, $F(2,48) = 2.78$, $p = .06$, $\eta p^2 = .11$, such that participants tended to become less aroused from pre- to post-task. The condition main effect for the arousal-calm factor was non-significant, $F(3,144) = 2.78$, $p = .07$, $\eta p^2 = .11$. Participants in the control and slow tempo conditions reported an overall decline in arousal, but the fast tempo condition did not discernibly change from pre- to post-task. Though the condition by administration interaction was nonsignificant, $F(2,48) = 1.62$, $p = .21$, $\eta p^2 =.06$, the fast tempo condition appeared to experience the largest increase in negative feelings (from the negative-relaxed factor) from pre- to post-task (see Figure 3.7), the slow tempo showed a lesser increase, and the control group showed no increase. The negative-relaxed scale had a non-significant administration main effect, *F*(2,48) = 2.34, *p* = .13, ηp^2 = .05, and a non-significant condition main effect, *F*)2,48) = .58, *p* = .56, ηp^2 = .02. The pleasant-unpleasant factor had a non-significant condition by administration interaction, *F*(2,48) = .18, *p* = .83, ηp^2 < .01, and a non-significant condition main effect, *F*(2,48) = .14, *p* = .87, ηp^2 < .01, but had a significant administration main effect, *F*(2,48) = 56.09, *p* < .01, ηp^2 = .54, with an increase in unpleasant feelings post-task across all conditions. For the positive-tired factor there was a significant administration main effect, *F*(2,48) = 66.99, *p* < .01, ηp^2 = .59, with an increase in tired feelings across all conditions. The administration by condition interaction was non-significant, *F*(2,48) = .55, *p* = .58, ηp^2 = .02, as was the condition main effect, *F*(2,48) = .43, *p* = .65, ηp^2 < .02.

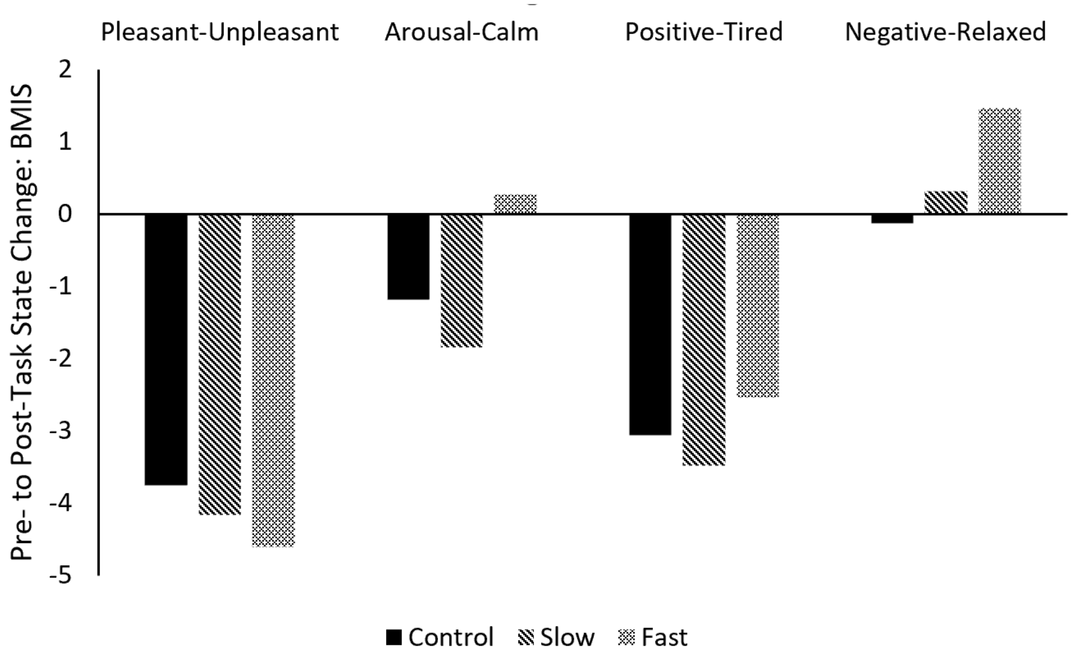

Figure 3.7. Change scores for BMIS state factors from pre- to post-task. Error bars are standard error of the mean.

3.2.4 NASA-TLX

The three factor analysis of variance (ANOVA) revealed a non-significant condition main effect, $F(2,48) = 1.26$, $p = .29$, $\eta p^2 = .05$. Independent-samples t-tests then revealed a difference in global workload that was approaching significance between the control (M = 63.44, SD = 9.84) and slow tempo condition (M = 57.32, SD = 12.41), $t(48) = 1.59$, $p = .12$ and nonsignificant differences between the control and fast tempo condition (M = 61.10, SD = 12.05), $t(48) = .59$, $p = .59$, and the slow and fast tempo conditions, $t(48) = .89$, $p = .38$.

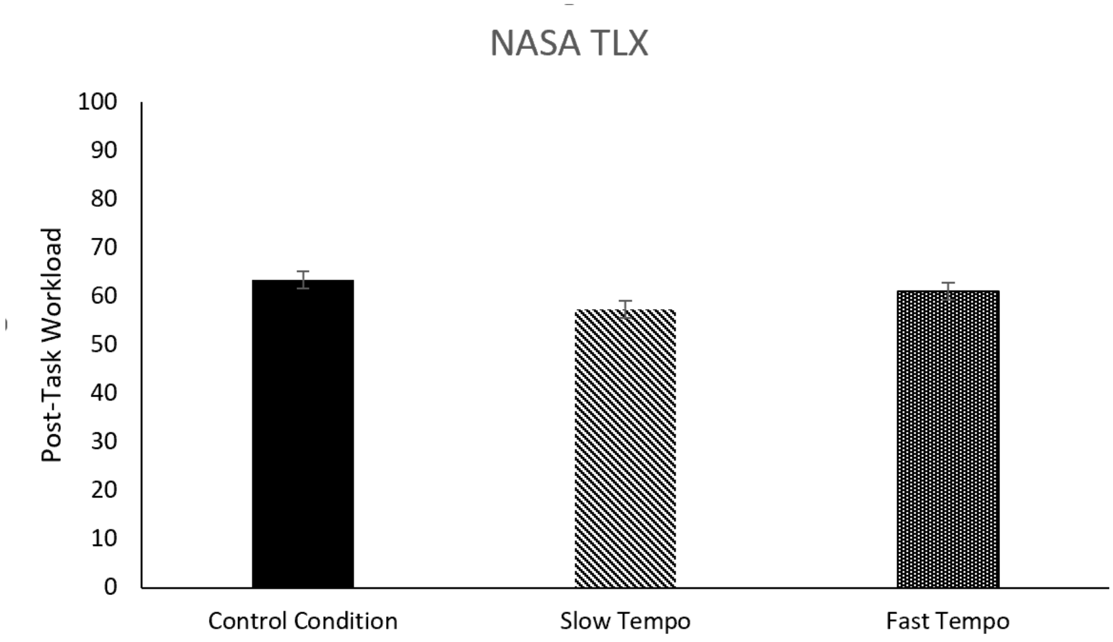

Figure 3.8. Post-task self-reported global workload in fast, slow, and no music conditions. Error bars are standard error of the mean.

3.3 Discussion

In all three conditions, participants detected fewer critical signals and had slower response times across the four periods. This was to be expected as it mirrors previous vigilance research utilizing a task of this difficulty. Contrary to my hypotheses, the intervention of music at a slow or a fast tempo had no discernible impact on any of the vigilance performance metrics including response time which is also contrary to previous vigilance findings. I utilized SDT to determine a metric of bias, c and found that participants became more conservative over time, meaning they became less likely to consider a signal to be a critical stimulus, ultimately responding less frequently. The SDT measure of sensitivity, or d' revealed a decline in participant ability to discriminate between critical signals and noise. The decline in correct detections over time coupled with the stable commitment of false alarms resulted in a higher minimum threshold for participant responses.

Interestingly, the SSSQ results do suggest that the fast tempo condition had the greatest increase in distress from pre- to post-task. The BMIS questionnaire also revealed that the participants in the fast tempo condition experienced the greatest increase in negative affect. In opposition to my hypothesis, participants in the fast tempo condition experienced the greatest increase in negative affect when compared to the other conditions. One of the limitations of this study, however, was the valence of the music selections. Moonlight Sonata had all movements tempo adjusted to 60 bpm, but there are differences in valence across the three movements. The first and third movements of the piece have a negative valence while the second movement has a positive valence. Beethoven's 5th Symphony, which was tempo adjusted to 180 bpm, also has a negative valence. Positively valenced music contributes to improved subjective mood compared to negatively valenced music, which may account in part for the increase in participant distress (Fontaine & Schwalm, 1979).

The results of the SSSQ do not suggest that varying music tempo reduced the task-induced increase in distress, but it may have had a mild effect on task-induced disengagement. Participants in the fast music condition reported no change in engagement compared to participants in the slow tempo and control who became more disengaged. A steady rate of engagement is a promising finding to explore in future studies. This finding may also be impacted by the valence of the music selections.

Additionally, the tempo changes of the music selections used may have had an impact on participant response timings. Due to the selection of classical music pieces that are largely considered recognizable, there may have been an effect on the participant from hearing the music at an unfamiliar tempo drawing attention away from the task at hand. Another plausible limitation is that the predictability of the music beat could have encouraged the participant to respond with the beat rather than with the identification of a critical signal. However, if people were responding with the beat, we would expect response times to be somewhat stable across the periods (due to the consistent tempo), which was not observed. Another study limitation is the fact that the music selection was set and the participant had no control over what they listened to. Music has an impact on the emotional state of the listener and studies where the music is chosen by the participant there is a significant improvement of mood when compared to no choice in music (Al-Shargie et al., 2019). Unfortunately, I did not collect post-task feelings of music likability or familiarity, as these would have been potentially valuable covariates to explore.

4 Overall Discussion & Conclusion

4.1 Overall Discussion

These studies both attempt to improve the post-task mood outcomes that are often observed post vigilance performance as well as mitigating the decrement in performance due to vigilance performance. From the two theoretical perspectives these studies show promise for both the overload and underload theories. From the perspective of underload theories, the steady rate of engagement observed in Study 2 with the fast tempo condition suggests that although there was no mitigation of the performance decrement, participants may be able to perform a task for longer before disengaging if there is appropriate background music present during task performance (Al-Shargie, et al., 2019; Davies & Parasuraman, 1982). Additionally, the lower rate of tiredness and steady rate of arousal in Study 1 from bright light suggests that the participants had a better overall engagement over the four periods supporting the underload theoretical perspective as well (Meesters et al., 2016). A limitation of this study is that sleepiness ratings were not collected for Study 2.

The results of the two studies reported above do not suggest that the interventions used would be successful in mitigating the decline in performance observed under vigilance, however the performance decline is not the only problem that needs to be solved. Though the performance decrement was not mitigated, there were observable effects on the participant mood state in both Study 1 and Study 2. The self-reported measures of arousal and tiredness in Study 1 and engagement in Study 2 demonstrate that while performance did not improve the interventions had an effect on the participant. The bright light condition in Study 1 that led to reduced tiredness and the fast tempo condition in Study 2 that led to a steady measure of engagement suggests that a brightly lit working environment combined with appropriate background music may lead to a working environment that is better suited for vigilance performance as other fields have found that enhancing the working environment improved worker performance (Gerlitz & Hülsbeck, 2023). The physical environment in which work is performed has an impact on worker satisfaction and an indirect impact on worker performance, as workers who are in a satisfactory physical environment experience increases motivation and performance (Mura et al., 2023). It bears noting that the response to the bright light is a physiological one with the reduction in melatonin production while the response to the music is subjective based on participants own enjoyment (Al-Shargie et al., 2019; Lehrl et al., 2007). Operator accuracy is important in reducing the amount of human error seen in fields that utilize vigilance, but the emotional wellbeing of the human operator is also important. An unhappy workforce will not be engaged in their task, nor will they find satisfaction in their work.

Future research could potentially utilize a within subjects design rather than the between subjects design used in Study 1 and Study 2. With the between subjects design the participants only had to complete one full vigilance task with their selected intervention. For Study 1 if a within subjects design was used then all participants would experience both the dim and therapy light conditions and the data could be examined to determine if they performed better due to the bright light. A similar argument should be made for Study 2 and the changing music tempos could have different impacts on performance or mood. This design would also possibly eliminate the beat predictability and encourage participants away from responding with the beat rather than with the stimulus with the fast and slow tempo music conditions. The between subjects designs for Study 1 and Study 2 were chosen due to time limitations as the completion of one condition took 60 minutes per participant as well as the potential for the learning effect as people do tend to get better at sustaining attention over time. There has also been evidence that participant mood states changes across repeated sessions of vigilance can be complex, not to mention the problem of participant attrition in the field of vigilance research, which utilizes tasks often considered simultaneously mentally fatiguing and boring (Smith et al., 2021).

A common point of departure in vigilance research is that of one of the two main theoretical perspectives that attempt to describe the underlying mechanisms of the vigilance decrement. Unfortunately, after more than 70 years of research, researchers in this domain are still ignorant of the fundamental factors that cause this phenomenon (Mackworth, 1948). This research appears to simply add to the large body of evidence that the vigilance decrement is still a problem to be solved. If one uses the overload or underload theoretical perspectives, most focus will be on the task environment and enhancing performance. However, in real world applications, the task environment cannot be altered more than superficially (i.e. long distance driving, military surveillance, air traffic control). The research I have performed above, using both underload and overload theoretical perspectives as a guide, demonstrates that it is not the task that should be the focus of future vigilance research, but the human being performing the task. While the vigilance decrement does indeed affect performance, the majority of the negative outcomes rest on the task operator. Making changes to the task domain that affect the person performing the task may not have immediate effect, as demonstrated here, but employees who are engaged and comfortable may be more productive and reduce overturn costs as a knock-on effect (Markos & Sridevi, 2010).

4.2 Conclusion

The present research explored the effects of altering aspects of the physical environment during completion of a visuospatial vigilance task. In congruence with previous research in this domain, participants demonstrated a decline in performance aspects of the task as well as the onset of some negative mood factors. The interventions used in these studies do little to impact the decline in task performance but show potential in mitigating the negative mood outcomes. These interventions are inexpensive and easy to implement and do show potential for improving the affect of operators in the state of vigilance. It is a worthwhile goal on its own to improve the mood of the operators who must perform vigilance tasks in the workplace even if there is no improvement to performance metrics like accuracy and response time. Operators who are in a pleasant environment may get more satisfaction in their work and make it easier to stay engaged for longer periods of time. This may improve vigilance performance over time in ways that may not be detectable in a 60-minute research session. Even if performance does not improve, decreased operator stress may lead to a decrease in burnout as stress and negative mood state contribute to it. This would lead to a decrease in employee turnover and reduce training costs and other incidentals. Further research in this area may consider combining the two interventions into one experimental procedure.

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6 Appendix A: Study 1 Survey Items

6.1 Demographic Questions

Q1: Have you abstained from alcohol, caffeine, nicotine, and other psychoactive drugs (e.g., Adderall) for the past 12 hours (choose one)?

◯ Yes

◯ No

Q2: If no, please disclose substance taken and approximate time:

Q3: Are you right or left-handed?

◯ Right-Handed

◯ Left-Handed

Q4: Gender:

Q5: Vision (choose one):

◯ 20/20

◯ Corrected to 20/20 (glasses/contacts)

◯ Other (please describe): ________________________________

Q6: Colorblind (choose one)?

◯ Yes

◯ No

Q7: Approximate time you fell asleep last night:

Q8 Approximate time you woke up this morning:

6.2 Stanford Sleepiness Scale

Degree of Sleepiness	Scale Rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

6.3 Short Stress State Questionnaire Pre-Task

Please indicate how well each word describes how you feel ***At The Moment*** (circle one value per row)

Not at all = 1 A little bit = 2 Somewhat = 3 Very much = 4 Extremely = 5

1. Dissatisfied	1	2	3	4	5
2. Alert	1	2	3	4	5
3. Depressed	1	2	3	4	5
4. Sad	1	2	3	4	5
5. Active	1	2	3	4	5
6. Impatient	1	2	3	4	5
7. Annoyed	1	2	3	4	5
8. Angry	1	2	3	4	5
9. Irritated	1	2	3	4	5
10. Grouchy	1	2	3	4	5

Please indicate how true each statement is of your thoughts During ***The Past Ten Minutes***.

11. I am committed to attaining my performance goals	1	2	3	4	5
12. I want to succeed on the task	1	2	3	4	5
13. I am motivated to do the task	1	2	3	4	5
14. I'm trying to figure myself out	1	2	3	4	5
15. I'm reflecting about myself.	1	2	3	4	5
16. I'm daydreaming about myself.	1	2	3	4	5
17. I feel confident about my abilities.	1	2	3	4	5
18. I feel self-conscious.	1	2	3	4	5
19. I am worried about what other people think of me.	1	2	3	4	5
20. I feel concerned about the impression I am making.	1	2	3	4	5
21. I expect to perform proficiently on this task.	1	2	3	4	5
22. Generally, I feel in control of things.	1	2	3	4	5
23. I thought about how others have done on this task.	1	2	3	4	5
24. I thought about how I would feel if I were told how I performed.	1	2	3	4	5

6.4 Short Stress State Questionnaire Post-Task

Please indicate how well each word describes how you feel ***During The Task*** (circle one value per row)

Not at all = 1 A little bit = 2 Somewhat = 3 Very much = 4 Extremely = 5

1. Dissatisfied	1	2	3	4	5
2. Alert	1	2	3	4	5
3. Depressed	1	2	3	4	5
4. Sad	1	2	3	4	5
5. Active	1	2	3	4	5
6. Impatient	1	2	3	4	5
7. Annoyed	1	2	3	4	5
8. Angry	1	2	3	4	5
9. Irritated	1	2	3	4	5
10. Grouchy	1	2	3	4	5

Please indicate how true each statement is of your thoughts During ***While Performing the Task***.

11. I was committed to attaining my performance goals.	1	2	3	4	5
12. I wanted to succeed on the task.	1	2	3	4	5
13. I was motivated to do the task.	1	2	3	4	5
14. I tried to figure myself out.	1	2	3	4	5
15. I reflected about myself.	1	2	3	4	5
16. I’m daydreaming about myself.	1	2	3	4	5
17. I felt confident about my abilities.	1	2	3	4	5
18. I felt self-conscious.	1	2	3	4	5
19. I was worried about what other people think of me.	1	2	3	4	5
20. I felt concerned about the impression I was making.	1	2	3	4	5
21. I performed proficiently on this task.	1	2	3	4	5
22. Generally, I felt in control of things.	1	2	3	4	5
23. I thought about how others have done on this task.	1	2	3	4	5
24. I thought about how I would feel if I were told how I performed.	1	2	3	4	5

6.5 Brief Mood Introspection Scale

Instructions: Circle the response on the scale below that indicates how well each adjective or phrase describes your present mood.

Lively	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Happy	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Sad	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Tired	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Caring	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Content	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Gloomy	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Jittery	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Drowsy	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Grouchy	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Peppy	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Nervous	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Calm	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Loving	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Fed up	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·
Active	·	definitely do not feel	·	do not feel	·	slightly feel	·	definitely feel	·

Overall, my mood is:

Very Unpleasant **Very Pleasant**

-10 · -9 · -8 · -7 · -6 · -5 · -4 · -3 · -2 · -1 · 0 · 1 · 2 · 3 · 4 · 5 · 6 · 7 · 8 · 9 · 10

6.6 NASA-Task Load Index (NASA-TLX)

NASA Task Load Index

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

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

7 Appendix B: Study 2 Remaining Survey Items

7.1 Demographic Questions

Q1: Have you abstained from alcohol, caffeine, nicotine, and other psychoactive drugs (e.g., Adderall) for the past 12 hours (choose one)?

○ Yes

○ No

Q3: Are you right or left-handed?

○ Right-Handed

○ Left-Handed

Q4: Gender:

Q5: Age:

Q5 Vision (choose one):

○ 20/20

○ Corrected to 20/20 (glasses/contacts)

○ Other (please describe):

Q6: Do you listen to music while performing other activities?

○ Yes

○ No

Q7: If so, please describe these activities?