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Implementation of Music in a Simulated Unmanned Aircraft System (UAS) Monitoring Task to Alleviate the Vigilance Decrement

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By

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Abstract

Title: Implementation of Music in a Simulated Unmanned Aerial Systems (UAS) Monitoring Task to Alleviate the Vigilance Decrement

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The vigilance decrement is a thoroughly researched phenomenon in psychological literature and has been identified in many monotonous tasks. Although the phenomenon has been recorded for approximately 80 years, no universal repair, or theory to account for its onset, has been identified. Jobs requiring monotonous task performance have been increasing as time has elapsed, in part due to the rise in automation. Furthermore, much of the vigilance literature does not address modern, more complex tasks, such as the Unmanned Aerial Systems (UAS) monitoring task. A potential method that has been proposed to combat the vigilance decrement is the inclusion of music during task performance to increase arousal and decrease the vigilance decrement. This study examined the impact of listening to music during performance of a simulated UAS monitoring task on the vigilance decrement, as measured by target detection performance and reaction time, as well as the impact on an individual's stress and boredom levels.

Keywords: vigilance, music, arousal, decrement, UAS

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List of Abbreviations

AGL: Above Ground Level

ANOVA: Analysis of Variance

BID: Boredom Influence Diagram

CRT: Cognitive Resource Theory

ECG: Electrocardiogram

EDA: Electrodermal activity

FL Tech: Florida Institute of Technology

GEMS-9: 9-item Geneva Emotional Music Scale

HRV: Heart Rate Variability

HUD: Heads Up Display

IRB: Institutional Review Board

MANOVA: Multivariate Analysis of Variance

MSBS: Multidimensional State Boredom Scale

RT: Reaction Time

SART: Sustained Attention to Response Task

SDT: Signal Detection Theory

SPSS: Statistical Package for the Social Sciences

TLX: Task Load Index

UAS: Unmanned Aerial System

UGV: Unmanned Ground Vehicle

Chapter 1 Introduction

Problem Statement & Background

Unmanned Aircraft System (UAS) pilots are tasked with sustaining attention for long periods of time, with little to no stimulation; a task referred to as a vigilance task (Cummings, 2013; Davies & Parasuraman, 1982). A UAS pilot shift can last up to twelve hours and is a prime example of a typical vigilance task; requiring individuals to continuously monitor a display for detection of signals that are seldom and challenging to identify (Eastwood, Frischen, Fenske, & Smilek, 2012). However, studies have revealed that people are not able to sustain the same level of attention for long periods of time without a decrease in attention taking place (Davies & Parasuraman 1982; Parasuraman, 1979; Hancock, 2013; Oken, Salinsky, Elsas, 2006; Mackworth, 1964). An individual's capacity to sustain attention at an effective level deteriorates over time in discrimination and monitoring tasks, and this drop in attention surfaces after about thirty minutes and is referred to as the vigilance decrement (Parasurman, 1979). Boredom is usually a byproduct of vigilance tasks and plays a key role in the vigilance decrement (Cummings, Gao, & Thornburg, 2016; Eastwood, Frischen, Fenske, & Smilek, 2012). O'Hanlon (1981) suggests that boredom results from prolonged exposure to monotonous tasks, leading to low cortical arousal, and as a result, attention shifts away from the task-at-hand towards more rewarding stimuli. However, in a domain such as UAS this can be disastrous. Furthermore, boredom has been cited as a direct cause for recruitment and retention issues for the U.S. Air Force's UAS workforce (Cummings, 2008). The Air Force has tried different tactics such as offering a bonus of up to $35,000 a year to try and not only recruit, but also retain, their UAS pilots, with little success (McGarry, 2015). Efforts must be made to both 1) prevent the onset of the vigilance decrement, and 2) reduce boredom resulting from the UAS task. A method proposed by other researchers to induce arousal, and in turn, reduce the vigilance decrement, is the introduction of music during task performance. Studies have yielded support for music's ability to decrease the vigilance decrement in simple vigilance tasks, finding an improvement in vigilance task performance while listening to music (Mori et al., 2014; Baldwin & Lewis, 2017; Shih, Huang, & Chiang, 2012; Davies, Shackleton, & Lang, 1973). Students and employees tend to listen to music while studying and working, respectively (Baldwin & Lewis, 2017). Drivers have been found to utilize music in low-task loading situations to stay awake (McCormick, Fabbirini, Palmer, 2018). Chapter 2 will describe the literature pertaining to vigilance, the vigilance decrement, boredom, and music as a possible mitigation.

Research Question & Hypotheses

The research questions for this study are:

RQ1: Does music reduce reaction time in a complex UAS monitoring task?

RQ2: Does music lead to higher target detection performance in a complex UAS monitoring task?

RQ3: Does music reduce boredom in a complex UAS monitoring task?

RQ4: Does music reduce stress in a complex UAS monitoring task?

Hypotheses:

Null Hypothesis 1

H01: There will be no significant difference in reaction time between music and non-music groups in a complex UAS monitoring task.

Alternative Hypothesis 1

HA1: There will be a significant difference in reaction time between music and non-music groups in a complex UAS monitoring task.

Null Hypothesis 2

H02: There will be no significant difference in target detection performance between music and non-music group in a complex UAS monitoring task.

Alternative Hypothesis 2

HA2: There will be a significant difference in target detection performance between music and non-music groups in a complex UAS monitoring task.

Null Hypothesis 3

H03: There will be no significant difference in boredom between music and non-music groups in a complex UAS monitoring task.

Alternative Hypothesis 3

HA3: There will be a significant difference in boredom between music and non-music groups in a complex UAS monitoring task.

Null Hypothesis 4

H04: There will be no significant difference in stress between music and non-music groups in a complex UAS monitoring task.

Alternative Hypothesis 4

HA4: There will be a significant difference in stress between music and non-music groups in a complex UAS monitoring task.

Potential Significance & Generalizability

The findings of this study could lead to a clarification of whether or not music can alleviate the vigilance decrement in a complex domain, such as UAS. These findings could lead to a better performing UAS pilot through decreased reaction times, increased detections, correct rejections, and decreased false alarms. The study could potentially illuminate whether music will lead to decreased boredom and stress in a vigilance task.

The findings of this study should be generalizable to multiple domains. Although the simulated task takes place in the UAS domain it should be generalizable to any monotonous monitoring task (i.e., inspection, highly automated jobs).

Limitations & Delimitations

A previously recorded restraint of utilizing music is that, if the participant does not like a particular song, it can affect their performance negatively (Baldwin & Lewis, 2017; Mori, Nghsh, & Tezuka, 2014). Utilizing the PANAS should allow for this effect to be taken into consideration. However, the actual participants will not be the one's rating the songs therefore it is feasible that although songs may have been scored as positive valence that the participants in the music group do not enjoy them.

Another limitation of the study will be attaining participants because vigilance is presented over time, so the study will not be short. Only students who are willing to participate in longer studies may sign up and it is possible that participants in this group will not yield an entirely representative sample of all different types of individuals. The BPS may account for some of this as we will be able to see some of the variability in participant's trait scores.

Chapter 2 Literature Review

Vigilance and Sustained Attention

Vigilance is the ability to sustain attention for an extended period of time (Cummings, Gao, & Thornburg, 2016; Mackworth, 1948). Sustained attention is the aptitude to both direct and focus cognitive activity on specific stimuli. Vigilance cannot happen without the ability to sustain attention (Oken, Salinsky, Elsas, 2006; See, Howe, Warm, & Dember, 1995). Vigilance, and human difficulties with sustaining vigilance, were first identified around the early 1900s with assembly line inspectors, but research did not truly commence until WWII during the use of the surveillance radar (Adams, 1963). Cases where radar operators in the military were missing targets on the screen were steadily rising and the human's capacity to perform this task began to come into question. Vigilance tasks are characterized as monotonous, repetitive tasks requiring sustained attention by an observer, to a relatively rare target, over a period of time (Hancock, 2013; Tiwari, Singh, & Singh, 2009; Davies & Parasuraman 1982). The psychologist D.B. Lindsey headed the first laboratory vigilance research in 1944 and researchers saw first-hand how operators were not identifying clear targets as the time on a vigilance task increased (Adams, 1963). This inability to sustain attention without deterioration over time is referred to as the vigilance decrement (Mackworth, 1948;

Parasuraman, 1979). The vigilance decrement onset occurs in about 30 mins however, depending on the monotony of the environment and demand of the task, this decrement can occur in as quickly as 5 minutes (Helton & Russell 2015; Warm, Parasuraman, & Matthews, 2008).

Figure 1 illustrates Mackworth (1948) vigilance decrement. The image depicts the results of a study using the clock test where participants are seated looking at a large black clock hand moving across a white surface, they must detect a .6 inch movement (i.e., the regular movement is only .3 inches) over a period of two hours. As time elapsed the reaction time to detection of the larger movement increased. Deterioration in performance of a vigilance task is seen in the form of longer reaction times and a decrease in the number of detections (Helton & Russell, 2015; See et al., 1995). Many theories have been generated as to what the underlying psychological and neural causes of this decrement. There are competing vigilance theories as different tasks result in varying decrement levels and onset times of the vigilance decrement (Eisert, Di Nocera, Baldwin, Lee, Higgins, Helton, & Hancock, 2016). Vigilance decrement levels are defined as the amount of increase in response latencies and missed detections. Factors such as complexity of the vigilance task, event rate (i.e., frequency of targets presented), and sensory modality affect the level of decrement (Parasuraman & Davies, 1977).The following section will focus on the two prevailing theories of vigilance: Cognitive Resource Theory and Arousal Theory.

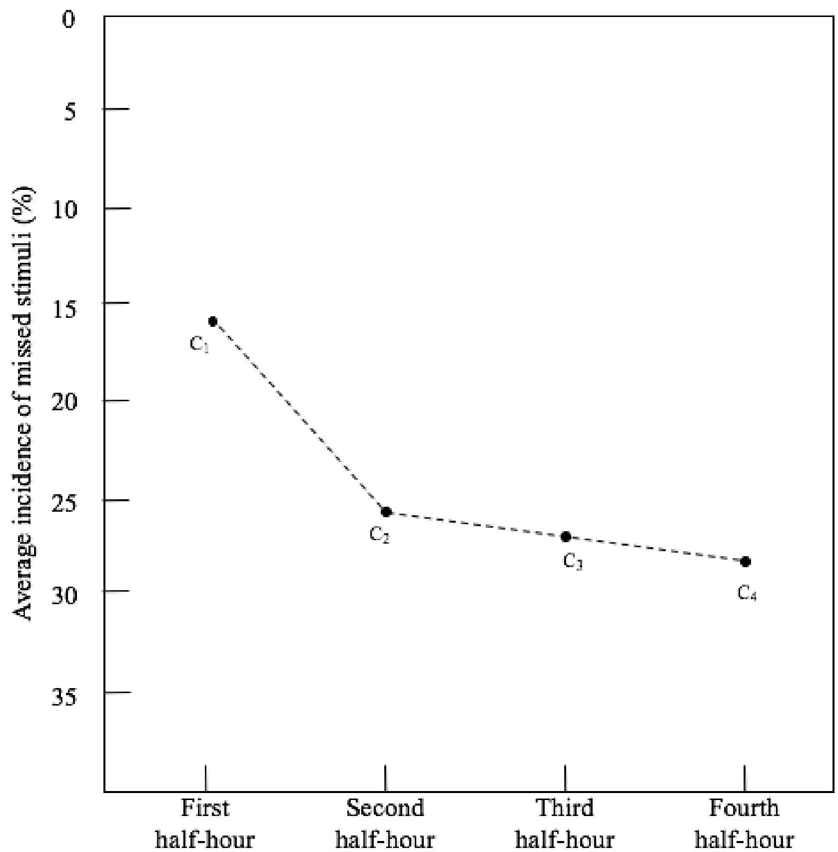

Figure 1., ***Mackworth's depiction of the Vigilance Decrement***

Reprinted from "The Breakdown of Vigilance During Prolonged Visual Search," by N. H. Mackworth, 1948, Quarterly Journal of Experimental Psychology, 1, p. 8. Copyright 1948 by Taylor & Francis.

Cognitive Resource Theory

A prominent theory of vigilance is the cognitive resource theory (CRT), wherein the vigilance decrement is attributed to one of three possibilities. First there is the viewpoint that cognitive resources are limited in supply, and when an individual utilizes their resources faster than they can be replenished, it leads to a vigilance decrement (Epling, Russell, & Helton, 2016; Simon, 1996). The remaining two viewpoints in the CRT literature focus on multiple resources, one that is an extension of the Epling et al., (2016) view that attentional resources are reallocated to other activities resulting in a performance decrement. Wickens (1980) multiple resource theory surmises cognitive resources are divided into separate pools, and as long as dual-tasks do not pull resources from the same pool, little to no decrement should occur.

In an attempt to further understand the interactions between resources and what mediates the vigilance decrement Helton & Russell (2015) tested the effects of different break types on the performance in a vigilance task. From a CRT standpoint, rest and/or interruption which pull from different pools of attention should allow for resource replenishment. In the Helton et al., (2015) study five hundred and twenty-one participants were allocated to one of five groups; complete rest (participants were interrupted with a portion of time allowing them to take a full break from the activity), no break (i.e., participants were interrupted to perform the same visuospatial vigilance task), a letter detection task (i.e., the letter detection task group performed a different vigilance task where they had to identify an O among Ds or backwards D among Ds, also known as a feature conjunction task). Participants performed a spatial match to sample task where they viewed a pattern of three black dots (400ms) followed by a screen containing only one dot and the participant must decide whether it is in the same location as one of the former three.

Participants in the letter match to sample task were interrupted with a task which flashed four uppercase letters and then were shown four lowercase letters; if the lowercase letters matched one of the uppercase letters, they hit the space bar. In accordance with Wickens' multiple resource theory, the letter match should pull from a separate pool, as it did not require spatial memory or sustained attention, and therefore not add to the decrement. Each participant performed the task two times (block one, interruption, block two). The results of the study did not support multiple resource theory as a driving force behind the vigilance decrement, as a significant decrease in reaction time and increase in detection sensitivity were only seen for the rest group and no significance was found in the remaining interruptions. However, support the singular CRT viewpoint as it postulates that there is one reservoir for cognitive resources therefore only rest will lead to RT reductions.

A criticism of the CRT is the lack of direct measures of attentional resources, stating that the findings are circular in reasoning (Helton & Russell, 2015; Hancock, 2013; Navon, 1984). Hancock explains, resources are nearly impossible to define operationally and therein test. Furthermore, modern vigilance tasks (i.e., military surveillance with UAS, air traffic control, and inspection) are not singular or even dual faceted; most of the time the tasks have multiple factors (e.g., monitoring buildings, switching between views, monitoring weather, communicating with the ground control station, adjusting the drones direction, etc.)

which cannot be changed (Cummings, Gao, & Thornburg, 2016; Adams, 1963). A study which incorporated the multifaceted environment was conducted by Taylor, Reinerman-Jones, Szalma, Mouloua, and Hancock (2013) and utilized automation as a means of easing the cognitive workload associated with an Unmanned Ground Vehicle (UGV) operator's job. They hypothesized automating portions of a multi-faceted task when a change in detection occurred would reduce the mental workload. The UGV operator had to complete three tasks concurrently; driving the vehicle along a predefined route, monitoring a video feed for threats, and monitoring a map display for changes in target locations. Automation was introduced either through cueing when a change occurred on a change detection map, or driving assistance through action execution. Although vigilance was not a focus of the study, the increased automation for participants in the driving group essentially created a vigilance task. The participants in the driving group's job changed with the inclusion of automation, requiring them only to monitor the displays for a target, and the map for a change in target location, before input was needed. Participants assigned to either group, auditory automation assistance or driving automation assistance were faced with periods of low and high task demand. The changes in task demand were followed by low and high automation, respectively. The study resulted in auditory alerts yielding performance improvements, however, mental effort and demand increased supporting the notion that people's perception of the task's cognitive load did not decrease (as measured by the NASA-TLX). The level of effort in the NASA-TLX, which is representative of stress, did not decline over time in the automated driving group. The driving group displayed an increase in heart rate variability (HRV), which is not typically indicative of a stress response, but of disengagement from the task and/or a vigilance response. The results are contradictory to the freeing of cognitive resources, which can be seen through both a lack of reduction in participant's stress levels and workload. A reduction in both would be expected to be found with the inclusion of automation (Taylor et al., 2013). Rather the findings are more consistent with a separate theory of vigilance, the arousal theory.

Arousal Theory

Arousal theory attributes the vigilance decrement to the under-stimulating nature or environment of vigilance tasks (Hancock, 2013; Warm, Parasuraman, & Matthews, 2008; Heilman, 1995; Loeb & Alluisi, 1984; Welford, 1968; Frankmann, & Adams, 1962). Physiological research done on cat's brain stems led to the discovery of a secondary pathway in the reticular formation of the brain stem closely related to alertness, and revealed repeated stimulation of this reticular formation reduced neuron firing and behavioral responsiveness, referred to as habituation (Adams, 1963; Sharpless, & Jasper, 1956). These findings led to the belief that the repetitive nature of vigilance tasks were the cause of a decrease in arousal, and in turn, responses. Furthermore Sharpness et al., (1956), tried changing the stimulation pattern and found that this change led to a replenishment of the firing, leading researchers to believe a change in stimulation (i.e., number of targets present or background events) could lead to an alleviation of the vigilance decrement. It is important to note that the original arousal theory does not take into account workload but rather attends to task-loading. These constructs are not synonymous as task-load has to do with the work environment and workload has to do with the interpretation of the task load by the individual, i.e., perceived task load. Therein task-load can be low yet still yield high workload (Cummings, Gao, & Thornburg, 2016; Warm, Parasuraman, & Matthews, 2008).

A well-known arousal theory is the Yerkes-Dodson Inverted U Theory. This theory postulates that in order to have the optimal performance levels the arousing stimulus has to be medial, not too arousing and not too under-arousing (Näätänen, 1973). The study was originally conducted with rodents and named the white-black discrimination habit. Rodents were lightly shocked when entering a white box and did not receive any stimulus when they entered black boxes. They found that as the strength of the shock (stimulus) increased the mice needed less shocks (only shocked a few times compared to many times) to learn the habit (Teigen, 1994). Unfortunately, too high of a stimulus created a negative reaction to performance (i.e., death of mice). Intermediate stimulation proved to be the most favorable. Seli, Carriere, Wammes, Risko, Schacter, and Smilek (2018) conducted a study wherein individuals were presented with an analog clock on a computer screen and then asked to push a button every time the clock's hand was on 12:00, however, the rate at which the hand landed on 12:00 was held constant at 20-seconds. They found that these low difficulty tasks lead to low arousal and commonly mind wandering (Carriere, 2018; Smallwood, Ruby, & Singer 2013) consistent with the Inverted U theory. However, they additionally found that people were able to modulate their mind wandering depending on the task difficulty when they increased the variability of the time when the hand landed on 12:00.

Scerbo (1998) proposed an adaptation of the arousal theory wherein under-stimulation leads to boredom, causing the operator to look for a coping mechanism in an attempt to combat boredom, resulting in stress and fatigue. This adaptation takes into account the increased stress which has been found in numerous vigilance studies (Oken et al., 2006; Desmond, & Hancock, 2001), and will be addressed later in the chapter. In line with the arousal theory, Davenport (1974) designed a study to test the effects of music of different temporal schedules on the performance of a vigilance task. The vigilance task was 160 minutes of watching an oscilloscope sine-wave pattern for an increase in amplitude wherein the participant had to show their identification of the change by hitting a key. Stimulation was randomly introduced to each of the forty-eight participant's in four, 40-minute conditions. Each condition was divided in half with two identical intervals of the condition the following will detail one of the twenty-minute intervals for each condition. For the Random Music condition an interval had thirty, 20-second music and 20-second silence intervals, which were randomly arranged. In the Variable Music condition: Thirty, 20-second music clips were combined with ten, 15-second silence clips; ten, 20-second silence intervals; and ten, 25-second silence intervals; arranged in an irregular order. Fixed Interval Condition: Thirty, 20-second silence intervals and thirty, 20-second music intervals, with a one-to-one ratio of silence intervals to music intervals. The final condition was Continuous Music, the subjects received instrumental music clips with no interruption. Participants listened to instrumental music at 70dB. Participants in the random interval schedules and the variable interval schedule appeared to maintain performance on the visual vigilance task at a significantly higher level than did the other two background schedules, which resulted in a slow degradation of reaction time. These findings support the arousal theory as a driving force behind the vigilance decrement, as the random interval and variable interval schedule would not allow for music habituation. Therefore the individual would become stimulated by the more unpredictable music intervals.

Adams & Boulter (1960) conducted a study to test the arousal hypothesis using a simulated air defense task called the Vigilance Film Apparatus. Twenty-four participants were recruited and tasked with detecting an alphanumeric value change in moving aircraft symbols over a period of 3 hours. Participants were divided into either the evaluation group or detection group. The evaluation group received varied response complexities, wherein they had to make a decision rather than a simple response when the detection group simply had to respond without making a decision. Both groups received varied signal rate, with periods of signals entering and exiting the display quickly followed by slow speeds. Performance was measured through response time. The study found a relationship between the response complexity and vigilance decrement, being that when an observer had to respond with a choice (i.e., complex response) the reduction in reaction time increased. However, no change in performance was found as a result of signal rate.

Adams et al., (1963) recreated the experiment varying the five following factors: signal rate, stimulus load, and proprioceptive and retinal stimulation through head and eye movements in hopes that these variables would further stimulate the participant and decrease the vigilance decrement. The addition of the five factors did not yield changes in the vigilance decrement, however, a decrement was still eliminated when response complexity was changed. The impact on arousal was not measured, therefore it is unclear if the impacts were due to the variables not increasing arousal. More research is needed to understand what factors increase stimulation, however, the findings yield support for a response-produced stimulation rather than task derived theory of arousal.

In order to better understand the causes of the vigilance decrement, Warm, Dember, & Hancock (1996) utilized Hart & Straveland (1988) NASA Task Load Index (NASA TLX) to attain a more quantitative measure of subjective feelings during a vigilance task. The vigilance task consisted of up to five, 10 minute periods of vigilance where participants had to watch repetitive flashes on a computer which displayed two vertical lines on either side of a circle. Participants had to hit the space bar when the distance changed. Participants were placed in one of two groups: high or low target salience. The study resulted in a vigilance decrement over time; participant's workload ratings increased as the time of the vigilance task elapsed, and higher workload ratings were recorded for low salience (hard to detect) as compared to higher salience (easy to detect) targets. An interesting finding was that fatigue and restlessness ratings, as well as workload, increased with time in the vigilance task. These findings are consistent with the view that the increase in workload and stress over time may originate from the performer's effort to combat the tediousness and boredom caused by the vigilance task (Sawin & Scerbo, 1995, 1994; Warm et al., 1996; Scerbo, Greenwald & Sawin 1992; Humphrey & Revelle, 1984; Thackray, 1981).

A study by Sawin & Scerbo (1995) tested this view by combining instruction type and boredom proneness in a vigilance task to see its effects on the performance of sixty participants. Studies have found people who score high on boredom proneness have been positively associated with distraction seeking, impatient behavior, and impulsiveness (Cummings et al., 2016; Dahlen, Martin, Ragan, & Kuhlman, 2005). These behaviors are those which lead to attention shifting from the primary task in search of more rewarding stimuli in turn leading to stress as the individual has to combat these feelings to try and stay alert

(Cummings, 2016; Scerbo, 1998). Two levels of instruction type detection emphasis (induce stress) and relaxation emphasis (reduce stress) were included. The instruction types were combined with two levels of boredom proneness, as measured by responses to Farmer and Sundberg's (1986) boredom proneness scale (BPS), producing four experimental conditions. Participants were asked to view a computer screen for changes in color and then respond, the change occurred at a random time within a minute timeframe for each individual (i.e., thirty flickers). Reaction time, correct response, state trait boredom was assessed, and false alarms were recorded. The NASA-TLX was given to the participants after the completion of the vigil to measure stress, as well as a state trait boredom scale (i.e., Barmack boredom scale). Subjects in the detection emphasis (induce stress) had an increase in stress as shown by the NASA-TLX, and participants in the relaxation emphasis (reduce stress) resulted in a decrease in stress as found when comparing scores before the task. A significant correlation between boredom proneness and vigilance performance was found, with individuals with high boredom proneness having lower performance compared to individuals with low boredom proneness. This study illuminates how boredom may play a critical role in onset of the vigilance decrement and how stress is an additional component of the vigilance decrement.

Boredom

Researchers have been interested in boredom and its defining factors since the early 1900s. The increasing pervasiveness of automation has led to an increase in jobs where the employee shifts from a position of operating the task, to monitoring the task, resulting in the potential for boredom (Hancock, 2013; Parasuraman & Davies, 1977). An issue within the boredom literature has been defining its features as it is closely related to other constructs. Cummings et al.; (2016) created the Boredom Influence diagram (BID) in an attempt to illustrate the multidimensional aspect of boredom and its interactions as found in the literature. Her research lead to the identification of behavioral states occurring when an individual partakes in a boring task. Cummings defined a boring task as a monotonous task, repetitive task, or one with low task loading. Interestingly, this definition is almost identical to the definition of a vigilance task in the literature (Hancock, 2013; Scerbo, 1998; O'Hanlon, 1981). Three behavioral states were identified as resulting from a boring task: 1) attentional lapse, the inability to maintain vigilance; 2) fatigue, which is divided into cognitive (i.e., weariness related to depletion of information-processing assets) and 3) physiological fatigue (i.e., physiological fatigue results when the body uses its energy reserves such as in repetitive gross-motor movements).

Boredom is divided into two components: 1) cognitive, which is how a person perceives and constructs the task, and 2) affective, which comes from the conflict between the inadequate stimuli and the inability to be stimulated in the current environment. Similarly, these two components mirror the vigilance theories, CRT is related to workload (i.e., the subjective interpretation of the task load by an individual) much like the cognitive component of boredom. Arousal theory is related to low-task loading (i.e., low demands required by the work environment) leading to under stimulation, similar to the affective component of boredom. Boredom has negative effects on vigilance task performance as identified through the inability of sustaining attention (Cummings et al., 2016; Parasuraman & Davies, 1977). Furthermore, Cummings notes how boredom can lead to stress and frustration which only worsens the vigilance decrement (Bruursema, Kessler, & Spector, 2011; O'Hanlon, 1981).

The effects of task boredom have been found to have varying effects concerning performance in vigilance tasks. In a study conducted by Cumming's et al., (2013) 30 participants were asked to find moving targets in a simulated UAS task, they searched the display for hostile targets for four hours. Participants were told to destroy hostile targets as quickly as possible, four targets were included through the duration of the study and only two were considered hostile. Each participant had to take part in three different tasks during the duration of the experiment; including responding to 1) automation prompting to consider a replan; 2) text messages asking for information, and 3) prompts from the system to generate search tasks. A cue in the form of an audio alert was sounded for all the three tasks, in addition to visual cues. There was an increase in reaction time across all events except in the last hour, in which there was a decrease in reaction time for the chat and the replan. Cummings attributed the reduction in reaction time to the participants knowledge that the task was ending. A decrease in reaction time was not found in the search generation, and this was proposed to be due to it being of low priority wherein, the participants were not attending to this task because they felt it was not as important to the mission. These findings are consistent with the arousal theory as the repetitive, low-event rate of the domain would cause boredom among operators, resulting in a decrease in arousal and increases in target misses. An interesting finding in this study was that participants found ways of coping with the boredom through distractions. Distractions were defined in the study as times when a participant was not in a physical position to see the interface (i.e., turned around in a chair), talking to other participants, at the table getting something to eat, and working on a personal laptop. Furthermore, distractions did not lead to low performance which Cummings attributed to the positive effects distraction can sometimes yield in boring environments. Overall, participants spent half of their time in a distracted state. Interestingly even the highest performer spent around a third of the task duration distracted.

These findings are not new in low-task loading environments, anesthesiologists have been known to listen to music or engage in conversation to mitigate the effects of boredom (Cummings et al., 2013; Weinger, 1999). The results of the study yield support for individual’s ability to manage distraction effectively from boring low-task loading tasks through task switching. Many researchers have come forward recommending music in low task-loading environments rather than a sterile environment in order to reduce boredom-induced stress and yield better sustained attention (Cummings et al., 2013; Dunn & Williamson, 2011; Fontaine and Schwalm, 1979; Warm and Dember, 1986). These findings are in line with the adapted version of the arousal theory, as music is proposed to induce stimulation, decreasing boredom, and in turn decreasing stress associated with combating boredom.

Music

Research has been conducted to examine the potential for music, as a distractor, to reduce the onset of the vigilance decrement, and has had promising results.   Baldwin & Lewis (2017) performed a study to identify the types of music which produced a restoration of sustained attention in a short two-block vigilance task. They began by creating a database of popular songs which was sorted into four categories: fast tempo positive valence, fast tempo negative valence, slow tempo positive valence, and slow tempo negative valence. They had eighty-nine participants perform a sustained attention to response task (SART) called Go-NoGo. The SART is divided into two, 7-minute blocks which present numbers 0 through 9, 42-times. Participants were given a 7-minute intervention between songs where they were given: one of the four music categories mentioned (i.e., fast tempo positive valence, etc.), a break with no music, or no break. During the blocks, participants were instructed to respond with a mouse click for all numbers, with the exception of 3. The following information was collected and coded: non-responses to the target (i.e., the screen displaying 3) were hits, responses to targets were coded as misses (i.e., clicking when the screen displayed a 3). Responses to non-targets (i.e., all other numbers) were coded as correct rejections and a lack of response to non-targets was coded as false alarms. The findings of the study were such that, participants in the positive valence slow tempo music break group showed the highest significant reductions in misses after the intervention, followed by positive fast. Participants in the negative valence conditions, no music, or no break showed an increase in misses. Furthermore, the participants in the positive valence slow tempo group were the only group who did not yield a performance decrement. Baldwin & Lewis (2017) concluded that positive valence music that a participant likes could lead to positive performance in the form of decreased misses.

A study conducted by Wokoun (1963) for the United States Army to test whether music could improve performance in a vigilance task. Performance was defined as decreased reaction time. Fourteen participants were recruited and sorted into one of two groups, music first or white noise first (i.e., both participants got each stimulation type, just in different orders). Participants were presented with one of three colors of light, displayed on a one inch square plastic one inch square. Each color of light corresponded to three different identification types. Green was a non-threat, yellow was undefined, and red was an enemy. Each identification had a corresponding key displayed on the table in front of them. Colors were randomly presented to participants who were to respond with the correct corresponding key. The task lasted for a total of one hour. Although not statistically significant due to a small sample size, reaction time was faster for participant during the music portion of the task regardless of which condition was received first. Participants, on average, reacted to the stimuli .14 seconds faster in the music condition (Wokoun, 1963). Furthermore, the white noise first condition yielded a vigilance decrement as seen by an increase in reaction time at the 30-minute mark, however in the last 20 minutes there was a slow decrease in reaction time. This is not uncommon as participants tend to have an increase in performance when they know the experiment is ending. The music group did not yield a vigilance decrement, this may indicate music has the potential to combat the vigilance decrement.

Davies, Lang, and Shackleton (1973) tested the effects of music and noise on an easy and difficult vigilance task. The participants were tasked with detecting changes in brightness for a span of forty minutes by hitting a yes button or a no button when there was no change. Targets were present for forty-eight times (each lasting one second) out of the full forty minutes. Correct detections, false alarms (i.e., incorrectly stating target presence when it did not occur), detection latencies (reaction time) and d' values were recorded for the forty participants. All subjects rated instrumental music as stimulating. Furthermore, a decrement did not occur in both the easy and difficult vigilance tasks, as there was no significant increase in reaction time. Concerning noise, an increase in reaction time was seen with the difficult vigilance task but not the easy task. In regards to correct detection, there was no significant difference found between music and noise in the easy condition, however, in the difficult condition there was a significant effect on the task when music was presented, with music improving the detection rate substantially. A negative result found was that music increased commission errors. The author notes that the increase in commission errors contradicts similar studies findings and suggests these results are due to a change in the participant's sensitivity. They propose that utilizing knowledge of results can change the commission errors as long as the incentive is high. Interestingly significant differences (i.e., increased correct detections and reduced reaction time) only appeared when the task was more difficult.

A study by Beh and Hirst (2010) investigated the effects of music on driving related and vigilance tasks. Participants were placed in one of three groups: no music, low- intensity music, or high-intensity music with either low demand or high demand tasks. Low demand tasks were singular in nature and high demand tasks required the participant to perform the vigilance and tracking task in conjunction. Low and high music intensities yielded improved response time to centrally located visual signals. Yet, loud music significantly affected response time to peripheral stimuli. Beh & Hirst (2010) recommend moderate intensity music to improve performance requiring a wide attentional span and explain that music which is too arousing may result in performance decrements as it can become too distracting.

Navarro, Osiurak and Reynaud (2018) assessed the influence of background music and tempo on driving performance. Arousal was measured using both a heart rate belt and a watch that collected heart rate information and performance was measured in terms of intravehicular time (IVT)(i.e., the more IVT the better the performance). Three experiments were performed with different music conditions followed by a metrinome, all experiments took place in a driving simulator where participants had to perform a car-following task. The car-following task lasted for 55 min with a 20-minute break between music and metronome conditions. The leading vehicle periodically varying its speed between 45 and 95 kph. In terms of music presence in experiment 1, the driver's preferred music track played at its original and a modified tempo (i.e., it was either a 30% increase or decrease in tempo) and followed b a ticking of a metronome. Experiment 1 found that preferred music with no modified tempo led to an increase in driving performance while no-music, music with an increased tempo, and music with a decreased tempo did not. When just the metronome was presented no significant difference between conditions were found. Furthermore, no significant increases in performace were found for any other conditions. In Experiment 2, music tracks of varying tempos were played followed by the metronome during driving. In experiment 2 none of the conditions had an effect on heart rate, however, slow music resulted in a significant performance improvement as it increased the gain in the drivers' responses to changes in the speed of the leading vehicle when compared to fast tempo music. In Experiment 3, music tracks were subjectively categorized as arousing or non-arousing by the participants and played . Increased HR was correlated with the subjective music arousal reported. Music with increased arousal lead to a smaller IVT, therefore influencing driving behaviors.

Conclusion

A criticism of the vigilance literature is that it focuses on the mundanity of the task and does not address the difficult nature of the modern vigilance task. The literature has shown that vigilance tasks are both boring and stressful. The vigilance decrement seems to be in part due to a lack of arousal. This lack of stimulation has been found to lead to boredom in multiple studies (Cummings et al., 2016; Eastwood, Frischen, Fenske, & Smilek, 2012; Scerbo 1998). Although boredom and monotony do not lead to stress, researchers believe the friction between the need to stay alert and yearning to disengage from the task can lead to considerable stress. Music may be a viable mitigating factor as it has been found to lead to increased arousal (Cummings et al., 2013; Dunn & Williamson, 2011;

Davenport, 1974). The music literature pertaining to driving is helpful in understanding the effects of music on arousal but does not address the progression and change in vigilance tasks wherein exogenous input is limited. Even in the driving domain with the rise in automation in cars there needs to be more focus in these low task loading environments. There is limited testing in more complex monitoring environments which are low-task load (i.e., that is there may be more information but there is still a small amount of input by the user) and are more reflective of the modern vigilance task. Given the gap in the literature, the goal of this study is to examine the impact of music on the vigilance decrement as seen through performance (i.e., reaction time and target detection), boredom, and stress for a complex simulated UAS monitoring task.

Chapter 3 Methods

Introduction

This study assessed the impact of music on vigilance by measuring reaction time, stress, target detection performance, and boredom in a complex simulated UAS monitoring task. The vigilance task was created using software available to UAS students at the Florida Institute of Technology (FL Tech).

Participants

Population & Sample

This study utilized students from FL Tech, a southeastern private university, through convenience sampling. Participants were recruited through an email to on FITforum, a list service provided through the University. The study utilized convenience sampling to attain participants. Participants who took part in the study were entered into a raffle for a $100 gift card. Color vision deficient individuals were not able to participate in the study as the target would be virtually impossible for them to identify. A power analysis for a MANOVA with one independent variable and four dependent variables was conducted in G*POWER to determine a sufficient sample size using an alpha of 0.05, a power of 0.80 and an effect size of = .28. This effect size was derived by averaging the effect size of two similar studies (i.e., .086 and .47), as the effect sizes ranged vastly between music studies.

Participant Protection

An Institutional Review Board (IRB) protocol was submitted to the FL Tech IRB detailing the proposed study. All data collected from participants was anonymous. Upon arrival, consent forms were given to participants through Qualtrics, including the possible risks of the study. Participants were free to withdraw from the study at any time. The primary study risk participants could have potentially faced was simulator sickness.

Procedure

Research Design

The study aimed to evaluate how music affected vigilance by measuring reaction time, target detection performance, stress, and boredom. The design was a between groups, Randomized Posttest Only Control Group experimental design. The independent variable was presence of music during task performance (present vs. not). Participants were assigned to groups using a Latin squares method. This design aimed to evaluate the performance, stress, and boredom experienced in the presence and absence of music. (See Figure 1).

IV = Presence of music

Music	**No Music**
G1	G2

Figure 2., *Research Design*

Experimental Task

When participants first arrived, they were directed to a desk where they were given the consent form followed by a pre-survey. Once completed, participants were instructed on how to dawn the Equivital sensor belt, how it worked, what data was being streamed, and then directed to the restroom to put on the belt. Upon returning to the room, the Equivital's system electronics module (SEM) which collected the Electrocardiogram (ECG) information was input into the belt. Participants' belts were checked to make sure no straps were twisted and that they were put on correctly. Participants were then directed to a chair and given a chance to see their ECG data being streamed and informed about the baseline procedure. A few magazines were presented for participants to choose and read from as they relaxed for their five-minute physiological baseline collection. After completing their baseline, they were given details about how to perform the simulated task and read the following scenario (for the full script see Appendix A):

> *The military has lost control of one of its covert drones in an area which has not been secured. Notify your squadron commander by selecting the space bar when the drone comes into sight. Be sure to watch your aircraft's altitude, if you fly below 100 AGL, mark it down on the sheet provided.*

After the scenario and instructions were read aloud, participants were presented with a sheet showing an example of the Heads Up Display (HUD) information they would be seeing on the screen (See Figure 3.). The sheet illustrated where the AGL information was located. Participants in both the music and non-music conditions were then fitted with MDRZX110NC SONY headphones which had 13 dB of noise suppression. If a participant was in the music condition, at this time they were told that they would be listening to music for the duration of the task. Participants in the music condition were then asked to dawn their headphones and a song was played (this song remained constant across participants) to allow them to pick a comfortable music volume. After selecting the volume, they were then asked to remove them. Both groups were asked whether they had any questions and the instructions were repeated for a second time. The participant then participated in the 31-minute vigilance task, in which they monitored a video presenting a landscape from a simulated UAS first person view. The only input for the simulation required from the participant was to hit the space bar when the UAS came onto the screen. They were also asked to type the number 1 into a word document (Microsoft Office Professional Plus 2010, Version 14.0.7128.5000) located on a separate laptop, when the UAS rose above 100 AGL. The simulated vigilance task followed parameters set by Daly, Murphy, Anglin, Szalma, Acree, Landsberg, & Bowens (2017) as closely as possible, on how to develop a laboratory vigilance task for a UAS environment. They suggest five to seven targets, presented one at a time, for a 30-minute vigilance task. Therefore, the target (i.e., the covert drone) was presented 7 times within the span of the 31-

minute simulation. The simulated environment was a barren junkyard which could be circled by the drone in approximately 5 minutes. This is in accordance with the Daly et al. (2017) requirement that the changing environment should not appear novel. Furthermore, knowledge of results was incorporated through a window which appeared stating: "Target identified!" when the participant selected the space bar during the time the drone was on the screen. If the drone was not in sight and the space bar was hit a prompt displaying: "Target not in sight!" appeared.

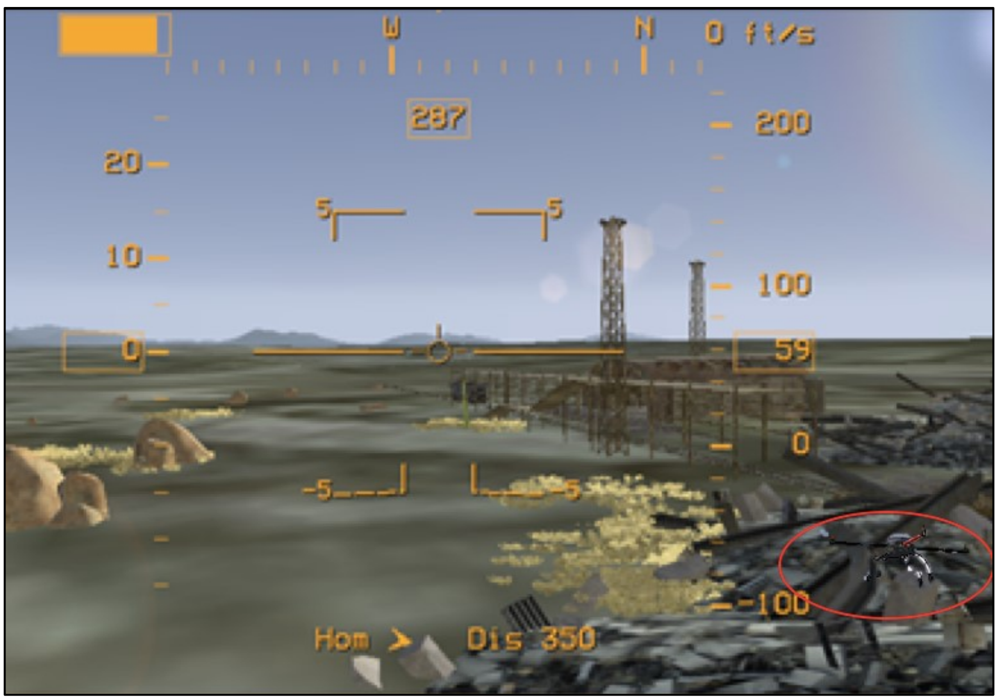

Figure 3., *Task Example*

*The user sees the flight through the nose view. When the drone comes into sight they must select the space bar. The vertical scale on the right side illustrated the AGL, as you can see the AGL is below 100 therefore the participant would not be expected to mark the AGL. The circled drone is the target drone for which participants will be searching. (**Note:** The image has been cropped and enlarged so that the information on the HUD can be seen).*

After the simulation ended, participants were asked to stand up so that the SEM could be removed and the data could be downloaded. Participants were then asked to complete the post survey. After the post survey participants were asked to watch the simulation and rate each target's difficulty (this will be addressed in more detail in the following section). The participants were then de-briefed and asked to make their way to the restroom to remove the Equivital belt. Participants were then told that they would be contacted if they won the raffle and told to contact the proctor if they had any questions.

Measurements

Struk, Carriere, Cheyne, and Danckert's (2017) adapted Boredom Proneness Scale-Short Form (BPS-SR) was administered as a pre-survey after the consent form. The BPS-SR is an 8-item, 5-point, Likert-type scale, measuring trait boredom. Studies have found individuals who score highly on the original Boredom Proneness Scale (BPS) perform poorer in vigilance tasks (Cummings et al., 2016). The BPS-SR has been validated and found to have construct validity comparable to the original BPS (Struk et al., 2017). (See Appendix C). All survey responses were collected via Qualtrics, including post survey results.

Four primary dependent variables were measured within the study: target detection performance, reaction time, stress, and boredom. Positive affect related to the music was collected in the post survey order to further explain results, along with demographic information, this will be addressed later in this section. Target detection was measured as either a "hit" (i.e., correct detection) or a miss (i.e., target not detected). Each correct detection input was recorded in the software output log with a timestamp which also accounted for the second measure, reaction time. Reaction time was calculated by taking the difference between the time in which the UAS became visible on the screen and when the participant hit the space bar.

It was anticipated that target difficulty would be a potential confounding variable. To account for this, participants rated the difficulty of each target on a 5-point scale (1 = *very easy* and 5 = *very difficult*) after completing the task, to gain quantitative data that would help assess whether there were any effects of difficulty on the dependent variables. Participants were showed the points in the simulation where the drone came into the screen and watched it until it left the screen then asked to rate how difficult it was to detect from very easy to very difficult.

Stress was measured using the adapted version of the NASA-TLX (i.e., the NASA-TLX short). This adapted version is a 6-item, 20-point scale, from low to high. The NASA-TLX (See Appendix B) and reaction time are important measures as they were used to validate whether the simulated task is a vigilance task and produced a vigilance decrement. If participant stress and workload are high and a performance decrement (i.e., increased misses and reaction time) is measured, a strong argument can be made for the task resulting in a vigilance task (Daly et al., 2017). Furthermore, the Multidimensional State Boredom Scale (MSBS) (See

Appendix D) was administered to the participants to measure the state of boredom after the activity, including assessment of disengagement, high arousal, low arousal, inattention, and time perception (Cummings et al., 2016).

Two additional exploratory measures were captured to aid in explaining the results of study. The Positive and Negative Affect Scale (PANAS) was administered to participants in the music group after the test to rate the playlist of songs for positive affect. The PANAS has been found to be a valid measure of evoked positive emotion comparable to the Geneva Emotional Music Scale (GEMS) (Fitzgerald, 2013). Second, arousal was measured by capturing heart rate from the Hidalgo Equivital sensor belt. Demographic information related to gender, age, academic level, and drone experience was collected in the post survey.

Instruments & Materials

Setup

The study was conducted in the Basic Aviation Training Device (BATD) Lab in George M. Skurla Hall at FL Tech. The simulation was run on a Dell Precision M2800 laptop computer with the following specs: Windows 7 Pro 64bit, Intel ® Core ™ i7-461 CPU, 3.00 GHz, and an 8.00 GB RAM. The participant's viewed the simulation on was a 25" Samsung monitor. The simulated UAS monitoring consisted of a video file which was created by converting video captured from the Real Flight UAS computer-based simulation software into a

Unity-based software system. This system allowed the videos to become interactive (i.e., allow user input) and record detection measures (i.e., the time the user hit the space bar). The Unity-based system was developed by a senior computer science student at FL Tech. The AGL input was presented on a Vostro laptop with the following specs: Windows 10 Enterprise 64-bit, Intel ® Core™ i7-3632QM CPU, 2.20 GHz, and an 8.00 GB RAM.

Music

A playlist of 9 songs was created on Spotify and played for participants in the music group. The music selected for the study attempted to follow Baldwin & Lewis (2017) criteria for songs which have been found to restore vigilance and lead to positive effects on performance, that is, positive valence slow tempo songs. Valence is defined here as the emotion emitted or perceived by the song. Positive valence was measured using the Watson, Clark, and Tellegen's (1988) Positive and Negative Affect scale. A group of four FLTech students varying in age and gender rated 40 songs for their level affect. Songs which scored in the top quadrant for valence were assessed for slow tempo. Tempo is the speed of the beat, commonly referred to as beats per minute (bpm). A slow tempo song falls in the range of 50-100 beats per minute (bpm). The songs on the playlist were checked through the bpm calculation software, GetSongbpm. Songs which did not fall within the 50 to 100 bpm were removed from the playlist.

Hidalgo Equivital Sensor Belt

The Hidalgo Equivital system sensor belt was utilized to measure heart rate as an indicator of arousal. Three sizes of the belt were utilized: Size 2, (79-84cm), Size 4 (89-94cm), and Size 6 (99-104cm). The belt which fits like a chest strap collects ECG data through sensors and electrodes embedded in the strap. ECG measures electrical activation of the heart. The data picked up by the belt was uploaded to VivoSense™ software (VivoSense, Version 3.1.6316.26848, Vivonoetics) where it was checked for artifacts, cleaned and aggregated.

Figure 4., *Equivital Sensor Belt*

Pilot Study

A pilot study was conducted to test the script, procedure, and instruments. 4 students at FL Tech (2F:2M) were recruited. The study yielded important information relevant to potential study issues, that is, it was found that there was variability across target detection and reaction time, in all targets, between all four participants. In order to investigate this a difficulty scale was added and participants of the pilot study were asked to rate the drones for difficulty. A difference in difficulty was found between targets. Therefore the difficulty scale was added as an instrument to the overall study in hopes this could be taken into accounts during analyses incase it was a confounding variable. Participants rated the difficulty of each target on a 5-point scale (1 = *very easy* and 5 = *very difficult*) after completing the task, to gain quantitative data that would help assess whether there were any effects of difficulty on the dependent variables. Participants were showed the points in the simulation where the drone came into the screen and watched it until it left the screen then asked to rate how difficult it was to detect from very easy to very difficult

Chapter 4 Results

Overview

This section presents the results of the statistical and quantitative analyses performed on the data resulting from the study. The data was entered into the Statistical Package for the Social Sciences (SPSS) (SPSS, Version 25) evaluated for missing data and then evaluated for outliers visually using histograms. Data was collected from twenty-eight students (M:17, F:8), ages 18 – 60 years, at FL Tech. Demographic data related to academics and experience with drones and video games was collected; a breakdown of the demographics can be seen in Table 1. Data from only twenty-five students were utilized in the analyses. Two participants were excluded because they were not able to complete the full simulation due to time constraints. The third participant was excluded because they appeared to have a significantly negative emotional response during the study. This response was recorded in detail during the duration of the study. The faculty advisor and the IRB were made aware of the situation, and the detailed response was reported to the IRB. No other students who participated in the study had this response and it was not deemed to be an adverse effect of their participation in their study, but rather due to a personal issue.

Missing data was an issue during analyses as several participants had missing reaction time data for multiple targets. This is because if a target is not detected, reaction time could not be captured. Due to the large number of participants that this affected, unconditional mean imputation was used (i.e., the missing reaction time data was replaced with the sample mean reaction time for that target, for participants who did not detect a target.

Table 1., *Demographics*

Variable	$M \pm SD$	Number (Percentage)
Age	23.36 ± 8.61	
18 – 21		14 (56%)
21 – 24		6 (24%)
25 +		5 (20%)
Sex		
Female		7 (28%)
Male		18 (72%)
Academic Level	3.52 ± *1.71*	
Freshman		6 (24%)
Sophomore		2 (8%)
Junior		2 (8%)
Senior		3 (12%)
Graduate		12 (48%)
Drone Experience	1.4 ± *.577*	
Never		16 (64%)
Sometimes		8 (32%)
Often		1 (4%)
Video Game Experience	2.12 ± *.927*	
None		1 (4%)
Little		6 (24%)
Moderate		7 (28%)
Significant		11 (44%)

Difficulty

Participant's target difficulty ratings were examined using a 2 x 7 (music presence [non-music, music] x target [1, 2, 3, 4, 5, 6, 7]) repeated-measures ANOVA. Results of repeated-measures revealed a significant main effect of target on difficulty ratings, (F (6, 18) = 21.633, p>.001, partial η^2 = .878. There was no significant main effect of music on difficulty ratings, (F (1, 23) = .041, p>.05, partial η^2 = .054. There was also not a significant interaction between target and music for difficulty ratings, F (6, 18) = 1.367, p>.05, partial η^2 = .313. Mauchley's (.334) was not significant for detection, p = .304 indicating homogeneity of variance. Figure 5. illustrates the difficulty across targets. These results reveal that there was a significant variation in difficulty across targets, and this was consistent across both treatment conditions. As such, the variability in target difficulty per target is a confound. To account for this, the decision was made to focus the repeated measures analyses on the last four targets for two reasons: First, they grouped together based on level of difficulty (i.e., all had target difficulty greater than two and a half. Second, they all took place after approximately 15 minutes, when the vigilance decrement has the potential to commence.

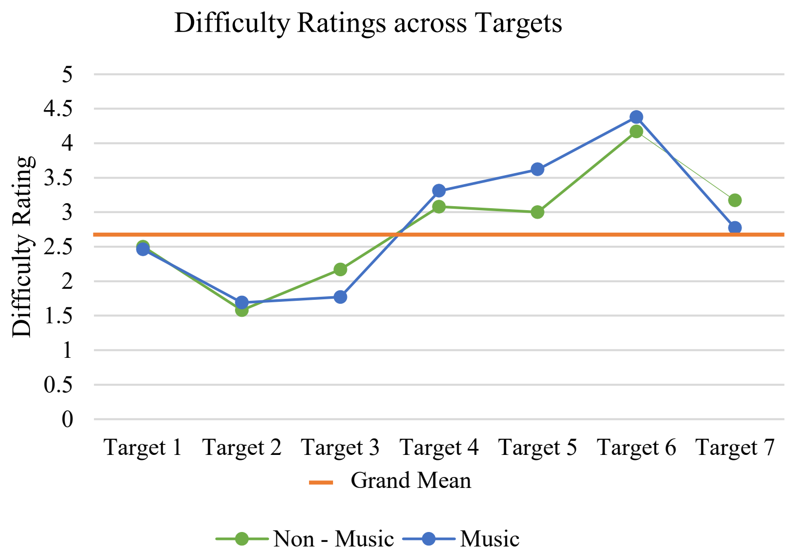

Figure 5., *Difficulty ratings across targets*

Performance

To examine the impact of music on performance across the final four targets a 2 x 4 (music presence [non-music, music] x target [4, 5, 6, 7]) repeated-measures MANOVA was conducted on measures of target detection and reaction time. At the multivariate level, there was not a significant main effect of music presence, $F(2, 22) = 1.276$, $p>.05$, partial $\eta^2 = .104$. However, within subjects, there was a significant main effect of target, $F(2,22) = 41.218$, $p<.001$, partial $\eta^2 = .932$. There was also a significant interaction between music presence and target, $F(2, 22) =$ .2.651, p=.05, partial $\eta^2 = 469$. Univariate results revealed that there was a significant main effect of target on detection, $F\ (1, 23) = 6.526$, $p = .001$, $\eta^2 = {\cdot}221$

and reaction time *F*(1, 23) = 19.288, p<001, $\eta^2 = .456$. There was not a significant effect of music on detection *F(*1, 23) = .270, p > .05, $\eta^2 =.012$ or reaction time, *F(*1, 23) = 2.064, p > .05, $\eta^2 = .082$. There was also not a significant interaction between target and music presence on detection, *F(*1, 23) = 1.543, $\eta^2 =.063$ or reaction time, *F(*1, 23) = .926, $\eta^2 = .039$. Figure 6., illustrates the changes in detection across the last four targets for both groups. Figure 7. illustrates the changes in reaction time across the last four targets for both groups. Mauchly's (6.437) was not significant for detection, p = .226 indicating homogeneity of variance, however, Mauchley's (24.414) was significant for reaction time, p = .000 indicating a violation of sphericity. Given that MANOVA's are robust to this violation when sample sizes are equal, and sample sizes were almost equivalent, a more stringent F-test was used (Pillai's Trace).

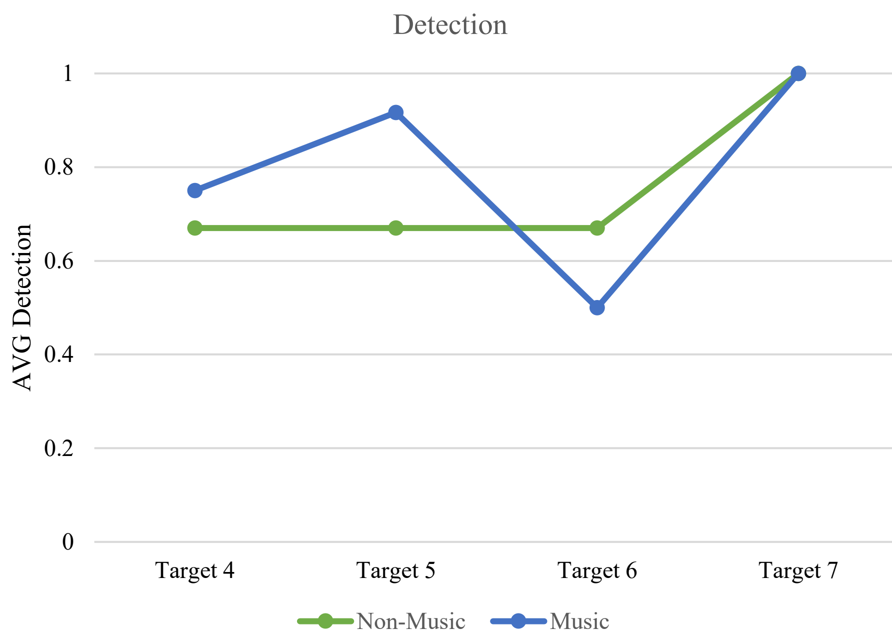

Figure 6. *Detection for the final 4 targets for both groups*

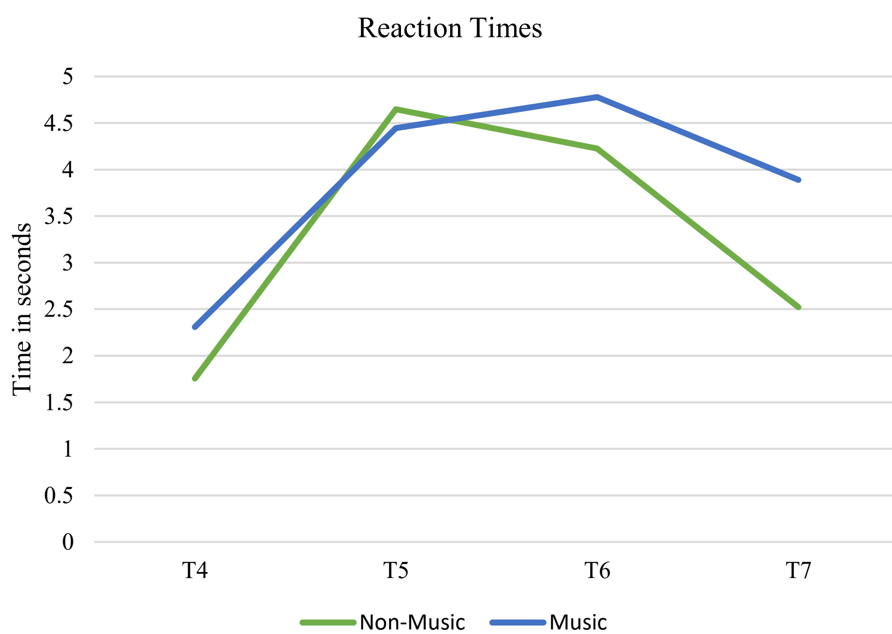

Figure 7. *Detection for the final 4 targets for both groups*

Boredom & Stress

A MANCOVA was performed on two dependent variables assessed after performance of the entire task: state boredom scores, as measured by the MSBS, and stress, as measured through the effort subscale of the NASA-TLX. The independent variable was music presence and boredom proneness was used as a covariate (see Figures 8 and 9). Multivariate analyses revealed that boredom proneness was a significant covariate, F (2, 21) = 14.10, $p < .001$, partial $\eta^2 = .564$, while no significant effect of music presence was found, $F(2, 21) = 1.810$, $p > .05$. Univariate analyses revealed that boredom proneness had a significant effect on state boredom, F (1, 22) = 28.511, $p < .001$, but no significant impact on stress, F (1, 22) = .321, $p > .05$. Box's M (1.70) was not significant, $p > .674$, indicating homogeneity of variance.

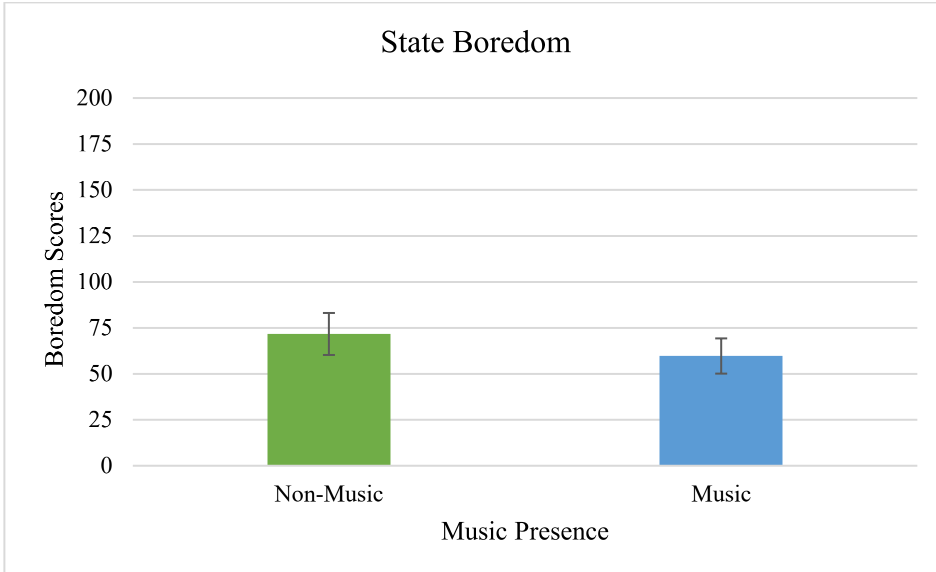

Figure 8., *State Boredom across both IVs*

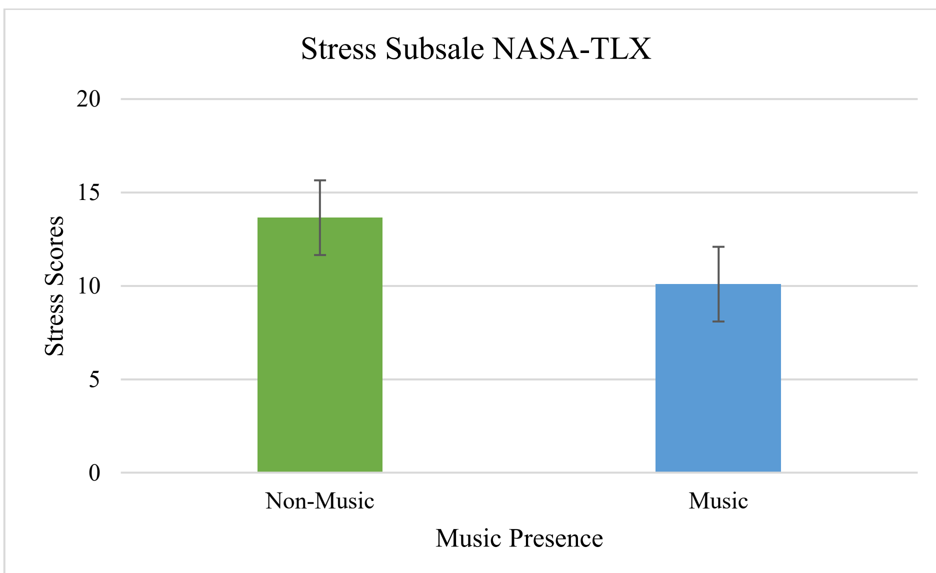

Figure 9., *Stress as measured by the Effort subscale in the NASA-TLX*

Exploratory Analysis

Heart Rate and Music Affect

Heart rate (HR) was explored over time across both groups. The data was first checked for any artifacts against notes collected by the researcher. Using VivoSense (VivoSense, Version 3.1.6316.26848, Vivonoetics), artifacts were removed. The automatic artifact management feature was utilized and compared to proctor notes. HR data was then averaged across three-minute time segments. These time segments allowed the data to be condensed into manageable chunks of data, with only one target maximum per segment (See Figure 10). To reduce noise in the data caused by individual differences in resting HR, the data was then baseline-normalized. Baseline-normalization was achieved by subtracting and then dividing each participant's average HR for time segment by his or her average baseline HR. Both groups experienced a drop in HR over the course of the experiment, followed by a plateau in HR. The non-music group experienced a general decrease in HR until approximately 24 minutes into the task at which point their HR plateaued. The music group only experienced a general decrease in HR until approximately 18-minutes when their HR plateaued.

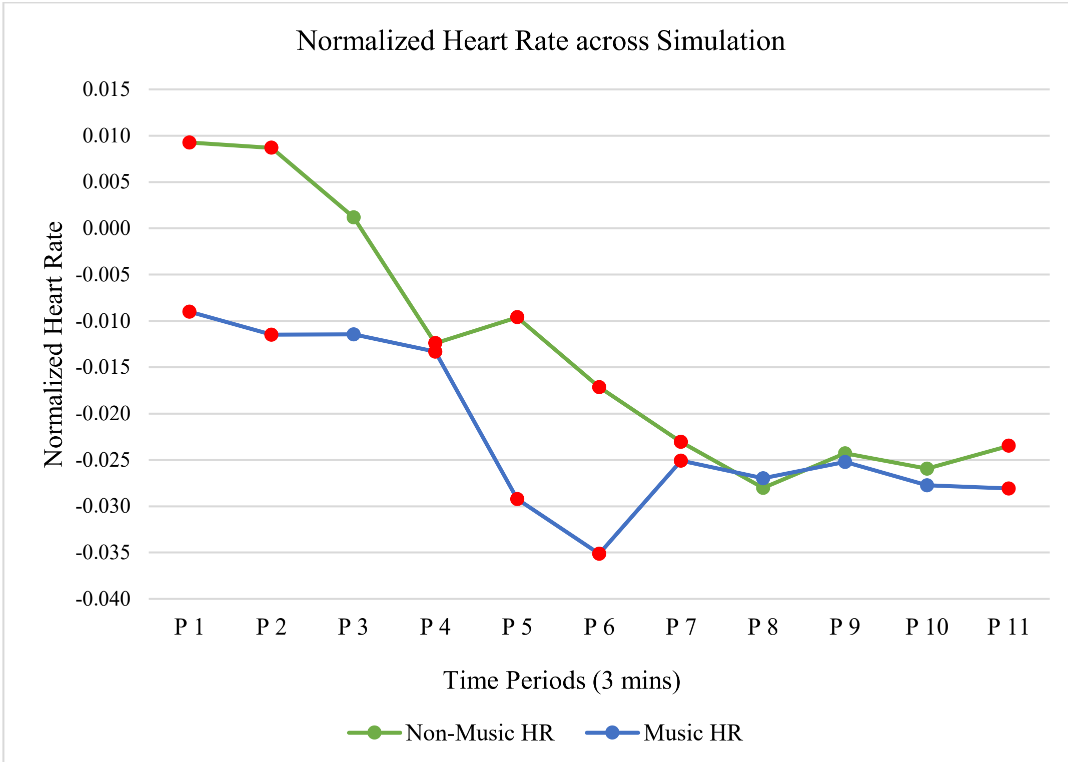

Figure 10., *Normalized HR across three minute periods; red circles indicate points in time when targets were present*.

The music group's normalized HR was presented alongside the positive affect scores of the students who validated the song playlist to look for similar trends across the simulation (See Figure 11). When looking at the data it stays consistent until the third target (i.e., P4 and 12 minutes) where a drop is seen in both until around the fifth target (i.e., P6 18 mins) where they both seem to level out and stay consistent again.

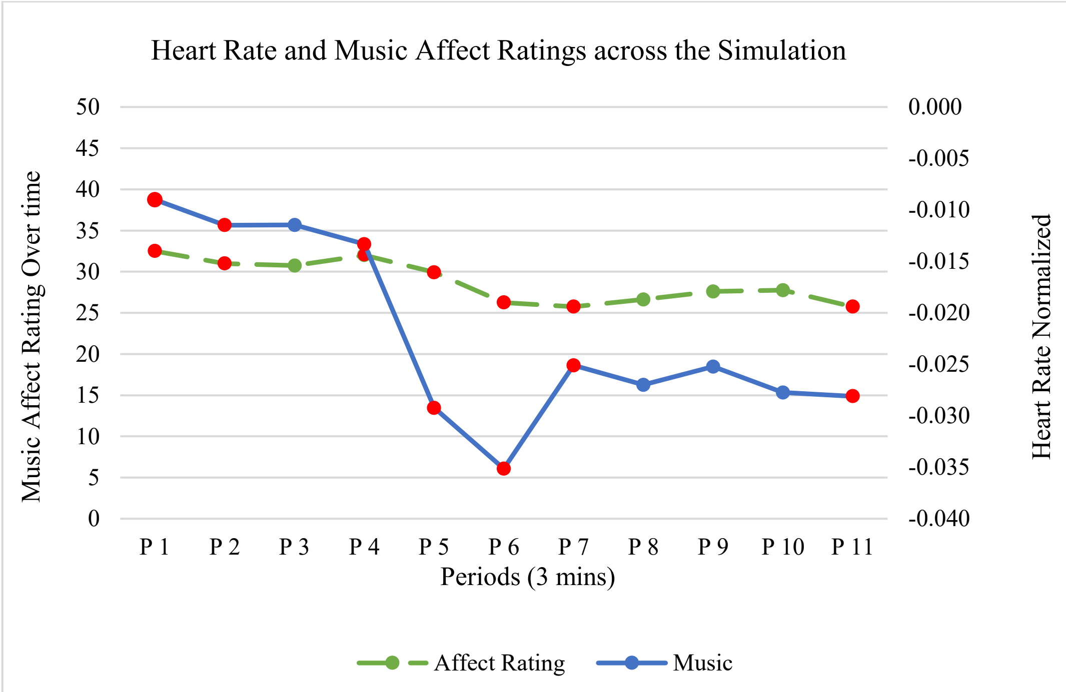

Figure 11., *Music Affect scores from the validation for the playlist and Normalized HR for the participants in the music condition across the 3 minute periods*

Chapter 5 Conclusion

Discussion

The purpose of this study was to find out whether music could alleviate the vigilance decrement in a simulated UAS task. The vigilance decrement is characterized by an increase in reaction time, over time, and a decrease in detection (Helton & Russell, 2015; See et al., 1995; Davies & Parasuraman, 1982). These two factors were divided into two hypotheses as previous studies utilizing vigilance tasks have found that one factor may be alleviated while the other is not (Helton & Russell, 2015; Taylor et al., 2013). Hypothesis 1 was not supported, as no significant difference in reaction time between groups was found due to the presence of music. In terms of the trend of reaction time over the 7 targets, both groups had a pattern of increased reaction time followed by decreased reaction time which repeated as the task time elapsed. The absence of a decrease in reaction time for the music condition when compared to the non-music may have been due to the inclusion of music. Music can yield a certain level of distraction (Mori et al., 2014) which can lead to increased reaction times, specifically in high arousal music (Dalton & Behm, 2007). From target 4 to target 5 there is a dip in HR and increase in RT which does not point to arousal (See figure 11). The dip may be due to boredom or the slight increase in difficulty. From target 5 to 6 there is another increase in both HR and RT, this is likely due to the significant increase in difficulty level of target 6. From target 6 to 7 reaction time decreases and HR plateaus, also likely due to an associated decrease in difficulty level. Due to the similarity in the reaction time trends for both the music and non-music groups, it appears that the addition of music was not strong enough to counteract the variable creating the fluctuations in reaction time.

Hypothesis 2 was not supported, no significant difference in target detection between both groups was found in the analyses. When looking at detection in the last four targets for the music group, we again see variability across targets. The music group seems to have a higher detection trend until the sixth target where there is a decrease in detection (see figure 6). It is not clear why there is such a decrease in detection for the music group, but a possible reason is that they were distracted by the music which impacted performance on the most difficult target. When looking at the normalized HR around this period (See figure 11, P6 to P7), there is an increase in HR occurring until Target 6 is presented. The song being played before Target 6 may have been too arousing to the point of distraction. Previous studies have found that music can lead to distraction in vigilance scenario such as driving (Dalton & Behm, 2007; Beh & Helen, 1999; North & Hargreaves, 1999;). North & Hargreaves (1999) study found that music which was high in arousal can compete with cognitive processing space and in turn lead to performance decrements. When looking at detection and the music x target interaction, music may be affecting detection differently at different levels of difficulty. Music may aide in detection as long as difficulty is not too high, at which point it becomes a distraction. Both groups had perfect detection for the final target. The trend for the participants in the non-music group seemed to stay constant until the final target. The perfect detection (*M*=1.0) of the final target points to the presence of a ceiling effect. However, the average rating did not fall under "very easy", another potential reason is knowledge of the study coming to an end leading to an increase in arousal. Malhotra (2009) found that when a challenge is nearing its end participant's arousal levels sometimes increase as they attempt to finish strong. The detection and reaction time results do not make it clear as to whether the study was successful in creating a vigilance decrement.

A potential reason that a vigilance decrement was not seen is the increase in difficulty across targets. Due to time parameters, when the inconsistency in difficulty was discovered it was too late to change. Target difficulty for the simulated vigilance task should have been equivalent across targets to facilitate the identification of the treatment effect (Daly et al., 2017). When looking at the difficulty ratings across targets this is not the case. The increase in difficulty in the last 15-minutes (i.e., target 4 and on) may have prevented a vigilance decrement altogether. Difficulty has been found to lead to stimulation (Manly et al., 1999, Robertson, Manly, Andrade, Baddeley, and Yiend, 1997). A study by Thomson et al., (2015) found that varying task difficulty can alleviate performance degradation in the vigilance task. Furthermore, the simulation may have not been long enough to create a vigilance decrement (Cummings et al., 2017; Davies & Parasuraman, 1982), other simulated UAS tasks measuring the effects of performance are longer (Cummings et al., 2013; Daly et al., 2017). However, another possibility is rather than it simply being the addition of difficulty, the significant variation in difficulty may have washed out any treatment effects.

Additionally, hypothesis 3 and 4 were not supported as both boredom and stress levels were not significantly different between conditions. There are several reasons differences in boredom between the music and non-music conditions may not have occurred. First, the task may not have induced boredom therefore not presenting any boredom for music to alleviate. The videogame-like atmosphere of the game may have been too engaging for the participant. Further, the novelty of the task may have been enough to keep both groups less bored than normal and it may be a reason for a somewhat similar pattern between groups (Cummings et al., 2017; Thomson, Smilek, & Besner 2015; Pop, Stearman, Kazi, & Durso, 2012; Scerbo, 1998). Second, difficulty may have impacted boredom as difficulty may have led to arousal and engagement which could have reduced the potential for boredom (Thomson et al., 2015; Pop et al., 2012). Additionally, the organization of the songs in the playlist may have created another confound. Rather than a playlist which incorporated constant or even consistent variability in music affect, as the songs progressed over the course of the vigilance task, the music affect scores decreased over time. Studies have found that negative affect can negatively impact performance (Baldwin & Lewis, 2017; Mori, Nghsh, & Tezuka, 2014). Interestingly, there seemed to be a slightly lower trend in boredom for the music group than the non-music group. When looking at figure 10., the music group's HR starts lower than the non-music, they also do not have as strong as a decrease over time. This trend could potentially be due to music, that is, music may aid in keeping arousal levels low. This has been found in other studies such as, Brown (1965) who found music lowered emotional arousal under frustrating circumstances of driving in heavy traffic. These lower arousal levels could be due to the distraction or relaxation caused by music (Dalton & Behm, 2007). When examining the trend in Figure 11., it is interesting that the biggest decrease in HR occurs around the 12-minute mark as does the biggest decrease in music affect; at the 18-minute mark both measures appear to begin rising again. Unfortunately, the inability to stop the simulation between songs due to it potentially influencing the onset of the vigilance decrement led to less data on participant's feelings of individual songs. More information on the evoked feelings of each song would have allowed us to see if maybe the song was too distracting and led to a decrease in performance or whether it was due to boredom or not liking the song playing. In order to see the change in affect over the course of the simulation, the scores of the students used to validate the playlist and rated each song, were averaged and utilized as affect scores.

Limitations

The study faced a large limitation in terms of participants. More participants were needed, however, aspects such as study length led to a difficulty in both getting participants and keeping them. The study was limited to FL Tech students and utilized convenience sampling which further limited the number of participants. In the future finding a more enticing method to incentivize participants should be utilized. Furthermore, trying to find a list of songs that all participants would enjoy was difficult. If there had been more time, making playlists by genre and allowing participants to choose a genre may have led to a more effective IV. Arousal has been linked to musical preferences and preferential music has been found to increase arousal (de Jong, Van Mourik, & Schellekens, 1973; Hirokawa, 2004; Schafer & Sedlmeier, 2011; Navarro, Osiurak, Reyanud, 2018). A few participants made comments about liking most of the songs but genuinely disliking one or two. Disliking the song can have a negative impact on performance (Baldwin & Lewis, 2017; Mori et al., 2014). Further, if possible, elongating the study to include measures which would aid in further supporting and refuting findings, such as adding a scale asking students how fatigued they were before and after the test as fatigue has been found to both accompany and be an indicator of boredom (Cummings, 2016; Hill & Perkins, 1985). Furthermore, individual differences may be an outlet to explore. For instance, we could collect information related to whether the individual listens to music when they work and then group them evenly in both groups (i.e., music and non-music) based on this variable. This would allow us to see how music affects people who do not listen to it normally when completing a task, and those who do, to see if there are differences between preferences.

Conclusion

This study aimed to address whether music could be a viable mitigation technique to prevent the vigilance decrement. Issues in managing difficulty, creating an appropriate playlist, and gathering a sufficient amount of participants led to an inability of the study to ensure a vigilance decrement was induced, and as such, the results do not provide support for music as a vigilance decrement mitigation technique. Regardless, this study is a step in the right direction in terms of understanding the steps, issues, and parameters for creating a task which is more comparable to the modern day vigilance task. Furthermore, this study has clarified some of the hurdles for creating a potential aide through music to reduce the effects of the vigilance decrement.

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Appendix A – Instruction Script & Sheet

Script

Hello and thank you for coming in today and participating in this study. Before we begin, I would like to give you a brief overview of what you will be doing. Today you will be asked to complete a monitoring task where you will scan the screen for a drone and report certain changes in its altitude*. You will fill out a series of questionnaires before and after completing the task while wearing sensors.

**If the participant is in the music condition the following will be included:*

while listening to background music

You will be wearing an Equivital Sensor belt (hold up belt). It is a chest strap with embedded sensors and electrodes that collects cardiovascular response, sweat response, and skin temperature. If you could go into the restroom and put the strap on under your shirt before we proceed. Make sure the vest fits snuggly on top of you skin **(**Show them how to put the Equivital on). Feel free to use the restroom at this time as well.

(Once the participant comes back into the room)

Please check to make sure neither the chest band or shoulder strap are twisted? Is the Equivital loose or snug on your skin? Is the band off center? Thank you for taking the time to check. Now if you could please fill out some questionnaires, which include demographic information and trait questions.

(The participant will be directed to a seat so that they can take the pre-survey).

(Once they have indicated they have finished)

Now, I would like you to sit and relax, you may read or get on your phone, so that I may record a baseline of your physiological response.

(after 5 mins have passed)

Now you will complete the monitoring task. The military has lost control of one of its covert drones in an area which has not been secured. Notify your squadron commander by selecting the space bar when the drone comes into sight. Watch your aircraft's altitude, if you fly above 100 AGL, make note of it on the sheet provided.

Before we begin, I would like to show you an example of what you will be scanning the screen for.

(present image of drone and HUD on paper)

To reiterate your task will be to hit the space bar when this drone (point to drone) comes onto the screen, furthermore, you will be monitoring the altitude, which is displayed on the right side of the HUD (point to the AGL information). Any time the drone dips from above 100 to below 100 AGL, make a note of it on the paper provided. All that is needed is a simple tally. Do you have any questions?

(Begin simulation)

Now I will have you fill out the final questionnaires. Please answer the questions with respect to the simulated activity you just completed. It should take about 10 minutes. Please let me know when you have completed the survey. If you have any questions, feel free to ask.

Thank you for participating in the study. If you know any other individuals participating please do not share the study with them, as conditions may be different per person. You will be entered to win a $100 gift card for participation in today's study. The winner will be picked at the end of the study. At this time can you can go to the restroom and remove the sensors.

Appendix B - Demographics Survey

Please fill out the following questions:

Age: _______________

Sex

Male Female

Have you ever flown an RC Aircraft and/or Unmanned Aerial System (UAS)?

Never Sometimes (1-3 times a year) Often (monthly)

What is your academic level?

Freshman Sophomore Junior Senior Graduate Student

What level of experience do you have with playing video games?

No experience Little experience Moderate experience Significant experience

Please circle any of the below items that you are using during this study:

Eyeglasses Contacts No Vision Correction

College Major

Aeronautics Business Engineering Psychology & Liberal Arts Science None

Appendix C – Short Boredom Proneness Scale

	Never	Moderately Untrue	Neither True nor Untrue	Moderately True	Very Often
I often find myself at "loose ends", not knowing what to do.	○	○	○	○	○
I find it hard to entertain myself.	○	○	○	○	○
Many things I have to do are repetitive and monotonous.	○	○	○	○	○
It takes more stimulation to get me going than most people.	○	○	○	○	○
I don't feel motivated by most things that I do.	○	○	○	○	○
In most situations, it is hard for me to find something to do or see to keep me interested.	○	○	○	○	○
Much of the time, I just sit around doing nothing.	○	○	○	○	○
Unless I am doing something exciting, even dangerous, I feel half-dead and dull.	○	○	○	○	○

Appendix – D Multidimensional State Boredom Scale (MSBS)

Instructions. Please respond to each question indicating how you feel right now about yourself and your life, even if it is different from how you usually feel. Use the following:

	Strongly Disagree			Neutral			Strongly Agree
1. Time is passing slower than usual.	○	○	○	○	○	○	○
2. I am stuck in a situation that I feel is irrelevant.	○	○	○	○	○	○	○
3. I am easily distracted.	○	○	○	○	○	○	○
4. I am lonely.	○	○	○	○	○	○	○
5. Everything seems to be irritating me right now.	○	○	○	○	○	○	○
6. I wish time would go by faster.	○	○	○	○	○	○	○
7. Everything seems repetitive and routine to me.	○	○	○	○	○	○	○
8. I feel down.	○	○	○	○	○	○	○
9. I seem to be forced to do things that have no value to me.	○	○	○	○	○	○	○
10. I feel bored.	○	○	○	○	○	○	○
11. Time is dragging on.	○	○	○	○	○	○	○
12. I am more moody than usual.	○	○	○	○	○	○	○
13. I am indecisive or unsure of what to do next.	○	○	○	○	○	○	○
14. I feel agitated.	○	○	○	○	○	○	○
15. I feel empty.	○	○	○	○	○	○	○
16. It is difficult to focus my attention.	○	○	○	○	○	○	○

17. I want to do something fun, but nothing appeals to me.	○	○	○	○	○	○	○
18. Time is moving very slowly	○	○	○	○	○	○	○
19. I wish I was doing something more exciting.	○	○	○	○	○	○	○
20. My attention span is shorter than usual.	○	○	○	○	○	○	○
21. I am impatient right now.	○	○	○	○	○	○	○
22. I am wasting time that would be better spent on something else.	○	○	○	○	○	○	○
23. My mind is wandering.	○	○	○	○	○	○	○
24. I want something to happen but I am not sure what.	○	○	○	○	○	○	○
25. I feel cut off from the rest of the world.	○	○	○	○	○	○	○
26. I didn't really have a choice about doing this Right now it seems like time is passing slowly.	○	○	○	○	○	○	○
27. I am annoyed with the people around me.	○	○	○	○	○	○	○
28. I feel like I am sitting around waiting for something to happen.	○	○	○	○	○	○	○
29. It feels like there is none around for me to talk to.	○	○	○	○	○	○	○

Scoring

MSBS Total Score: sum of all 29 items; 1 = Strongly disagree…. 7 = Strongly Agree

Disengagement subscale: Items 2, 7, 9, 10, 13, 17, 19, 22, 24, 28

High Arousal subscale: Items 5, 12, 14, 21, 27

Inattention subscale: Items 3, 16, 20, 23

Low Arousal subscale: Items 4, 8, 15, 25, 29

Time Perception subscale: Items 1, 6, 11, 18, 26