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BEYOND COMPLIANCE: EXAMINING THE ROLE OF MOTIVATION IN VIGILANCE PERFORMANCE

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Psychology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

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ABSTRACT

Vigilance, or sustained attention, is the capacity to attend to information for a prolonged period of time (Davies & Parasuraman, 1982; Jerison, 1970; Warm, 1977). Due to limitations of the human nervous system, as well as the environmental context, attention can begin to wane over time. This results in a phenomenon referred to as the vigilance decrement, or a decline in vigilance performance as a function of time. The vigilance decrement can manifest as poorer attention and is thusly associated with poor performance, which is defined behaviorally as more lapses in the detection of critical signals and an increase in response time to these signals during watch. Given this, the present dissertation seeks to systematically examine the impact of two types of motivation (i.e., achievement motivation, autonomous motivation) on vigilance performance across four experiments. The present experiments manipulate information processing type, source complexity, and motivational task demands. Three hundred and ninety-eight participants completed either a cognitive task or sensory task, which were psychophysically equated in previous studies (Szalma & Teo, 2012; Teo, Szalma, & Schmidt, 2011), with or without motivational instructions, and with either low, medium, or high source complexity. Performance measures, perceived stress and workload, and changes to state motivation and engagement at pre-task and post-task are interpreted across three theories of information processing: resource-depletion theory, mind-wandering theory, and mindlessness theory. The results of each of the four studies are discussed in terms of overall support for the resource-depletionist account. The limitations of the present set of experiments and the future directions for research on motivation and sustained attention are also discussed.

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CHAPTER ONE: INTRODUCTION

Motivation is an important, but often neglected, factor in human-technology interaction (Szalma, 2009, 2014). It is particularly important in the context of monitoring tasks, which are associated with performance decrements and are often unpleasant experiences for the human operator (Hancock, 2013; Warm, Parasuraman, & Matthews, 2008). Early research at the intersection of motivation (Lucaccini, Freedy, & Lyman, 1968; Montague & Webber, 1965) and vigilance is being reexamined for several reasons. First and foremost, initial studies of vigilance did not examine the role of motivation on perceived stress and workload scores, which are integral to the perception of monotony or boredom associated with vigilance tasks. Second, the effects of state motivation and trait motivation have not been examined together as factors that may covary with vigilance performance, perceived stress, or perceived workload. However, recent pilot work has suggested that both state and trait motivation may be important in vigilance performance (Dewar, Fraulini, Claypoole, & Szalma, 2016) and perceptions of stress and workload that are associated with the vigilance task (Dewar & Szalma, 2016). Furthermore, in early research, motivation tended to be *presumed*, rather than *measured* (Karwowski & Cuevas, 2003), which is problematic given that motivation toward vigilance tasks is not a stable trait across individuals (Fishbein et al., 2006). This trend is not unique as there is a “tradition” of attributing performance, stress, and workload to external factors in the environment, rather than internal individual difference factors (Matthews, 2016, pg. 801).

The presumption of a motivated operator dates to the origins of vigilance research. Mackworth (1948, 1950) assumed his participants were highly skilled and motivated observers. These assumptions could very well be correct, given Mackworth’s samples consisted of Royal Air Force operators who monitored radar that aided in threat detection (albeit with limited success) in World War II. The importance of the Clock Test was clearly conveyed to Mackworth's participants, but performance on the task still continued to decline despite assumed motivation. The current set of four studies seeks to rectify this performance discrepancy by measuring achievement and autonomous motivation across several types of tasks.

The present research for this dissertation is seeks to address the gap in the literature on motivation and vigilances. As well, the effects of individual differences in trait and state motivation on vigilance performance have not been reexamined for nearly fifty years (Lucaccini et al., 1968; Montague & Webber, 1965; for exceptions see Bonnefond, Doignon-Camus, Hoeft, & Dufour, 2011; Slade & Rush, 1991). Therefore, in four following experiments motivation effects are examined as both an important individual trait (i.e., achievement motivation) or state (i.e., autonomous motivation) that impacts performance, perceived engagement, perceived stress, and perceived workload in various vigilance paradigms, as well as an instruction manipulation that can effect task perception. The present dissertation seeks to apply recent research on autonomous motivation (a facet of intrinsic motivation) and achievement motivation (a desire to perform successfully) to the study of vigilance given the myriad of benefits associated with each of these types of motivation.

First, a review of the literatures on vigilance and motivation is presented. Following this, the present plan of study for this dissertation is outlined across four experiments. Reports of task engagement and task motivation, perceived stress and perceived workload, and performance outcomes are interpreted across three theories of information processing: resource-depletion theory, mind-wandering theory, and mindlessness theory. Finally, the discussion concludes with future directions for work at the conjuncture of motivation and vigilance.

CHAPTER TWO: VIGILANCE

Vigilance, or the ability to sustain attention over a period of time, is crucial to human performance, particularly in monotonous contexts. For instance, students are required to direct attention toward lengthy lectures and Soldiers toward long-duration reconnaissance missions. Furthermore, whole occupations (i.e., airport baggage screeners, loss prevention specialists, nuclear power plant operators, etc.) are dedicated to the ability of an observer to remain attentive to threats over time.

When a threat goes undetected, the cost of such an error can be enormous. Lapses in the detection of threats can result in financial losses (Williams, 2005), nuclear meltdowns (Casey, 2006; Reinerman-Jones, Matthews, & Mercado, 2016), medical complications (Scott, Rogers, Hwang, & Zhang, 2006; Wakefield, 2000), breaches of homeland security (Hancock & Hart, 2002; Meuter & Lacherez, 2016), unsuccessful military operations (McBride, Merullo, Johnson, Banderet, & Robinson, 2007), and, most unfortunately, in the loss of life or widespread destruction (Casey, 2006). Such threats have a very low probability of occurring and are extremely infrequent, which makes their likelihood and expectancy rare (Davies & Parasuraman, 1982; Warm & Jerison, 1984). The rarity of potential threats results in more inattention to these potential threats over time (c.f., Hancock, 2013; Loeb, Noonan, Ash, & Holding, 1988; Parasuraman, 2011; Sprauge, 1981; Tomporowski & Tinsley, 1996) and manifests behaviorally as poorer performance, especially in visual search (Hout, Walenchok, Goldinger, & Wolfe, 2015).

The decline in human performance in vigilance tasks over time is colloquially referred to as the “vigilance decrement” (Davies & Parasuraman, 1982; Jerison, 1970; See, Howe, Warm, & Dember, 1995; Warm, 1977). The vigilance decrement is commonly associated with increases in self-report measures of stress and workload (Dillard, Warm, Funke, Vidulich, Nelson, Eggemeier, & Funke, 2013; Warm, Dember, & Hancock, 1996; Warm, Matthews, & Finomore, 2008), as well as many other adverse psychological outcomes (e.g., boredom; Scerbo, 2011).

Understanding the Vigilance Decrement

During World War II, Mackworth's (1948, 1950) seminal research on the vigilance decrement indicated that Royal Air Force radar operators exhibited poorer performance as time on task increased. In this study, the radar operators were asked to monitor and detect small jumps in the hands of a clock (see Figure 1). Mackworth found that it became more and more difficult to detect the jumps in the hands of the clock with the passing of time on task. His results have been replicated in thousands of vigilance studies in the following 68 years. The decrement has become a hallmark associated with vigilance research, though it should be noted that a vigilance decrement is not always observed in traditional tests of vigilance.

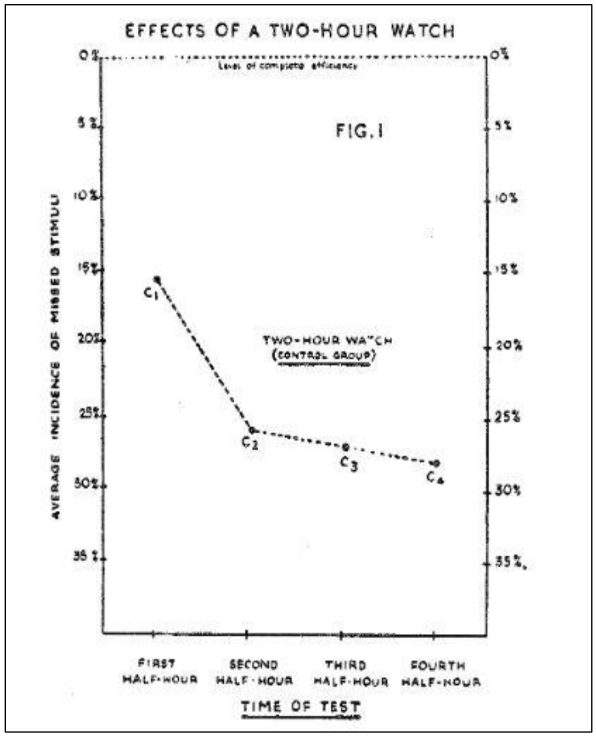


Figure 1. The vigilance decrement as first observed by Mackworth (1948, 1950) demonstrates the decline in performance as a function of time on task.

Some researchers argue that the vigilance decrement is iatrogenically created by the researcher (Hancock, 2013; Hancock, Volante, & Szalma, 2016). This implies that the perception of boredom and monotony reported by numerous observers and participants is induced by the design of the task. This is particularly true in the cases of fuzzy signal detection and tasks involving low probability of threat or target stimulus presentation (i.e., baggage screening, x-ray examination, etc.). When the task is designed in a way in which is perhaps motivating or helpful to the observer (i.e., visual cues or alerts to threatening stimuli), the vigilance decrement is almost entirely eradicated (Hancock et al., 2016). To overcome the vigilance decrement, it is argued that the task can be designed to support the limitations of human attention and bolster individual differences, which assist in vigilant attention (Hancock et al., 2016). The present dissertation will seek to extend support for this theoretical assumption by systematically manipulating task complexity, task instructions, and task type. This will demonstrate the extent to which the vigilance decrement is an iatrogenically created psychological phenomenon.

Theoretical Explanations for the Vigilance Decrement

While task design can determine whether or not the vigilance decrement is observed, there are several theoretical debates over the state of the mind during vigilance performance. For example, early explanations of the vigilance decrement suggested that performance declined as a function of reactive inhibition (Hull, 1943) or arousal (Hebb, 1955; Yerkes & Dodson, 1908). Drive and arousal theorists suggested the monotonous nature of vigilance tasks lowered activity in the brainstem and thalamic projections (Loeb & Alluisi, 1984; Welford, 1968), which reduced the ability to remain vigilant to threats over time. While drive and arousal theories accounted for the vigilance decrement, these theories could not explain the subsequent increases in subjective stress and workload post-task.

In an effort to explain the changes in subjective ratings of stress and workload was resource theory (Hirst & Kalmar, 1987; Kahneman, 1973; Moray, 1967; Navon & Gopher, 1979; Wickens, 1984). And in more recent years, two new information processing theories have emerged to explain the vigilance decrement because of some of the pitfalls associated with the resource account. These theories are outlined below and an overview is provided in Table 1. Interestingly, there is little integration between resource theory, mindlessness theory, and mind-wandering theory. Rather than theoretical coalescence, these theories tend to operate in isolation, oft ignoring seminal research studies related to sustained attention (for more on this see Fraulini, Hancock, Neigel, Claypoole, & Szalma, 2017). This tends to leave participants keen on research involving vigilance intrigued, but confused (as described in a later part of this chapter). Understanding the differing perspectives on task engagement is crucial to both the present dissertation and broader scientific understanding of motivation's relationship with vigilance.

Table 1. The table below lists important distinctions between each theory of information processing in relation to vigilance.

	Information Processing Required	**Cause of the Vigilance Decrement**	**Use of Task Engagement to offset the Decrement**
Resource Theory	Overload	Resource depletion	Cognitive and/or behavioral engagement
Mindlessness Theory	Underload	Task monotony	Not described
Mind-wandering Theory	Underload	Task monotony in conjunction with intentional or unintentional mind-wandering	Behavioral engagement

Resource Theory as a Means of Explaining the Vigilance Decrement

Resource theory has arguably been the reigning account of the vigilance decrement, particularly since the decline of unitary arousal theory (Hancock & Warm, 1989). Resource theory suggests that declines in performance stem from overload of information processing capacities induced by either the task environment. Resource theory relies on the assumption that individuals are capacity-limited, meaning only so much information can be processed at a given time (Wickens, 1984). Research suggests that such capacity limitations result from the depletion of "resources" as time on task and task demands increase. This assumption implies that resource depletion can be either task-induced (i.e., high demand, high task complexity) or state-induced (i.e., high stress, high fatigue) (Caggiano & Parasuraman, 2004).

Traditionally, resources have been defined as pools of energy (or cognitive capacity; Moray, 1967) that can be both drained or restored (Hirst & Kalmar, 1987). Resources have been described either as a general underlying attentional process (Kahneman, 1973) or as separate task-specific capacities (Wickens, 1984, 2002). The latter is referred to as multiple-resource theory, which delineates between the types information processing resources associated with task specificity (i.e., auditory tasks, visual tasks, etc.). However, some researchers oppose multiple resource theory and propose that only two types of resources are involved in vigilance tasks. One type of resource is involved in sustained information transfer (i.e., long-term memory transfer) and the other is involved in short-term memory processing (Humphreys & Revelle, 1984).

To summarize, resource theorists tend to argue that cognitive resources underpin the ability to efficiently attend to and process information over time. Resource theory also assumes that if individuals are overstimulated or overloaded, fewer resources are available for information processing and the quality of performance subsequently declines. In more demanding attention tasks, a greater decrement will be observed because more resources are depleted with time on task (Parasuraman, Warm, & Dember, 1987).

Importantly, resource theory is not without its limitations and has garnered several criticisms. First, the logic of resource theory is circular: performance declines because of resource overload, and when resources are overtaxed, performance subsequently declines (Navon, 1984; Szalma & Matthews, 2015, pg. 221). Furthermore, it is difficult to pinpoint where, exactly, resources are located in the brain and what a resource may consist of physiologically. But, it is worth noting that the neurological phenomena associated with resources and information processing is currently under investigation (Langner & Eickhoff, 2013; Matthews, Warm, Reinerman-Jones, Langheim, Washburn, & Tripp, 2010b; Reinerman-Jones, Matthews, Langheim, & Warm, 2011). It is also difficult to physiologically discern between the resources that are dedicated to specific processing or unitary processing, or if these resources are paradoxically both (Hancock & Szalma, 2003, 2008; Szalma, Hancock, & Hancock, 2012).

For these reasons, resource theory is extremely difficult to falsify (Popper, 1959). However, due to emerging physiological evidence (e.g., cerebral blood flow velocity) and other imaging techniques (e.g., fMRI, transcranial Doppler ultrasonography), advocates of resource theory are much closer to understanding how and where resources may reside in the brain based on converging evidence (i.e., subjective individual ratings of stress and workload, objective performance measures, and psychophysiological indicators).

The Mindlessness Explanation of the Vigilance Decrement

Despite the decline of drive and arousal theories, reincarnations of these theories have recently surfaced (see Fraulini et al., 2017). Under these new accounts of information processing, it is suggested that vigilance arises from underload or understimulation, which manifests as mindlessness (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) or mind-wandering (Smallwood, 2013; Smallwood & Schooler, 2006).

The mindlessness account of vigilance assumes that the task induces understimulation through monotony (Manly et al., 1999; Robertson et al., 1997), which produces the vigilance decrement. The rarity of threats and the monotony of the task environment lead to increases in boredom and fatigue as time on task increases. Furthermore, the monotonous task environment results in inattentive responding and the detection of fewer threats over time (Robertson et al. 1997). Mindlessness theory posits that the mind inactively processes information for a period of time, which causes lapses in attention and threats to potentially go undetected. This idea very much parallels the theory of automaticity, which argues that behavioral responses to cognitive tasks become thoughtless over time and with repetition, thus leading to performance errors when the environment or scenario becomes novel (Logan, 1980, 1992).

Researchers in support of mindlessness theory suggest that simple tasks, compared to complex or demanding tasks, will be more likely to facilitate the onset of the vigilance decrement. From this perspective, the task structure of simple tasks is boring, thus mindlessness quickly sets in, and performance on the vigilance task declines. According to the mindlessness assumption, if vigilance tasks were designed to be more behaviorally engaging, performance would not decrease as a function of time. Additionally, there would be less mental demand or workload associated with the task. If the task is engaging, the individual is less likely to perform mindlessly or thoughtlessly.

While the mindlessness theory of vigilance accounts for fatigue and performance declines, it is not without its limitations. The mindlessness explanation has been criticized for its inability to explain the high demand and stress reported by individuals post-task. Individuals should not report high stress and workload when engaged in a ‘mindless’ activity, since cognition is limited when the mind is thoughtless or blank. Moreover, a number of vigilance studies have indicated that attention does not merely ‘slip away over time,’ as mindlessness theory seems to suggest (Thomson et al., 2015). In the same vein, another issue with mindlessness theory is that it does not describe the underlying attentional mechanisms associated with mindlessness or the recovery of attention (Pashler, 1998). For instance, it is unclear whether mindlessness occurs because of a lack of available resources, or whether mindlessness is induced because of a habituation or automatic responding (Logan, 1980, 1992; Pashler, 1998). Moreover, mindlessness theorists do not discuss what happens to the mind when ‘attention drifts away’ (Thomson et al., 2015, pg. 82), or the mechanisms by which attention toward the task is recovered.

Another limitation of mindlessness theory is that it cannot explain the performance increment, which is an improvement in performance as a function of time on task (Hancock, 2013). These theorists could possibly argue that the task is not a vigilance task if it does not induce mindlessness, but that seems counterproductive, especially if it is a traditional vigilance task known to induce the decrement in some individuals. In the same vein, mindlessness theory cannot explain the performance of Parasuraman’s (2011) “cognitive superstars.” The monotony associated with the vigilance task should afford thoughtlessness, which results in poor performance, not superb performance.

The Mind-Wandering Account of the Vigilance Decrement

The theory of mind-wandering was developed to overcome some of the issues with mindlessness theory. For example, mind-wandering theory attempts to explain what happens to the mind when it disengages from the task and how engagement with the task is potentially recovered. Champions of mind-wandering theory suggest that attention becomes directed inward and away from the vigilance task (Smallwood & Schooler, 2006; Thomson et al., 2015). Inward reflection results in more self-related thoughts or thoughts about task-related performance (Thomson et al., 2015). According to mind-wandering theory attention can also be directed outwards and away from the vigilance task (Thomson et al., 2015). Behaviorally, this shift in attention is exemplified by an increase in thoughts related to daydreaming (Thomson et al., 2015), or task-unrelated thoughts (TUTs; Kluger & DeNisi, 1996; Matthews et al., 2002). Because attentional resources that could be directed toward the vigilance task are instead directed inward or outward, performance declines due to an attentional shift (Smallwood, 2010).

Mind-wandering theory also distinguishes between two overarching types of mind-wandering: intentional and unintentional (Seli, Risko, & Smilek, 2016a,b). Intentional mind-wandering occurs when an individual makes an intentional, conscious choice to abandon focus on the task at hand (Seli et al., 2016b). This is also referred to as deliberate mind-wandering (Seli et al., 2016a,b). Conversely, unintentional mind-wandering occurs when the individual does not deliberately intend to disengage attention from the task, rather attention from the task has merely slips away because the participant loses focus or spontaneously begins to daydream (Seli et al., 2016a,b; Seli, Wammes, Risko, & Smilek, 2015). This is also referred to as spontaneous mind-wandering (Seli et al., 2016a,b).

Like mindlessness theory, mind-wandering theorists propose that vigilance tasks are inherently monotonous and induce underarousal because of the repetitive environment and rarity of threats (Thomson et al., 2015). Intentional or unintentional mind-wandering thereby occurs because of task monotony (Seli et al., 2016; Smallwood, Beach, Schooler, & Handy, 2008). However, if the task were designed to be more engaging, or the stimuli more interesting, then mind-wandering should not occur and individuals will remain engaged with the task (Eastwood et al., 2012; Thomson et al., 2015). This assumption overcomes the issue with mindlessness theory, which cannot explain the cognitive increment in some individuals, by arguing that participants demonstrating a performance increment are superb at self-regulating task-unrelated thoughts and controlling mindless cognition. However, there is no evidence to support this claim, rather this is simply a common retort from mind-wandering theorists.

The Land of Confusion: Information Processing Theories and Issues with the Operationalization of 'Engagement'

One issue that is particularly relevant to this dissertation is the lack of consistency between definitions of 'task engagement' across each of the aforementioned information processing theories. For example, the mind-wandering theory suggests that vigilance tasks do not 'engage' individuals (Thomson et al., 2015, pg. 84), therefore mind-wandering increases with time on task and results in a "larger decrement." Mind-wandering theorists argue that vigilance tasks that require 'engagement' will result in improved performance. But, in mind-wandering theory, engagement is never clearly defined. It appears across several publications that under the mind-wandering account engagement refers to some form of physical engagement with the task (i.e., push a button, use a mouse to click on a threat; Thomson et al., 2015, 2014, 2013; Seli et al., 2016a,b).

In contrast, resource theory suggests that task engagement is highlighted by energetic arousal toward the task and the desire to succeed in performing the task (Matthews, 2016; Matthews et al., 2002; Matthews, Warm, Reinerman-Jones, Langheim, & Saxby, 2010a;

Matthews et al., 2010b). In this vein, task engagement includes "energy, interest in the task, and concentration" (Saxby, Matthews, Warm, Hitchcock, Neubauer, 2013, pg. 3). Task engagement in the resource theory instantiation has more to do with cognition and information processing, than physical, behavioral engagement. Task engagement, as operationally defined by resource theory, has also been found to be more reliable in predicting vigilance performance than worry or distress (Helton, Matthews, & Warm, 2009). Higher levels of task engagement manifest behaviorally as higher proportions of correct detections and fewer false alarms (Matthews, Warm, Shaw, & Finomore, 2014; Salcedo, Lackey, Maraj, & Reinerman-Jones, 2014). Lower task engagement is associated with "a prototypical fatigue state characterized by tiredness, lack of motivation, and distractibility" (Matthews, 2016, pg. 803).

To date, only one study has indicated that tasks, which afford physical engagement, improve vigilance performance. And as a result, this study tends to be heavily cited by proponents of mind-wandering theory. In this particular study, Pop, Stearman, Kazi, and Durso (2012) had participants 'engage' by clicking on an incoming airplane in a flight collision detection task. Participants who had to use a mouse to click on an incoming aircraft outperformed participants who had to simply monitor planes for possible collisions (Pop et al., 2012). Mind-wandering theorists strongly cling to this study and use it to support many of their arguments about engagement (Thomson, Besner, & Smilek, 2016). It is possible that this behavioral engagement task supports the idea of Hancock (2013), in that engagement in the task is determined by the design of the task (Hancock et al., 2016).

In one instance, Thomson et al. (2015) cites the Pop et al. (2012) study to demonstrate how a "more engaging" task results in "completely abolishing the vigilance decrement" (pg. 87). If this is the case, then tasks that require a great deal of physical engagement should yield similar results. However, as research demonstrates, situations that require constant physical engagement (like the Sustained Attention to Response Task) actually result in some of the worst vigilance performance (c.f., Wilson, Head, de Joux, Finkbeiner, & Helton, 2015a; Wilson, Russell, and Helton, 2015b).

In the Sustained Attention to Response Task (SART), participants *withdraw* a physical response to threats and must hold a button or the spacebar during all neutral events (i.e., non-signals) and release this button when a target stimulus is presented. Following the logic of mind-wandering theory, the mere action of keeping the button or spacebar pressed in the vigilance task should result in more task engagement and thereby better performance. However, several studies have demonstrated that individuals have substantially worse performance on the SART than traditional vigilance tasks. In one study, Dillard et al. (2014) found that the SART was highly mentally demanding and effortful, which is not in line with the assertions of mind-wandering theory, which implies that vigilance tasks are not effortful (Thomson et al., 2015, pg.84). Others have indicated that the SART affords impulsive responding (Helton, Kern, & Walker, 2009; Dillard et al., 2014), which makes it difficult to distinguish between intentional performance and impulsivity, or intentional impulsive responding.

In an effort to replicate SART research in a more ‘engaging’ context, Head and Helton (2012) used non-repeating naturalistic or urban stimuli analog of the numeric SART. They found that this version of the SART task was no more ‘engaging’ than the numeric SART, which does not support mind-wandering theory. Participants performed poorly and were clearly not cognitively engaged with the task (as measured by the DSSQ and NASA-Task Load Index), though they were quite behaviorally engaged in the task (e.g., repeatedly pressing down a button).

To summarize, behavioral engagement may not correspond to cognitive engagement, consequently it should not be assumed that because individuals are physically engaged with the task that they are therefore cognitively engaged in the task. This is not the first time in the history of psychology that researchers have tried to equate behavior with cognition (to revisit the downfall of behaviorism and cognitive revolution see Goldstein, 2014). This dissertation urges researchers interested in attention and engagement to focus on the cognitive aspects of task engagement, not the physical, and clearly operationalize their conceptualization of engagement.

Attenuating the Vigilance Decrement

The overarching goals of vigilance research include: 1) understanding the mechanisms underlying sustained attention, and 2) attenuating the vigilance decrement. While the above information processing theories serve to explain the attentional mechanisms, other streams of research attempt focus on methods of diminishing or eliminating the vigilance decrement through the study of individual differences, differences in task types, and differences in task demands.

The Effect of Individual Differences on the Vigilance Decrement

Individual differences have been important in guiding our understanding of vigilance over time. Research has indicated that low levels of boredom proneness (Sawin & Scerbo, 1995; Scerbo, 1998; Thackray, Bailey, & Touchstone, 1977), advanced occupational training (Donald

& Donald, 2015; Donald, Donald, & Thatcher, 2015), greater control of attention (Ilkowska & Engle, 2010), greater self-control/self-regulation (Becker, Mandell, Tangney, Chrosniak, & Shaw, 2015), high levels of intellect (Craig, 1984; Lehman, Olson, Aquilino, & Hall, 2006; McGrath 1963a) and aptitude (McGrath, 1963a, 1963b; Wiener, 1975), and higher working memory capacity (Caggiano & Parasuraman, 2004; Helton & Russell, 2011, 2013; Matthews, Warm, Shaw, & Finomore, 2014; McGrath 1963a, 1963b) can all influence the performance decrement.

In this same vein, many studies have examined how individual differences in personality may influence vigilance performance. Of the span of individual differences, a relatively great deal of attention has been directed toward the study of traits related to the "Big Five" (e.g., extraversion, neuroticism, conscientiousness, agreeableness, and openness; Costa & McCrae, 1992; Mandell, Becker, VanAndel, Nelson, & Shaw, 2015; Matthews, Deary, & Whiteman, 2003; Matthews, 2001; Shaw, Matthews, Warm, Finomore, Silverman, & Costa, 2010). A number of studies have indicated that introverts outperform extroverts on vigilance tasks (Mackworth, 1969; Rose, Murphy, Byard, & Nikzad, 2002), though the effect size for this trait has collectively been rather small (Koelega, 1992). Higher extraversion in particular has been associated with poorer performance in cognitive-based vigilance tasks (Revelle, 1993; Shaw et al., 2010). Similarly, participants high in conscientiousness tend to outperform participants low in conscientiousness in vigilance tasks (Rose et al., 2002). High neuroticism has been associated with greater performance decrements (Revelle, 1993, pg. 351), which is in line with other research that indicates individuals high in neuroticism tend to be more prone to stress (Costa & McCrae, 1992; Matthews, Deary, & Whiteman, 2009). However, these results have become more mixed over time.

One individual difference variable relevant to this dissertation is motivation. A number of studies have indicated that motivation may attenuate the decrement and vigilance performance. For example, recent meta-analytic evidence has indicated that extrinsic motivators are rather limited in their effect on performance and may only work in the short-term (Cerasoli, Nicklin, & Ford, 2014), whereas intrinsic motivators improve performance in the long run. In one study, when observers were given a monetary reward (an extrinsic motivator), motivation was undermined and performance suffered (c.f., Esterman, Reagan, Liu, Turner, & DeGutis, 2014; Murayama & Kuhbander, 2011). In an earlier study, Montague and Webber (1965) found that monetary rewards had little effect on performance in an extremely long vigil (e.g., 6 hours). Thus, the research on extrinsic motivators and performance tends to demonstrate limited effects, which are generally improvements in the short-term, but not over time.

In a similar vein, Unsworth and McMillan (2013) found that poorly motivated (i.e., low intrinsic motivation) students engaged in more mind-wandering and had worse performance than their peers higher in intrinsic motivation in a long-duration reading task (which some argue is a cognitive vigilance task). In another cognitive vigilance task, Dember, Warm, Bowers, and Lanzetta (1984) found that intrinsic motivation facilitated consistent performance (e.g., conservative responses to both correct detections and false alarms) in the task over time. In sensory vigilance tasks, it seems that intrinsic motivation may be one of the most predictive variables related to vigilance performance (Matthews, Davies, & Lees, 1990). Intrinsic motivation resulted in better performance in a sensory sustained attention task (Matthews, Davies, & Lees, 1990).

Reward pathways in the brain, which are related to motivation, have also been implicated in performance on vigilance tasks (Kelley & Berridge, 2002; Wise, 1985). In one physiological study, Bonnefond et al. (2011) administered a 60-minute Flanker Task to participants. The results indicated that motivation regulated activity in the anterior cingulate cortex (ACC), which is an area of the brain that corresponds to sustained attention abilities. Higher activation in this area of the brain corresponded with better performance. Matthews, Warm, Reinerman-Jones, Langheim, and Saxby (2010a) have also reported similar results. In two studies, physiological measures of energy expenditure (in this case cerebral blood flow velocity and blood oxygenation) were obtained. Higher activation in areas of the brain related to reward (i.e., dopaminergic pathways) of the brain corresponded to improved performance in a vigilance task (Matthews et al., 2010a; Matthews et al., 2010b).

The Effect of the Type and Design of the Task on the Vigilance Decrement

In addition to personality and motivational differences, the type of vigilance task can also influence the vigilance decrement. For example, tasks that are more ‘game-like’ in nature may better facilitate motivation or include a task structure designed to afford more motivation and engagement in the vigilance task (Hancock & Szalma, 2003; Szalma, Schmidt, Teo, & Hancock, 2014; Szalma, 2014). Furthermore, in one meta-analytic review of the sensitivity decrement, See et al. (1995) reported a greater vigilance decrement for sensory simultaneous tasks, than sensory successive tasks, in conditions with a low event rate. Successive tasks require the observer to compare new stimuli to stimulus representations held in memory, whereas simultaneous tasks require observers to compare stimulus elements presented at the same point in time (see Figure 2). Additionally, Parasuraman and Mouloua (1987) found that successive discrimination tasks are more mentally demanding than simultaneous discrimination tasks (c.f., Desmond, Matthews, Bush, 2001), especially in low event rate conditions.

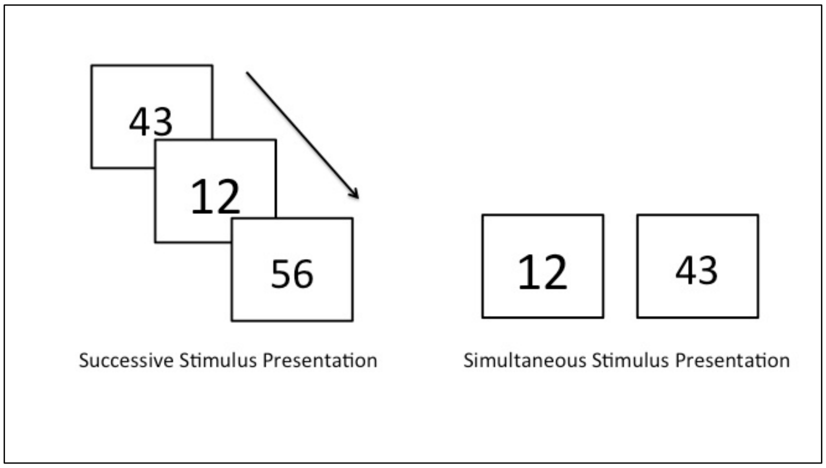


Figure 2. A redrawing of the simultaneous and successive stimuli used in Desmond et al. (2001) is included to demonstrate the differences between the two task types. In Desmond et al. (2001) participants were asked to discriminate between slightly larger digits and include a button response when a difference in digit size was detected.

In the same meta-analysis, See et al. (1995) indicated that cognitive tasks tend to be more complex, and for this reason can decrease the vigilance decrement, since these types of tasks are thought to be more "engaging" (Becker, Warm, Dember, & Howe, 1994; Parasuraman, Warm, & Dember, 1987; Warm & Dember, 1998). Different types of tasks may afford more or less cognitive engagement (Szalma, 2014), and thus attenuate the vigilance decrement differently. For example, cognitive tasks require the individual to manipulate the information presented in the task to identify a threat or critical signal. Sensory tasks require observers to monitor perceptual or physical changes to some attribute of the stimuli or the task environment. The distinction between these two task categories is important because different information processing systems may be utilized for each task (i.e., top-down versus bottom-up processing).

In terms of the vigilance decrement, See et al. (1995) reported that greater decrements tend to occur in sensory vigilance tasks than cognitive vigilance tasks, but this is dependent on event rate and task type as well. In one study, Deaton and Parasuraman (1988) observed that cognitive vigilance tasks were “more resistant to the decrement over time than sensory vigilance” (pg. 1458). In this same study, participants in the high event rate cognitive condition were most susceptible to performance errors (i.e., fewer hits, more false alarms). There was no effect of event rate (e.g., high or low) on performance in the sensory condition, which is interesting given that previous research has indicated that correct detections can decrease as event rate increases (Parasuraman, 1985).

Another aspect of vigilance tasks that can affect the decrement is information processing load, or task complexity. Less demanding or less complex tasks tend to have a low event rate (i.e., less than five critical hits per minute; Galinsky, Dember, & Warm, 1989) and do not require much effort beyond mere perception of the critical signal or threat. These types of tasks tend to be defined as “simple” tasks in the literature. One example of a simple task could be the simultaneous sensory task used by Desmond et al. (2001; Figure 2). Participants had to observe two sets of digits and determine which set of digits was slightly larger than the other (the number “12” in the example). Contrasting this, the successive sensory task used by Desmond et al. (2001) argued by researchers to be more demanding, especially temporally demanding. Participants in this condition had to remember the size of the previously presented digit set and compare the size of the previous set to the following set, then indicate a difference in physical size using a button response.

Furthermore, complex tasks can also attenuate or reverse the vigilance decrement (Warm, Dember, Lanzetta, Bowers, & Lysaght, 1985). More demanding or more complex tasks typically require a greater degree of thinking than less demanding or less complex tasks. Complex tasks also tend to involve a working memory component and symbolic manipulation. This could explain why better performance is observed in complex tasks than simple tasks, especially considering that many simple tasks tend to be sensory (Levine, Romashko, & Fleishman, 1973). Take for example one study by Molloy and Parasuraman (1996). They found that participants completing a complex-single task condition actually outperformed participants in a complex multi-task condition or simple single-task condition. This suggests that performance is better with some degree of complexity (Warm, Howe, Fishbein, Dember, & Sprague, 1984), but it also demonstrates an optimal level of complexity: the task was neither too simple nor too demanding. It is possible that "the effect [of complexity] is most likely based upon motivational rather than learning factors" (Warm et al., 1985, pg. 19). In this vein, complex or demanding tasks may afford (Szalma, 2014) more cognitive engagement. However, these latter claims require more empirical testing, thus the impetus for the present research.

It is also worth noting that very little agreement exists in the vigilance literature regarding which tasks are more or less demanding. And, there is also disagreement about what qualifies as a cognitive task. There is a large discrepancy between what may be simple or sensory to some, but complex or cognitive to others (the vigilance literature is rife with examples). Generally, it appears that the researchers subjectively choose which task is more complex versus simple *a priori*. Therefore, to overcome any ambiguity and to distinguish between the tasks prior to any experimentation in this dissertation, Table 2 is included as a guide to the most commonly accepted definitions of sensory, semantic, cognitive, successive, and simultaneous vigilance tasks. Examples of each task are also included in this Table. These operationalizations and examples are used throughout the present dissertation.

Table 2. The table below includes a definition for each type of task, as well as examples of the type of vigilance task.

Task Type	Definition	Example	Information Processing Type
Simultaneous	Compare critical signals or neutral events at the same point in time.	Figure 2 (Desmond et al., 2001).	Simultaneous
Successive	Compare critical signals or neutral events to previously displayed critical or neutral stimuli (compared at different points in time).	Figure 2 (Desmond et al., 2001).	Successive
Cognitive	Require observers to manipulate information.	Perform addition or subtraction to observe a critical signal vs. neutral event (Szalma & Teo, 2012).	Symbolic; top-down processing
Sensory	Require observers to detect a perceptual or physical difference between stimuli.	Critical signals are bolded or italicized, whereas neutral events are normal text (Szalma & Teo, 2012).	Perceptual; bottom-up processing
Semantic	Require observers to process the meaning of text.	Critical signals include four-legged animals, whereas neutral events are non-four-legged animals (Thomson, Besner, & Smilek, 2016).	Symbolic; top-down processing
Simple	Low event rate; low task demand; typically sensory in nature	Critical signals occur when one digit of a two-digit pair is slightly larger than another digit; neutral events consist of same-sized digit pairs (Deaton & Parasuraman, 1988;	Low processing load

Task Type	**Definition**	**Example**	**Information Processing Type**
		Desmond et al., 2001).	
Complex	Greater task demands; typically involve a working memory component; dual-tasks	Critical signals include four-legged animals (e.g., cow, horse, rabbit, etc.), neutral events include non-four-legged animals (e.g., barn, chair, rock, etc.), and distractors (referred to in this manuscript as 'lures') include two- or no-legged animals (e.g., eel, sparrow, etc.) (Thomson, Besner, & Smilek, 2016).	High processing load

The Importance of Time on Task

The perception of time associated with the pace of the task or the perceived length of the vigil can have an effect on subsequent perception of task complexity and task demand. The duration of the vigilance task is a critical factor influencing the magnitude of the performance decrement. Typically, the vigilance decrement manifests within the first fifteen minutes of the task (Teichner, 1974). But, as Smit, Eling, and Coenen (2004) have pointed out, highly demanding vigilance tasks can produce a vigilance decrement in a matter of minutes. Others have found that when a vigilance task is complex or difficult, it is possible to observe a decline in performance within a very short amount of time (i.e., five to ten minutes; Helton, Dember, Warm, & Matthews, 2000; Helton et al., 2007; Nuechterlein, Parasuraman, & Jiang, 1983). Even short vigilance tasks are hard mental work even if time is perceived to pass quickly (Finomore, McClernon, Amick, Pee, Funke, & Warm, 2016). In this vein, the length of the task is also associated with the perception of the task being more or less demanding or difficult.

The Effect of Task Instructions on Vigilance Performance

Another factor that impacts the observer's perception of the task is the phrasing of the task and the language used to communicate task instructions. The way in which a task is framed drastically changes how subsequent information is processed. For example, in one study conducted by Matthews, Panganiban, and Hudlicka (2011) observers who received task instructions framed in terms of 'threat' (or danger) were more motivated to seek out these harmful stimuli and had a higher proportion of hits compared to participants who received neutral task instructions. The type of instructions changed the type of information participants focused on and differently directed their attention.

In another study, Matthews and Desmond (2002) found that subjective fatigue in a driving task was moderated by motivational task instructions (i.e., the words "MEASURING DRIVING SKILL" were presented on screen for a brief period of time) (pg. 673). Participants receiving the motivating instructions imputed more effort into a driving task and demonstrated superior driving performance (as measured by slower speeds on corners, less drifting, smaller angles of the steering wheel) because they believed their driving skills were being assessed at this moment in time.

In an early study of motivational instructions, Lucaccini et al. (1968) found that when instructions framed the vigilance task as a 'challenge,' and not as a 'monotonous' task, no decrement was observed. Interestingly, when the task was framed as being 'monotonous,' participants viewed the vigilance task more negatively and had a much lower proportion of hits compared to participants who were instructed that the task was ‘challenging’ (Lucaccini et al., 1968). However, false alarm and response time data were not reported in this study, thus it is unknown how these changes to instructions might affect criterion setting or response time.

The findings of Lucaccini et al. (1968) are particularly intriguing given that Deci, Eghrari, Patrick, and Leone (1994) found that when a task is acknowledged as being boring, participants are more likely to reengage with the task when left alone with the task for a brief period of time. Therefore, it is possible that this is why Lucaccini et al. (1968) did not observe similar effects of task instructions. Although the seminal task used by Deci et al. (1994) was not a traditional vigilance task, it does approximate a monotonous computer-based vigilance task. In this study, participants were required to perform an 8-minute dot monitoring task. Deci et al. (1994) found that when an experimenter provided acknowledgement of the ‘boring’ aspects of the task, rationale for performing the task, and gave participants some control during the experiment, there was a longer duration of engagement (defined in this study as the length of time participants spent on the task) in the monotonous dot task when the experimenter left the room. The goal of Deci et al. (1994) was to demonstrate that when acknowledgement, rationale, and autonomy (i.e., choice) are provided in boring tasks, individuals are more likely to engage in the task on their own. However, because of the aim Deci et al. (1994) was mainly to study engagement, performance on the dot task was unfortunately not measured. This is particularly intriguing for vigilance, because this study is the first of its kind to demonstrate that boring, monotonous tasks do not necessarily induce disengagement when the correct ingredients are combined.

In a very recent study of instruction manipulations, Salcedo, Lackey, Maraj, and Reinerman-Jones (2014) did not find any effects of motivating instructions on performance in a human-robot interaction vigilance task. This evidence demonstrates that manipulations to task instructions may have an effect in some cases, but not in every instance. Additionally, the sporadic reporting of performance data and differences in performance metrics (i.e., correct detections vs. steering wheel angle) in vigilance studies makes it difficult to synthesize the effects of instruction manipulations across task types. The differences in significant results between studies and the lack of research on task instructions in general, make it difficult to draw conclusions from these mixed findings. Therefore, the present pilot work for this dissertation and present set of studies described in this dissertation seek to capitalize on the research on human motivation. This dissertation should further elucidate the relationship between sustained attention and motivational processes.

Pilot Work

A pilot study was conducted for this dissertation to test the claims of Deci et al. (1994), as well as establish a clearer pattern of results in terms of the effect of motivational manipulations on task instructions in vigilance task. The goal of this study was to replicate as best as possible the work of Deci et al. (1994) and control for individual differences in intrinsic motivation, which may also influence performance on the vigilance task, especially if the instructions are manipulated to be more or less motivating. For example, the seminal research of Deci and colleagues' (1994) indicated that motivational instructions (i.e., a sense of autonomy, acknowledgement for participation in the study, and rationale for completing the study) had a positive effect on engagement with the task such that participants who received motivating instructions spent more time on a boring dot monitoring task than any of the other available tasks (i.e., reading magazines, etc.). In the present pilot work, we utilized the original Deci et al. (1994) instructions, but had participants perform a traditional (sensory) vigilance task. The original Deci et al. (1994) study did not report performance data on the dot task, so the effect of their instructional manipulations on performance cannot be evaluated from their study. The only dependent measure collected in the original Deci et al. (1994) was 'free' time spent on the task. In sum, the present pilot work attempts to partially replicate the results of Deci et al. (1994) in a vigilance paradigm and to determine whether the effects of motivating instructions can facilitate performance. We seek to expand upon this research by collecting performance data as well.

Task Conditions

Participants were randomly assigned to either a motivating instruction condition or neutral instruction condition. The motivating instruction conditions could include the presence of acknowledgment, rationale, and autonomy. Before the mean split on the data (which allowed us to split the group into participants high and low in motivation), 24 participants were randomly assigned to received meaningful rationale (19 participants did not receive any rationale), 25 participants received acknowledgement of the boredom associated with the task (18 participants did not receive any acknowledgement of the task demands), and 22 participants received autonomous instructions, which used language supportive of choice, (21 participants received neutral instructions) during the experiment. The original wording of these task instructions can be found in Deci et al. (1994) and the original instructions have been modified for the present set of experiments, which are discussed later in this dissertation.

Measures

Differences in intrinsic motivation were assessed using the Intrinsic Motivation Inventory (IMI; Deci et al., 1994). All self-report measures used in this study were counterbalanced across participants to control for order effects and included: the IMI (Deci et al., 1994; Ryan, 1982), DSSQ (Matthews et al., 2002), NASA-TLX (Hart & Staveland, 1988), and a demographics form. All measures were administered online using Qualtrics survey software on a desktop computer.

Procedures

Participants completed the experiment on a desktop computer in a quiet laboratory space. Data were collected from one participant at a time. All participants were required to surrender any timepieces, such as watches or mobile phones prior to their participation in the study. First, participants were given an informed consent and then completed pre-task measures. Participants were then introduced to the sensory vigilance task by the researcher (for the protocol and stimuli see Szalma, 2011). All participants completed the same sensory task. Task type was not manipulated in this experiment. Participants completed a short block of practice trials, which lasted approximately two minutes and oriented them to the pace and format of the task.

After this practice session, participants were asked if they had any questions and the researcher left the room for the duration of the vigil. After the experiment, participants then completed all post-task measures and demographics.

Task Design and Stimuli

The entire vigilance task was approximately 24 minutes in length and had an event rate of 26 events per minute. The task consisted of monitoring the movements of three dots positioned above three bar graphs (see Szalma, 2011 for study stimuli; Teo et al., 2011). A critical signal resulted when the uniformity in spacing was unequal between the dots and graphs. Twelve critical signals appeared at random intervals during each of the four 6-minute periods on watch. Neutral events were cases in which all three dots were an equal distance from their respective bar graphs. Participants were instructed to press the spacebar on the keyboard when a critical signal was detected and withhold response to neutral events.

Participants

The sample consisted of 43 (32 females; 11 males) undergraduate students (60.6% freshmen; 7.0% sophomores; 23.3% juniors; 9.3% seniors) recruited from the research participation system at the University of Central Florida. The average age of participants was 20.02 years (*Median* = 19.00 years, *SD* = 2.92 years). The oldest student in this sample was 33-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants reported that they did not consume caffeine prior to participation in this study.

Results

A significant difference between intrinsic motivation at pre-test was not observed between men (*M* = 152.45, *SD* =28.35) and women (*M* = 164.06, *SD* = 28.27), $t(41) = -1.174$, $p = .247$. Given this, a mean split was performed on intrinsic motivation scores, collapsed across participant sex. Twenty-one participants had high intrinsic motivation (scores greater than or equal to 166) and 22 participants had low intrinsic motivation (less than or equal to 165). The means and standard deviations for all measures are reported in Table 3.

Table 3. The table below includes the means and standard deviations across intrinsic motivation, stress, and workload measures ($N = 43$).

Measure	High Intrinsic Motivation ($N = 21$)	Low Intrinsic Motivation ($N = 22$)
IMI	184.24** (15.83)	139.00** (18.17)
Pre-IM	20.14** (4.81)	15.79** (4.25)
Post-IM	11.52 (6.82)	8.65 (6.85)
Pre-SM	23.05 (6.19)	21.09 (5.99)
Post-SM	19.67 (8.42)	17.58 (7.50)
Pre-TRTs	19.95 (7.37)	20.05 (6.48)
Post-TRTs	22.05 (6.59)	24.44 (7.12)
Pre-TUTs	17.14 (8.26)	15.25 (6.11)
Post-TUTs	16.15 (7.14)	18.01 (8.05)
Workload	60.87 (17.17)	56.45 (14.40)

Note. IM = intrinsic motivation. SM = success motivation. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations. * = $p < 0.05$, ** = $p < 0.01$.

Participants higher in intrinsic motivation reported significantly more intrinsic motivation at pre-test than participants low in intrinsic motivation on both the IMI and pre-DSSQ subscale. No significant differences in success motivation were observed between participants low and high in intrinsic motivation at pre-task or post-task. No significant differences in TRTs, TUTs, or global workload scores were observed between participants low and high in intrinsic motivation at pre-task or post-task.

A 2 (high motivation vs. low motivation) x 2 (motivating instructions vs. neutral instructions) x 4 (watch period) mixed measures factorial ANOVA was performed for each of the performance measures collected in this study. There was no significant main effects or interactions for period on watch. Additionally, there were no significant main effects or interactions of intrinsic motivation on motivating or neutral instructions across any of the performance measures.

A 2 (High Motivation vs. Low Motivation) x 2 (Acknowledgement present vs. Acknowledgement absent) x 4 (Period on Watch) mixed factorial ANOVA was performed for hits and false alarms. There were no significant main effects or interactions for intrinsic motivation or acknowledgement. There were no significant main effects or interactions for watch.

A 2 (High Motivation vs. Low Motivation) x 2 (Rationale present vs. Rationale absent) x 4 (Period on Watch) mixed factorial ANOVA was performed for hits and false alarms. There were no significant main effects or interactions for intrinsic motivation or rationale. There were not significant main effects or interactions for watch.

Discussion

The present study expanded upon the original experiment by Deci et al. (1994) by measuring performance outcomes as a function of intrinsic motivation, meaningful rationale, acknowledgement, and motivating instructions. In the original study, Deci and colleagues (1994) found that participants engaged with a boring dot task for longer periods of time when they received a rationale for completing the task, the researcher acknowledged that the task was boring, and the participants had some autonomy over the task during the study. However, based on the present results, it does not appear that these findings do not necessarily translate to all boring tasks (at least not traditional vigilance tasks).

Generally, the results indicated that motivational manipulations to task instructions had different effects on performance outcomes in terms of accuracy for participants high or low in intrinsic motivation, but these differences were not statistically significant. A classic vigilance decrement in performance was only observed in the autonomous instruction condition for participants low in intrinsic motivation, otherwise performance was consistently poor across conditions and by intrinsic motivation. This is a major limitation of this study. Many participants found it difficult to discern between critical signals and neutral events and reported very low hit rates over time across all conditions. This is not in line with Szalma (2011), which established this task a monotonous vigilance task and resulted in a drastic vigilance decrement.

CHAPTER THREE: MOTIVATION

"Control leads to compliance, autonomy leads to engagement." – Daniel Pink (2009, pg. 56).

Autonomous Motivation

One theory that aims at facilitating intrinsic motivation and autonomous engagement in activities is self-determination theory (SDT; Deci et al., 1994; Ryan & Deci, 2008; Ryan, 2012). SDT suggests that all individuals, to differing degrees, innately desire to be actively engaged in activities and wish to become competent at their work (Ryan & Deci, 2008). Self-determination theory also suggests that people are inherently motivated to internalize the goals and values of uninteresting, but important tasks (Deci et al., 1994).

SDT assumes that people are at least initially engaged with the task or activity at hand through a combination of extrinsic and intrinsic motivators (Deci & Ryan, 1985, 2012a). This engagement is directly related to the extent that individuals feel controlled by the task or feel some control over the task (Deci & Ryan, 1985, 2012a). According to SDT, when people act with a sense of volition and experience choice, they are said to be autonomously motivated (Gagné & Deci, 2005; McBride et al., 2010). In contrast, controlled motivation occurs when performing an activity feels forced (McBride et al., 2010; Sheldon & Elliot, 1998). SDT also "maintains that knowing whether people's motivation is more autonomous or more controlled is far more important for making predictions about the quality of people's engagement, performance, and well-being" (Deci & Ryan, 2012a, pg. 86). Autonomy also inherently exists on a continuum, wherein some activities begin through extrinsic motivation and progress toward intrinsic motivation through the regulation of certain types of needs, but the reverse is also possible.

According to Ryan and Deci (2000, 2008), autonomous regulation occurs for several reasons. Self-determination theory states that three contextual factors can influence autonomous motivation, such as meaningful rationale (e.g., explaining the purpose of the activity), acknowledging the individual's feelings (e.g., understanding how that person feels about the activity), and facilitating more autonomy (e.g., giving the person some choice or control in the activity). SDT assumes that when the task environment incorporates these three factors, the activity will be experienced as fully autonomous.

Moreover, SDT posits that three universal needs also facilitate motivation and autonomy. Importantly, these needs are not forced homeostatic deficiency mechanisms, but are more like omnipresent "nutriments" for sustaining well-being (Ryan, Sheldon, Kasser, & Deci, 1996). Needs can also be thought of as "necessities" that each person must have in order to grow and to flourish (Ryan, Sheldon, Kasser, & Deci, 1996). These needs include autonomy, competence, and relatedness. Autonomy is the degree of choice in activities or tasks, or an experience of personal control (Ryan & Deci, 2008). Activities and lifestyles that thwart the need for autonomy may deplete energy and therefore result in amotivation, or a lack to engage in the task at hand (Ryan & Deci, 2000). According to SDT, it is crucial to have some choice over the engagement in activities or tasks because this may serve to bolster intrinsic motivation toward the activity over time (Ryan & Deci, 2000, 2008).

Autonomous motivation is also influenced by both individual traits and the environmental context, much like a symbiotic relationship (Ryan & Deci, 2008). Competence is efficacy in that individuals feel effective in what they do and the knowledge they utilize when performing a task or activity (Deci & Ryan, 1985; White, 1959). Relatedness is the feeling of connectedness with others and belonging to others socially (Ryan & Deci, 2008), which is akin to Baumeister's conceptualization of belongingness (Baumeister & Leary, 1995). Additionally, individuals can differ in the strength of each need, but the needs themselves are universal and generally autonomy and competence account for the most variance when measuring engagement in a given task or activity (Ryan & Deci, 2008). Autonomy is an important human need that must be fulfilled regardless of gender, social status, or cultural climate (e.g., collectivist or individualistic; Ryan & Deci, 2000).

Autonomous motivation has been found to significantly influence performance across many domains, such as school (Black & Deci, 2000; Cordova & Lepper, 1996; Deci & Ryan, 1987, 2012b; Reeve & Lee, 2014; Reeve, 2002; Ryan & Deci, 2013), work (Gagné & Deci, 2005), and health-related behaviors (Ryan, Patrick, Deci, & Williams, 2008). Students autonomously motivated in school perform better on examinations and can write more creatively (Ryan & Deci, 2012). Students high in autonomous motivation also tend to study for longer periods of time and have better relationships with their teachers (Black & Deci, 2000).

Studies of workplace motivation indicate that work tasks which are structured to be more complex or challenging, are more likely to be viewed as more meaningful and more likely to prompt autonomous motivation (Gagné & Deci, 2005; Stone, Deci, & Ryan, 2009). Work tasks that are perceived as mundane are found to lead to lower satisfaction and prompt controlled motivation toward these tasks (Gagné & Deci, 2005).

In terms of the domain of health, those that chose to participate in healthy activities and healthy lifestyles had a lower incidence of disease (Ryan, Patrick, Deci, & Williams, 2008). Furthermore, when healthcare providers offered patients some degree of choice in their medical treatments, patients exhibited better health over time and better relationships with their providers (Ryan, Patrick, Deci, & Williams, 2008).

Achievement Motivation

Much like self-determination theory, the research on achievement motivation maintains that individuals seek to excel in what they do and actively strive to accomplish goals. Goals are future-based ideals used to approach the achievement of an outcome or the avoidance of an outcome (Elliot, 1999). More specifically, achievement goals "relate to wanting to develop, attain, or demonstrate competence" (Harackiewicz, Barron, & Elliot, 1998, pg. 2). The approach-avoidance distinction comes from Elliot (1999), who argued that approach goals are utilized to pursue success and seek out positive outcomes, whereas avoidance goals are important in avoiding negative outcomes like failure (McClleland, 1985; Muis, Winne, & Edwards, 2009).

Another important dimension of the achievement goal framework is the quality of the goal pursued, which is determined by the type of outcome (e.g., *develop* competence, a mastery goal, versus *demonstrate* competence, a performance goal). According to Ames (1992; Ames & Archer, 1988), mastery goals are used to integrate the task value into one's current value system, bolster self-efficacy, and foster deep learning. Conversely, performance goals are important in accomplishing tasks, outperforming others, or completing something quickly with minimal effort (Ames, 1992; Murayama, Elliot, & Friedman, 2012). Individuals driven primarily by performance goals tend to complete work well, but do not glean any additional knowledge from the task, unlike individuals driven primarily by mastery goals.

Together, the theories of mastery and performance goals, and approach and avoidance goals comprise the 2 x 2 achievement goal model (see Figure 3 for an illustration). The 2 x 2 achievement goal framework has been used in a myriad of studies on achievement motivation and performance, particularly scholastic achievement (Bipp & van Dam, 2014).

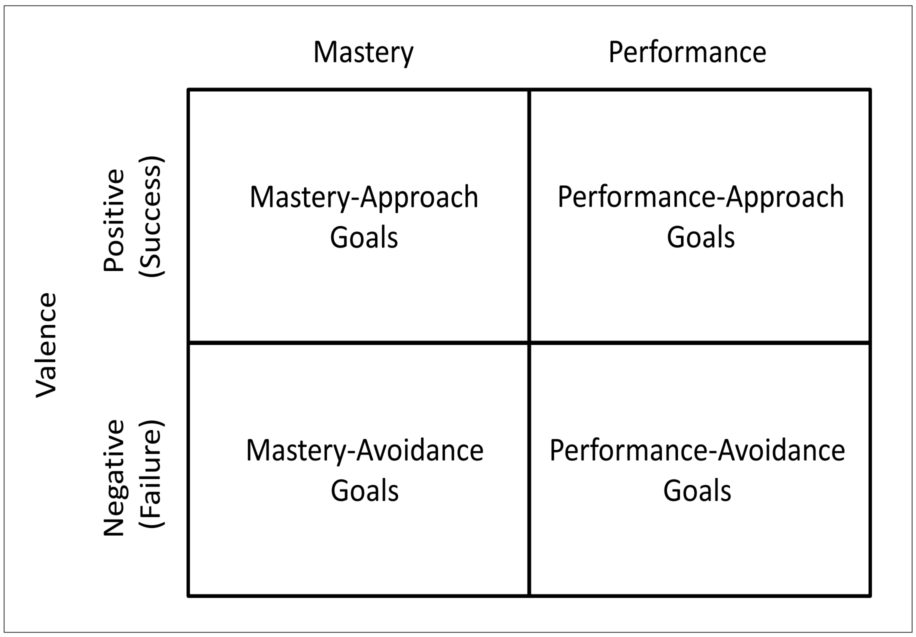


Figure 3. A redrawing of the 2 x 2 achievement goal model (Ames, 1992; Ames & Archer, 1988; Elliot, 1999).

In academic settings, approach goals are important in student perceptions of interest and value of the activity, as well as persistence in their academic efforts (Pintrich, 2000). On the other hand, avoidance goals in academia have been linked to maladaptive behaviors like cheating and plagiarism (Pintrich, 2000). In a study of students majoring in accounting, Dull, Schleifer, and McMillan (2015) found that both mastery and performance approach-goals were integral to student success in the accounting course. Others have found mastery-approach goals to be important in predicting student affect, and performance-avoidance goals to predict anxiety toward school and more boredom in school (Ranellucci, Hall, & Goetz, 2015).

Mastery-avoidance achievement goals helped students to strive to avoid academic losses (i.e., failing a test, losing points on a homework assignment) (Senko & Freund, 2015). In a similar vein, Michou, Vansteenkiste, Mouratidis, and Lens (2014) found that autonomous versus controlled motivation influenced student performance in school and had a significant impact on the types of goals (e.g., mastery, performance, approach, avoidance) adopted by the students. Students who engaged in their coursework autonomously had higher needs for achievement (Michou et al., 2014). These students also reported allocating more effort to their studies and education (Michou et al., 2014), than participants reporting more controlled motivation.

To summarize, the research on achievement motivation suggests that people innately strive for successful performance on a given activity (McClleland, 1961; Nicholls, 1984). High achievement motivation may help individuals approach their work, study, or leisure activities with a need for success and skilled performance, which is supported by meta-analytic evidence that achievement motivation in fact carries over into multiple domains (Van Yperen, Blaga, & Postmes, 2014).

Pilot Work

Theories of achievement motivation argue that this construct is a stable trait that predicts performance across domains. However, there has been little research examining the effect of achievement motivation in a vigilance context. Because there is little research investigating the influence of achievement motivation in sustained attention tasks (Schneider & Eckelt, 1975; Slade, 1988; Slade & Rush, 1991), the present pilot work remains relatively exploratory. Thus, the goal of this pilot work is relatively simple in that the effects of achievement motivation on vigilance performance, as well as dependent measures of perceived stress and workload, will be examined to better inform the hypotheses that were developed for the present dissertation. One limitation of this pilot work was that response time was unable to be collected due to an error in the software. It is important to note that this error was addressed for all four experiments described later in this dissertation.

Procedures

Data were collected from one participant at a time in a quiet laboratory space. All participants were required to surrender any timepieces, such as watches or mobile phones prior to participation in the study. It is important to note that participants were not aware of the length of the vigil, but that the entire experiment would not exceed two hours. First, participants were provided an informed consent and then completed pre-task measures (e.g., pre-DSSQ and the AMS).

Following this, participants were introduced to the practice task, which required approximately 1-2 minutes to complete. The practice task demonstrated the difference between critical signals and neutral events, as well as allowed participants to acclimate to the task. After the short practice task, participants completed the vigil. The researcher left the room at this time. The entire task was approximately 24 minutes in length and consisted of four periods on watch with the restriction that signals were presented on adjacent trials (i.e., one critical signal would never immediately follow another critical signal). Five critical signals appeared at random within each six-minute period on watch. The second critical signal never appeared immediately after the first signal.

After the vigil, participants then completed all post-task measures (e.g., post-DSSQ and the NASA-TLX) and provided relevant demographic information. The order of self-report measures used in this study were counterbalanced across participants to control for order effects and included: the Ray Achievement Motivation Scale (AMS; Ray, 1979), DSSQ (Matthews et al., 2002), NASA-TLX (Hart & Staveland, 1988), and a demographics form. All measures were administered using Qualtrics survey software on a desktop computer.

Participants

The sample consisted of 59 (39 females; 20 males) undergraduate students (76.3% freshmen; 15.3% sophomores; 8.5% juniors) recruited from the research participation system at the University of Central Florida. The average age of participants was 18.75 years (*Median* = 18.00 years, *SD* = 1.65 years). The oldest student in this sample was 27-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants were asked refrain from consuming caffeine 24 hours prior to participation in this study.

Conditions

Participants were randomly assigned to either a sensory-based vigilance task requiring perceptual processing or cognitive-based task requiring symbolic processing (Szalma & Teo, 2012). Twenty-six participants were randomly assigned to the cognitive condition and 33 to the sensory condition. For purposes of analyses, a median split was performed after data collection to divide participants by high or low achievement motivation. Participants scoring under twenty-one points (which was the average achievement motivation score reported by this sample) on the AMS were categorized as being low in achievement motivation and participants scoring over twenty-one points on the AMS formed the high achievement motivation group. After this mean split was performed, sixteen participants low in achievement motivation (AchM) were assigned to the cognitive condition and seventeen participants low in achievement motivation were assigned to the sensory condition. Sixteen participants high in achievement motivation were assigned to the sensory condition and ten participants high in achievement motivation were assigned to the cognitive condition (note that different sample sizes are a result of data cleaning).

Results and Discussion

Participants low in AchM reported an average score of 19.03 (*SD* = 1.63) on the AMS, whereas participants high in AchM reported an average score of 24.46 (*SD* = 2.52). AchM was not significantly correlated with any measures of performance or with the condition to which participants were assigned. Participants higher in AchM outperformed peers lower in achievement but only in a cognitive vigilance condition (Dewar & Szalma, 2016), which may afford more engagement because it is more challenging and complex (Matthews, 2016).

Overall, participants reported a moderate degree of global workload associated with the vigilance tasks (*M* = 43.50, *SD* = 17.33). Participants reported moderate levels of engagement with the vigilance tasks at pre-test (*M* = 19.28, *SD* =4.65), low levels of distress prior to completing the vigilance tasks (*M* = 5.79, *SD* = 4.07), and moderate levels of worry at pre-task (*M* = 18.84, *SD* = 5.89).

In terms of performance, the average number of false alarms across conditions was 3.25 (*SD* = 4.24) and the proportion of correctly detected critical signals was 85% (*SD* = .19), while performance is not perfect, the results indicate that all participants exuded some effort in each vigilance task and performance was not subject to a floor effect. The means and standard deviations for these data are reported in Figure 4.

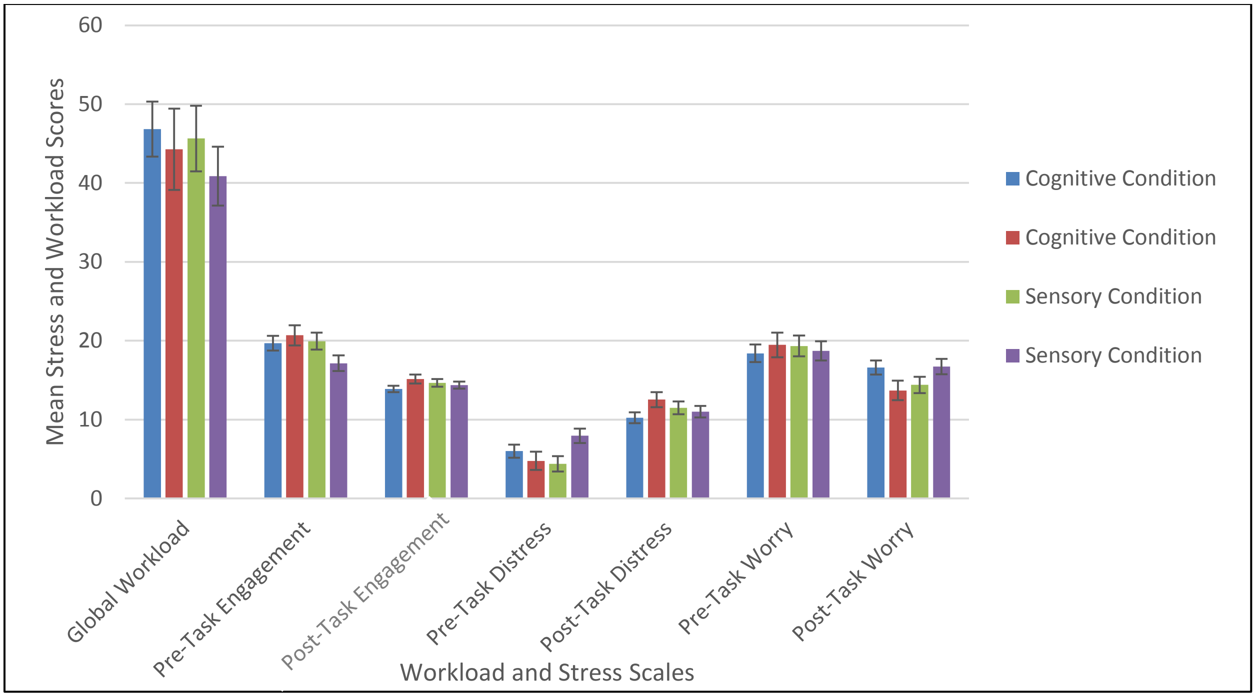


Figure 4. The figure includes stress and workload changes from pre-task to post-task for participants high or low in achievement motivation in the cognitive and sensory conditions. Note: blue columns = cognitive task low AchM; red columns = cognitive task high AchM; green columns = sensory task low AchM; purple columns = sensory task high AchM.

A two (high or low achievement motivation) by two (cognitive or sensory condition) factorial analysis of variance (ANOVA) was performed for change scores for each of the three factors on the DSSQ: engagement, distress, and worry. There was a significant interaction between achievement motivation and condition for the change in distress scores between pre-task and post-task, $F(3, 55) = 3.73$, $p < .10$, $\eta_p^2 = .06$. There was a significant change in distress scores from pre-task to post-task for participants low in achievement motivation in the sensory condition and for participants high in motivation in the cognitive condition. No main effects of achievement motivation or condition were observed for pre-task or post-task scores on the distress subscale of the short DSSQ. The most dramatic increase in distress between pre-task and post-task was observed for participants high in achievement motivation in the cognitive condition and participants low in achievement motivation in the sensory condition.

There was a significant interaction between achievement motivation and condition for the change in worry scores between pre-task and post-task, $F(3, 55) = 3.86$, $p < .10$, $\eta_p^2 = .07$. Participants low in achievement motivation in the sensory condition and participants high in achievement motivation in the cognitive condition reported the greatest change in worry on the short DSSQ. All worry scores decreased post-task. No main effects of achievement motivation were observed for pre-task or post-task scores on the worry subscale of the short DSSQ. Worry decreased for all groups between pre-task and post-task.

There were no significant main effects for pre-task or post-task engagement scores. There was no significant interaction for pre-task engagement, post-task engagement, or change in engagement scores. However, engagement decreased between pre-task and post-task across all groups.

A two (high or low achievement motivation) by two (cognitive or sensory condition) factorial ANOVA was performed on global workload scores. No significant main effects or interactions were observed. Participants in the cognitive condition did not report significantly greater workload associated with the task than participants in the sensory condition. Participants high in achievement motivation did not report significantly greater workload associated with the task than participants low in achievement motivation.

A two (high or low achievement motivation) by two (cognitive or sensory condition) by four (watch period) mixed measures factorial ANOVA was performed for proportion of hits and errors of commission. There were no significant effects of watch period on proportion of hits.

There was a significant main effect of condition on proportion of hits, $F(3, 55) = 28.43$, $p < .001$, $\eta_p^2 = .34$. No other significant main effects or interactions were observed. Participants in high in motivation in the cognitive condition outperformed participants low in achievement motivation, but participants in the sensory condition correctly detected more signals. This could be due to the information processing requirements related to the task. Participants in the sensory condition performed similarly, regardless of high or low achievement motivation. The average proportion of correct detections per period on watch is reported in Figure 5.

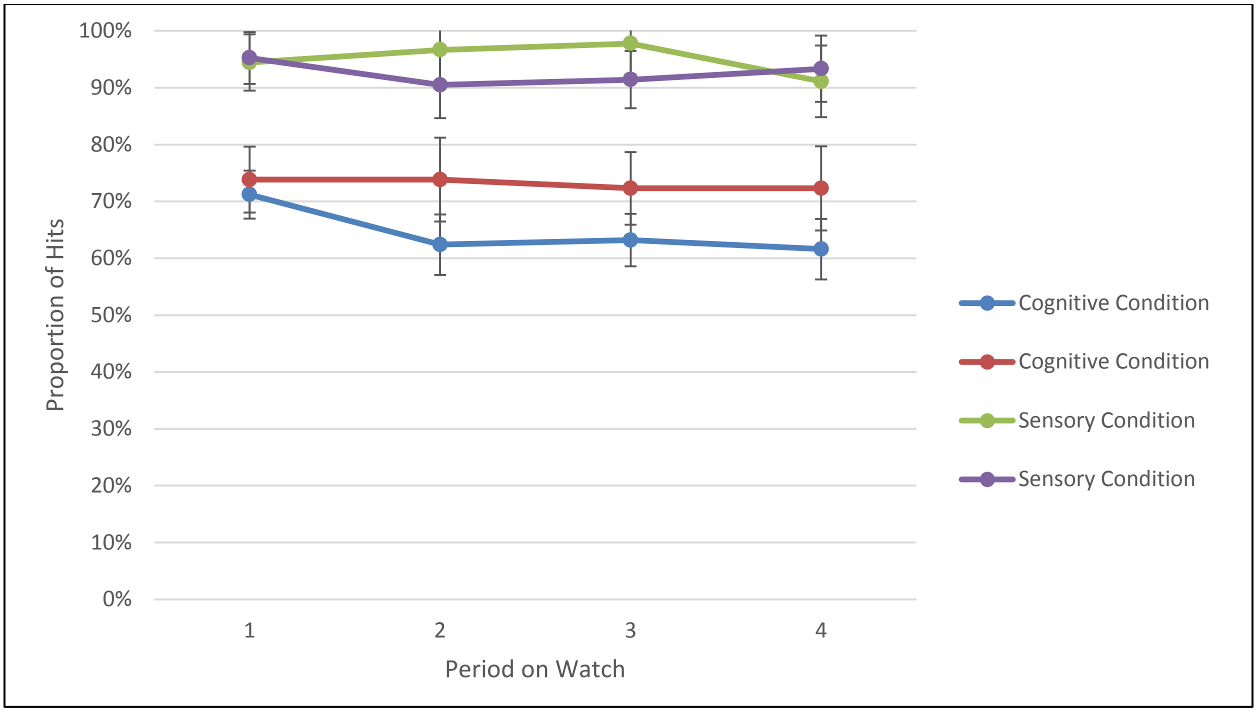


Figure 5. The average proportion of correct detections are reported for the present pilot study for participants low and high in AchM for both the sensory and cognitive conditions. Note: blue line = cognitive task low AchM; red line = cognitive task high AchM; green line = sensory task low AchM; purple line = sensory task high AchM.

A two (high or low achievement motivation) by two (cognitive or sensory condition) by four (watch period) mixed factorial ANOVA was performed for number of false alarms. There was a significant effect of watch on proportion of false alarms, $F(3, 55) = 9.47$, $p < .001$, $\eta_p^2 = .147$. There was a significant watch by motivation interaction, $F(3, 55) = 2.46$, $p < .10$, $\eta_p^2 = .043$. Participants high in achievement motivation in the cognitive condition showed consistently low rates of false alarms across all periods on watch. Interestingly, participants high in achievement motivation did not commit any false alarms in the cognitive condition. Participants high in achievement motivation in the sensory condition performed similarly to participants low in achievement motivation in the cognitive and sensory conditions. False alarms tended to decrease over time on watch. No other significant main effects or interactions were observed. The average number of false alarms over time is reported in Figure 6.

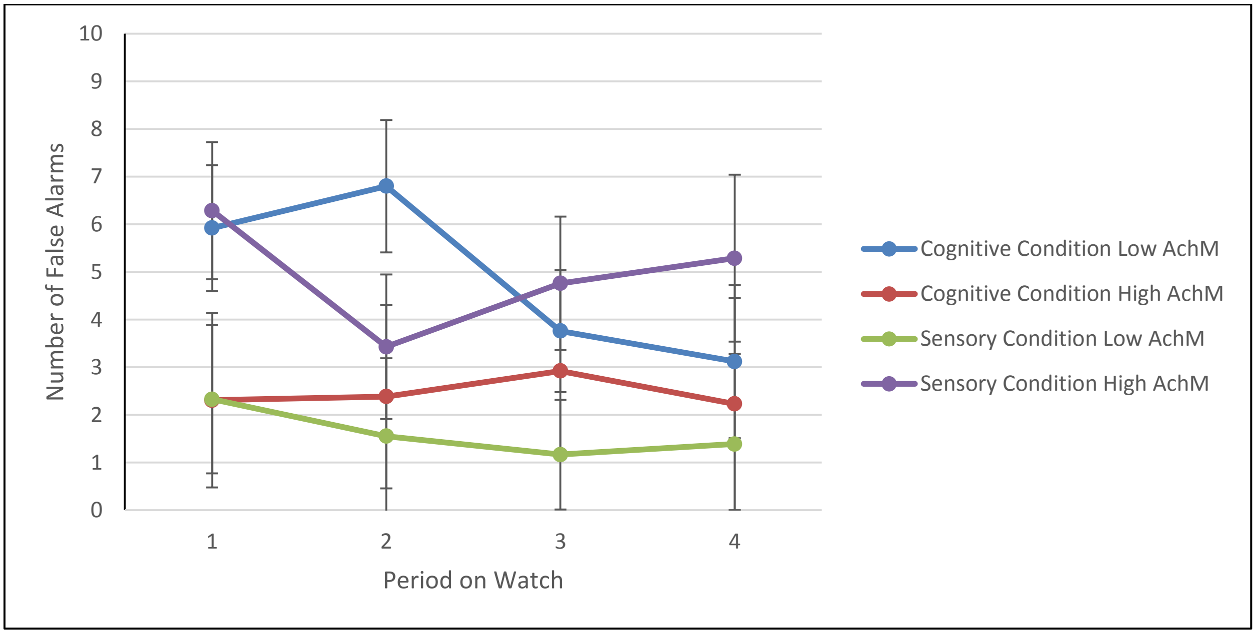


Figure 6. The average number false alarms are reported for the present pilot study for participants low and high in AchM for both the sensory and cognitive conditions. Note: blue line = cognitive task low AchM; red line = cognitive task high AchM; green line = sensory task low AchM; purple line = sensory task high AchM.

The performance data indicated that participants high in achievement motivation behave more like conservative responders. However, participants high in motivation in the sensory condition performed similarly to participants low in motivation in the sensory and cognitive conditions. Participants low in achievement motivation indicated some of the worst performance in the cognitive vigilance task. Thus, it appears that achievement motivation impacts response bias. Participants high in motivation in the cognitive condition did not achieve as much correct detection as participants in the sensory condition. This performance effect is most likely an artefact of the difficulty associated with the cognitive condition. The sensory task merely requires perceptual sensitivity and does not include a symbolic manipulation component like the cognitive task. Importantly, participants in the cognitive condition high in achievement motivation committed the fewest false alarms.

Achievement motivation appears to be related to overall performance, at least in the cognitive condition. This could be due to the challenge associated with the task, but this is a speculation that will require further testing and hopefully an answer will be divulged in this dissertation. Since the cognitive condition requires a working memory component, which may appeal to participants high in achievement motivation, these individuals may approach this task with a sense of mastery goals in mind: make as few mistakes as possible (i.e., false alarms, misses) and correctly detect as many critical signals as possible.

CHAPTER FOUR: THE PRESENT RESEARCH

While a handful of studies examining extrinsic motivation or intrinsic motivation in vigilance exist, there has been relatively little research on other possible manifestations of motivation in vigilance (i.e., motivational manipulations to task perception, manipulations to task instructions, etc.). Therefore, the present dissertation seeks to extend the understanding of the role of motivation in vigilance. In this dissertation, two forms of motivation, achievement motivation (a trait measure) and autonomous motivation (a state measure) will be examined in relation to their effect on sustained attention in varying vigilance conditions.

Achievement motivation, which is the motivation to experience success, is associated with the need to perform a given task in a manner that meets goal completion criteria. Achievement motivation is not necessarily the innate joy of performing a specific activity, but it may be closely related to intrinsic motivation. In a similar vein, autonomous motivation may incorporate some facets of intrinsic motivation, but this type of motivation is another type of motivation. Autonomous motivation, which is the motivation to experience and perceive choice, focuses more on the need for choice or control over an aspect of the task, and less on the pure enjoyment associated with the activity. Again, autonomous motivation should be related to intrinsic motivation, but it is ultimately distinct. Importantly, pilot work demonstrated that achievement motivation might help to offset the vigilance decrement, but does so differently than autonomous motivation or other forms of motivation. The present dissertation will attempt to further elucidate under which conditions these types of motivation influence vigilance performance.

To summarize, the present dissertation seeks to better understand the role of achievement motivation and autonomous motivation on human performance in several vigilance tasks that require different types of information processing (e.g., cognitive vs. sensory) and manipulate the types of instructions surrounding the task (i.e., motivational or controlling). No study, to date, has examined the role of instruction manipulations of motivation in conjunction with state and trait measures of motivation across several vigilance conditions. It is possible that the way in which a task is framed may influence vigilance performance by activating motivational schemas (i.e., high or low autonomous motivation or high or low achievement motivation) linked to performance.

Implications for Theory

As previously discussed in the literature review, there is substantial disagreement regarding the mechanisms subsuming attention and information processing during vigilance tasks. There is also disagreement amongst the three theories of vigilance over the role of individual differences in vigilance performance. For example, as Thomson et al. (2015) incorrectly propose that, "manipulations of task engagement should either have no effect on the vigilance decrement or they should increase the decrement" (pg. 86). This would be untrue in instances where *motivation* was used to manipulate engagement in the vigilance task. Motivation, by definition, facilitates engagement in tasks, even in unimportant or boring tasks (Deci et al., 1994; Ryan & Deci, 2000, 2008). Motivation is important in assisting the human operator to "understand and cope with the task demands" (Matthews, 2016, pg. 801).

Moreover, Thomson et al. (2015) argue that an “engagement condition would arguably place the highest demand on attentional resources and should therefore have displayed a great decrement according to the [resource-] depletion account” (pg. 87). This postulation fails to consider motivational theories, which suggest that motivation directs and drives attention, as well as behavior (Chelazzi, Perlato, Santandrea, & Della Libera, 2013; Della Libera & Chelazzi, 2009; Hughes & Zaki, 2015; Zedelius, Broadway, & Schooler, 2015; Zedelius, Veling, & Aarts, 2012). Because of the debate betwixt these three theories of information processing, the present dissertation seeks to understand the role of both achievement motivation and autonomous motivation across several types of sustained attention tasks.

Goals for this Dissertation

There are several goals for the present dissertation. An overarching goal for this dissertation is to systematically demonstrate the extent to which the design of the vigilance task induces a performance decrement and how individual differences in motivation can potentially offset this decline in performance over time. This research would support the theoretical idea that the vigilance decrement may in fact be a phenomena constructed entirely by the researcher, wherein the decrement can only be “defeated” based on the design of the task and appropriate selection of individual differences (Hancock, 2013; Hancock et al., 2016).

The four following experiments seek to empirically compare the arguments proposed by the three theories of information processing (i.e., the resource-depletion model, the mindlessness account, and mind-wandering theory) in vigilance. This dissertation will consider the importance of manipulating task type (i.e., cognitive, sensory) and task load (i.e., complexity) within a single study, as the results linked to motivation may differ based on the task type (as demonstrated by pilot work and the broader vigilance literature). Different tasks require different forms of information processing, thus individual differences may be better elucidated in one type of task over another. Each study is explained in detail in the following chapters.

CHAPTER FIVE: EXPERIMENT ONE

Experiment One of this dissertation examined the role of individual variation in autonomous motivation and achievement motivation with respect to engagement in vigilance tasks, stress and workload associated with sustained attention, and vigilance performance across task types. These individual differences in motivation have been selected because of their influence on task engagement and potential influence on attention.

Hypotheses

Engagement and Motivation Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) should be significantly related to the level of engagement and motivation at post-task. Task engagement and motivation will be measured by energetic arousal, concentration, success motivation, intrinsic motivation, task-related thoughts (TRTs), and task-unrelated thoughts (TUTs). Cognitive task engagement will be measured using concentration, TRTs, and TUTs.

   Note: TRTs and TUTs are typically associated with the Worry dimension of the Dundee Stress State Questionnaire. However, mind-wandering theory suggests that these subfactors are unique byproducts of vigilance performance. This claim was tested across each of the four experiments included in this dissertation.

2) Specific hypotheses related to cognitive engagement were developed given the three theories of information processing:

    a. Under the resource theory account of vigilance, AchM and AuM should be significantly related to concentration at post-task, but not under the mindlessness or mind-wandering account.

    b. If cognitively engaged with the task, AchM or AuM should be significantly related to an increase in TRTs at post-task under the resource-depletion account.

    c. According to mindlessness theory, there should be few if any TRTs.

    d. Under the mind-wandering assumption, there will be high TRTs at pre-task and low TRTs at post-task, regardless of the type of motivation involved in vigilance.

    e. Assuming a resource theory perspective, if individuals are engaged with the task, participants AchM or AuM should be related to a significant decrease in TUTs at post-task.

    f. According to mindlessness theory, there should be more TUTs as the mind drifts away from the task because vigilance tasks afford this behavior.

g. Under the mind-wandering assumption, there will be high TUTs if disengaged with the task, especially at post-task as inward or outward task-unrelated thoughts increase during the vigil.

Stress and Workload Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) may affect stress and workload. Stress and workload will be measured by tense arousal, hedonic tone, anger/frustration, and global workload. Thus, the hypotheses are as follows:

   a. AchM and AuM should be significantly related to tense arousal. Participants lower in motivation will lack effective coping strategies to overcome the monotony associated with the task.

   b. AchM and AuM should be significantly related to higher hedonic tone because these individual differences are related to finding enjoyment in the task.

   c. AchM and AuM should be significantly related to anger/frustration. Participants lower in motivation will lack effective coping strategies related to managing perceived anger and frustration.

2) It is hypothesized that the cognitive task will be perceived as more work than the sensory task based on previous evidence from the existing literature on vigilance.

    a. However, participants high in AchM and AuM may be significantly related to global workload. It is possible that participants high in AchM or AuM will approach the cognitive task as if it is a complex challenge, which may reduce overall perceived workload.

Performance Measures

1) Proportion of correct detections, number of false alarms, average response time, and signal detection theory measures of sensitivity and response bias will serve as measures of performance.

2) AchM and AuM should be significantly related to the proportion of correct detections because individuals high in these differences want to strive toward success and perceive control over their performance.

3) Similarly, AchM and AuM should be significantly related to the number of false alarms because individuals high in these differences want to strive toward success and perceive control over their performance, thus reporting a low number of false alarms over time.

4) AchM and AuM may be significantly related to mean response time because previous literature has demonstrated that motivation is linked to attention.

Participants

An *a priori* power analysis for ANCOVA was conducted for Experiment One using G*Power Version 3.1 with a medium effect size and conventional criteria (α = 0.05, 1-β = 0.80; Faul, Erdfelder, Lang & Buchner, 2007), which is useful tool that allows researchers in the social, psychological, and biomedical sciences to estimate power and effect sizes prior to data collection. This power analysis indicated that 72 participants needed to be recruited from the University of Central Florida’s research participation system (SONA) for Experiment One. To qualify for participation in the present study, participants reported normal or corrected-to-normal vision and were at least 18 years of age or older. ANCOVA was selected as the method of data analysis because the covariates AchM and AuM are continuous variables. ANCOVA permits testing interactions between each of these continuous variables and both between-groups (cognitive vs. sensory task condition) and within-groups (period on watch) independent variables.

Data Cleaning and Final Sample

One hundred participants were collected from the online SONA study pool for Experiment One. Five of these participants were removed from the sample for incomplete SuperLab data and three participants were removed for incomplete survey data.

The inclusion criteria were as follows: participants achieved a minimum score of 70% correct detections (i.e., hits) in the first period on watch and did not commit more than two or three standard deviations above ten false alarms in any given watch period. This inclusion criteria was utilized for two reasons: 1) it is a common performance threshold utilized in the vigilance literature, and 2) if the performance criteria were made stricter, the amount of data included in the present study could be substantially reduced and another potential issue of restriction of range could become present.

After data cleaning based on the inclusion criteria, the final sample for this study consisted of 79 undergraduate students. Thirteen participants (10 cognitive task; 3 sensory task) were removed for performance deviations that required them to be excluded from the present analyses.

Design

Participants were randomly assigned to one of two conditions: cognitive or sensory. The number of participants in each condition are included in Table 4.

Table 4.The table below indicates the two conditions to which participants were randomly assigned in Experiment One.

Task Type	Number of Participants Assigned to Each Condition
Cognitive	35
Sensory	44

In the sensory task, participants were asked to monitor only one specific quadrant at a time (see Figure 7 for an example). The specific quadrant, which participants monitored, was randomized across conditions to control for any effects related to quadrant location (i.e., top, bottom, left, right). No such effects of the location were observed. Critical signals were cases in which one of the digits in the two-digit pair was physically larger in font size than the other (see Figure 7). Participants were instructed to press the spacebar on a keyboard when they detected a critical signal. All other two-digit pairs were considered neutral events and participants were asked to withhold response to these non-signals. This task required no symbolic manipulation, merely perceptual processing, which is similar to bottom-up processing or spatial magnitude processing.

Participants in the cognitive task were instructed to respond to critical signals that result from symbolic manipulation (i.e., subtraction). Critical signals were cases in which the difference between the two-digit pair was equal to -1, 0, or 1 (see Figure 7). Participants were instructed to press the spacebar on a keyboard when they believed a critical signal had appeared on the screen. All other difference solutions (i.e., -5, -3, 6, 8) were considered neutral events and participants were asked to withhold response to these stimuli.

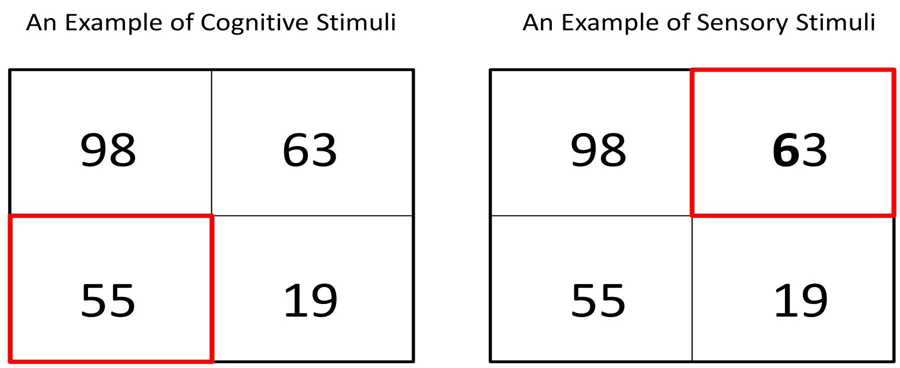


Figure 7. An example of the cognitive versus sensory stimuli with task instructions included for clarification (from Szalma & Teo, 2012; Teo et al., 2011). The two types of tasks are redrawn together for comparison. The red highlighting indicates the display participants were asked to monitor (note: the red highlighting disappeared once the vigil began). Display location was randomized once per participant.

Task Stimuli and Environment

Each experimental task consisted of four blocks of 123 neutral events and five critical signals (i.e., signal probability of 0.039), or a total of 20 critical signals and 492 neutral events over the course of a 21-minute vigil. Stimuli were presented for 2500 milliseconds using SuperLab 4.0 software on a Dell Optiplex 745 desktop computer. The stimuli are adapted from Szalma and Teo (2012). These stimuli have been psychophysically equated for discrimination difficulty across a number of studies in our laboratory and across several other studies (Deaton & Parasuraman, 1985; Fraulini, Claypoole, Dewar, & Szalma, 2016; Szalma & Teo, 2012).

Participants were seated approximately 50.8 centimeters from the desktop computer monitor in a uniformly lit, quiet cubicle. Data were collected from only one person at a time. A researcher was not present in the room for the vigil, but did return to administer the post-task surveys. All participants shut down electronic devices (e.g., cellphones, tablets, laptops, etc.) and surrendered watches (if worn) to the researcher prior to beginning the experiment.

Measures

The survey software controlled for order effects during administration by randomly counterbalanced pre- and post-task measures. All measures were completed prior to beginning the vigil (with the exception of the demographic information, post-Dundee Stress State Questionnaire, and NASA-TLX, which are post-task measures and administered at the end of the vigil). All measures were completed online using the Qualtrics system survey software on the desktop computer. Participants could leave an item blank if they did not wish to respond to it (this is in accordance with IRB protocol; i.e., no forced response). Participants could ask the researcher any questions at any time, except during the vigil in which the researcher left the room.

Individual Difference Measures of Motivation

Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI; Deci et al., 1994; Ryan, 1982) is a state measure of subjective experience related to intrinsic motivation and self-regulation. The IMI has been found to have strong reliability and validity across samples (McAuley, Duncan, & Tammen, 1989). The 25-item IMI consists of three subscales: perceived interest/enjoyment (8 items), value/usefulness (9 items), and choice/autonomy over (8 items) a selected activity.

Given the manipulations to the instructions in subsequent studies of this dissertation and the pilot work for this dissertation, only the autonomy/choice subscale of the IMI was utilized in the present study. Higher scores on the IMI autonomy/choice subscale indicate that participants feel more autonomous motivation toward the task than controlled motivation. The reliability of this measure for Experiment One is reported in Appendix I.

Achievement Motivation Scale

The Ray Achievement Motivation Scale (AMS; Ray, 1979) is a trait index of student achievement. The AMS has been cross-culturally validated and the average of the cross-validation reliabilities indicated that Cronbach's α = .70. The short form of the AMS consists of fourteen questions, with seven items requiring reverse scoring. Higher scores on the AMS indicate stronger motivation toward achievement and success. The reliability of this measure for Experiment One is reported in Appendix I.

Stress and Workload Measures

Dundee Stress State Questionnaire

The Dundee Stress State Questionnaire (DSSQ; Matthews et al., 2002) was used to assess the subjective stress levels of participants in the experiment. The long version (i.e., 70 to 90-item version, Matthews et al., 2002) yields eleven primary scales that measure the following: mood and affect, motivation, cognitive state, and thinking style, all of which are of particular interest to this dissertation. After reverse-scoring relevant items, the items corresponding to each subscale are then summed to compute a score for that particular subscale. Higher scores indicate more of that factor. For example, higher scores on the motivation subscales indicate higher motivation toward the task at pre- or post-task.

NASA-Task Load Index

The NASA-TLX (Hart & Staveland, 1988) has been used extensively to measure the perceived workload associated with sustained attention tasks (Warm, Dember, & Hancock, 1996). The NASA-TLX is comprised of six subscales: Mental Demand, Physical Demand, Temporal Demand, Performance, Frustration, and Effort. These six subscales are used to calculate an overall, or "global," workload score. Participants rate each subscale from 0 – 100, with 100 indicating a high level of workload and 0 reflecting very little. Next, participants completed fifteen paired comparisons. Participants are asked which subscale in each pair contributed more to workload, and these were used to compute a weighted scale score. Higher scores are indicative of greater workload.

Procedure

Participants arrived at the laboratory and were seated at a cubicle in the data collection room. Next, participants read and signed an electronic informed consent. Participants then proceeded to complete the pre-task individual difference measures (e.g., AMS, Autonomy/Choice subscale of the IMI) and pre-task stress measures (e.g., pre-DSSQ). Participants then completed a short set of practice trials (approximately one-two minutes in duration), which were designed to facilitate understanding of the presentation pace, as well as practice recognizing and responding to critical signals.

After the brief practice trial, participants completed either the cognitive or sensory vigilance task (participants were randomly assigned to either condition). Instructions within this practice trial explained how to complete the task. Participants were asked to press the spacebar if they detected a critical signal. When the vigil ended, participants completed all post-task measures (e.g., post-DSSQ, NASA-TLX). Demographic information was collected at the end of the study. Participants were given a post-participation form and thanked for their participation in the study. A visual representation of the procedures is illustrated in Figure 8.

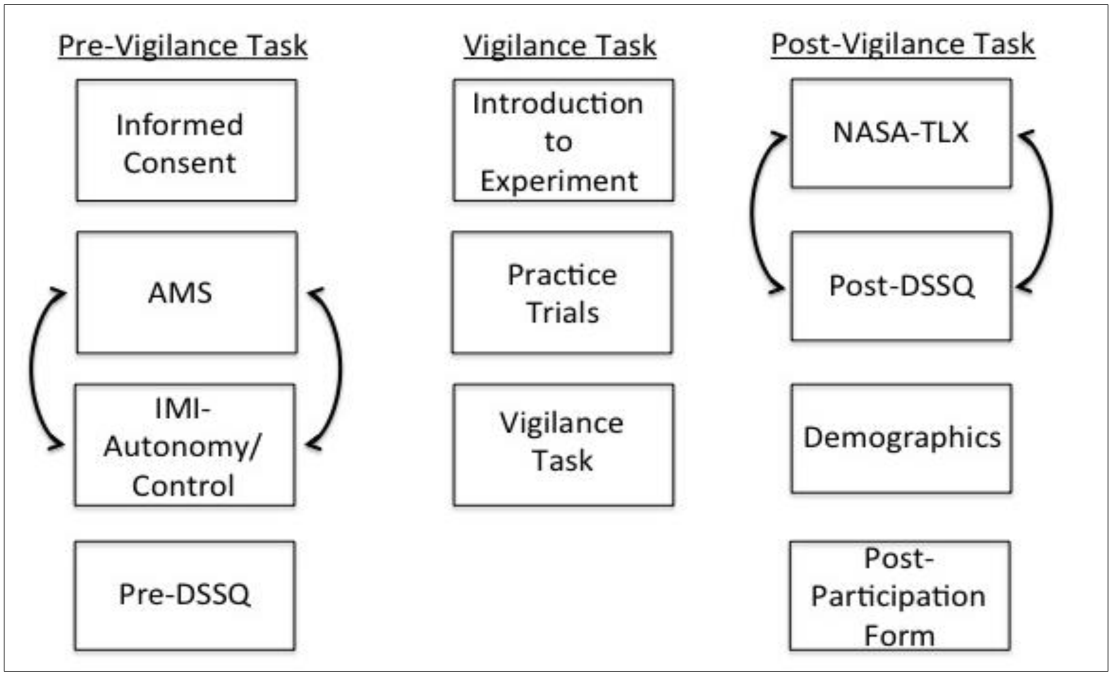


Figure 8. A pictorial representation of the procedures used in the present dissertation. Double arrows represent randomized counterbalancing of the measures to control for order effects.

Descriptive Statistics

Data from 79 undergraduate students (53 females; 26 males) was collected from the research psychology pool (SONA) at the University of Central Florida for Experiment One. Of the students who participated, 58.2% were freshmen, 15.2% were sophomores, 19.1% were juniors, and 7.6% were seniors. The average age of participants was 19.25 years (*Median* = 19.00 years, *SD* = 1.95 years). The oldest student in this sample was 30-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants indicated that they did not to consume caffeine 24 hours prior to this study.

The participants included in the present study did not differ substantially from those excluded from Experiment One (based on inclusion criteria). For example, the average age of participants that were excluded was 19.08 years of age (*Range*: 18 – 24), 3 male participants were removed, and 10 female participants were removed. There was only one significant difference between participants that were included and those that were excluded from analyses.

Participants differed significantly across post-task tense arousal; participants excluded from the present analyses reported a higher average post-task tense arousal score, which had a relatively large effect. The complete engagement, motivation, stress, and workload scores for the participants removed from Experiment One are listed in Appendix J. The effect sizes for analyses on the excluded data are included in Appendix K.

Results

Engagement and Motivation Measures

The average AchM score was 22.32 (*SD* = 3.68; *Range:* 16.00 – 32.00) and the average AuM score was 35.15 (*SD* = 10.36; *Range:* 7.00 – 49.00). There was a slight negative skew for AchM scores and a strong positive skew for AuM scores. AchM and AuM scores were used as covariates to conduct separate one-way Analyses of Covariance (ANCOVA) with task type as the independent variable and pre-task and post-task engagement and motivation measures as the dependent variables.

The purpose of the ANCOVA was to test for interactions between the individual difference variables (e.g., AchM and AuM, respectively) and the independent variables (e.g., task type, time on watch). Thus, the main effects of condition and time are not of primary concern in this dissertation, but are included for the purposes of completeness. The means and standard deviations of these measures are reported in Table 5. The means and standard deviations for the full DSSQ are reported in Appendix D.

Table 5. The table below includes the means and standard deviations for all measures of engagement and motivation (*N* = 79).

	Cognitive Task (*N* = 35)		Sensory Task (*N* = 44)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	22.63 (4.23)		22.07 (3.22)		22.32 (3.68)	
AuM	33.34 (9.47)		36.59 (10.91)		35.15 (10.36)	
Success Motivation	21.11 (5.58)	19.89 (7.05)	20.75 (6.53)	19.73 (7.49)	20.91 (6.09)	19.80 (7.25)
Intrinsic Motivation	25.43 (3.51)	15.97 (4.92)	24.43 (6.01)	14.84 (5.26)	24.87 (5.05)	15.34 (4.92)
Energetic Arousal	16.40 (4.49)	17.57 (4.41)	16.70 (3.80)	17.05 (4.02)	16.57 (4.10)	17.28 (4.18)
Concentration	15.09 (6.25)	7.94 (6.56)	15.88 (5.99)	6.23 (7.22)	15.53 (6.08)	6.99 (6.95)
TRTs	19.51 (7.78)	24.29 (7.49)	20.18 (8.15)	23.11 (7.00)	19.89 (7.94)	23.63 (7.20)
TUTs	17.86 (7.65)	15.03 (7.10)	17.50 (8.67)	14.77 (7.30)	17.66 (8.18)	14.89 (7.17)

Note. Numbers in parentheses represent standard deviations. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. TRTs and TUTs are proposed to be indicators of engagement under the mind-wandering account of vigilance. However, resource theorists argue that task engagement manifests through intrinsic motivation, success motivation, concentration and energetic arousal.

There was a significant main effect of AchM, but not condition, on pre-task energetic arousal, $F(1, 75) = 5.44$, $p = .022$, $\eta_p^2 = .068$, and post-task energetic arousal, $F(1, 75) = 5.36$, $p = .023$, $\eta_p^2 = .067$. There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant interaction between AuM and task type on post-task intrinsic motivation, $F(1, 76) = 3.28$, $p = .074$, $\eta_p^2 = .041$. There was a significant main effect of AuM, but not task type, on post-task energetic arousal, $F(1, 75) = 6.13$, $p = .016$, $\eta_p^2 = .076$, pre-task intrinsic motivation, $F(1, 76) = 6.55$, $p = .012$, $\eta_p^2 = .079$, and post-task task-unrelated thoughts, $F(1, 76) = 5.90$, $p = .018$, $\eta_p^2 = .072$. There was a significant correlation between AuM scores and pre-task intrinsic motivation ($r = .261$, $p < .004$) and post-task intrinsic motivation ($r = .426$, $p < .004$). No additional significant main effects, interactions, or correlations were observed for these analyses. These correlations are reported in Appendix C.

Stress and Workload Measures

AchM and AuM scores were used as covariates to conduct separate one-way ANCOVAs with task type as the independent variable and pre-task and post-task stress and workload measures as the dependent variables. The means and standard deviations of these measures are reported in Table 6. The means and standard deviations for the full NASA-TLX are reported in Appendix E.

Table 6. The table below includes the means and standard deviations for all measures of stress and workload (N = 79).

	Cognitive Task (N = 35)		Sensory Task (N = 44)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	12.86 (4.61)	17.03 (5.92)	13.05 (3.67)	15.40 (4.93)	12.96 (4.08)	16.13 (5.42)
Hedonic Tone	25.54 (4.25)	22.23 (4.22)	25.70 (3.73)	22.11 (4.36)	25.63 (3.94)	22.16 (4.27)
Anger/ Frustration	7.46 (3.16)	11.03 (4.46)	8.02 (3.61)	11.50 (4.65)	7.77 (3.41)	11.29 (4.55)
Global Workload		38.37 (14.37)		38.68 (12.50)		38.55 (13.27)
Mental Demand		42.91 (28.04)		31.55 (27.11)		36.58 (27.93)
Temporal Demand		36.85 (28.39)		34.32 (25.95)		35.44 (26.91)
Physical Demand		9.00 (8.34)		9.61 (9.77)		9.34 (9.11)
Perceived Performance		33.86 (25.45)		48.45 (34.51)		41.98 (31.50)
Effort		36.43 (26.50)		26.45 (23.22)		30.87 (25.06)
Frustration		34.69 (31.06)		34.98 (35.00)		34.84 (33.10)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations are reported for the NASA-TLX and are included for completeness.

There were no significant main effects or interactions when AchM was entered as the covariate. However, there was a significant correlation between AchM scores and pre-task anger/frustration, (r = -.300, $p < .01$), and post-task anger/frustration (r = -.485, $p < .01$). No additional significant main effects, interactions, or correlations were observed for these analyses.

There was a significant effect of AuM, but not task type, on post-task tense arousal, $F(1, 75) = 3.81$, $p = .055$, $\eta_p^2 = .048$, post-task hedonic tone, $F(1, 76) = 21.31$, $p < .001$, $\eta_p^2 = .219$, pre-task anger/frustration, $F(1, 76) = 8.55$, $p = .005$, $\eta_p^2 = .101$, and post-task anger/frustration, $F(1, 76) = 25.305$, $p < .001$, $\eta_p^2 = .250$. There were no additional significant main effects, interactions, or correlations to report for these analyses. These correlations are reported in Appendix F.

Performance Measures

Mixed-measures ANCOVAs with task type as the between-subjects variable, period on watch as the within-subjects variable, and AchM or AuM entered as the covariate were performed on all dependent measures related to performance (e.g., proportion of correct detections, number of false alarms, mean response time, sensitivity, and response bias). Separate ANCOVAs were performed for each of these dependent variables. The correlations between each type of motivation and the proportion of correct detections, number of false alarms, and mean response time are reported in Appendix G.

There were no significant main effects or interactions to report for proportion of correct detections when either AchM or AuM was entered into the separate mixed-measures ANCOVAs. However, performance in terms of correct detections tended to be variable. The proportion of correct detections tended to increase in Periods 2 and 4 for participants in the cognitive condition, while performance decline for participants in the sensory condition until Period 4 where an increase in proportion of correct detections was observed. The average proportion of correct detections over time is displayed in Figure 9.

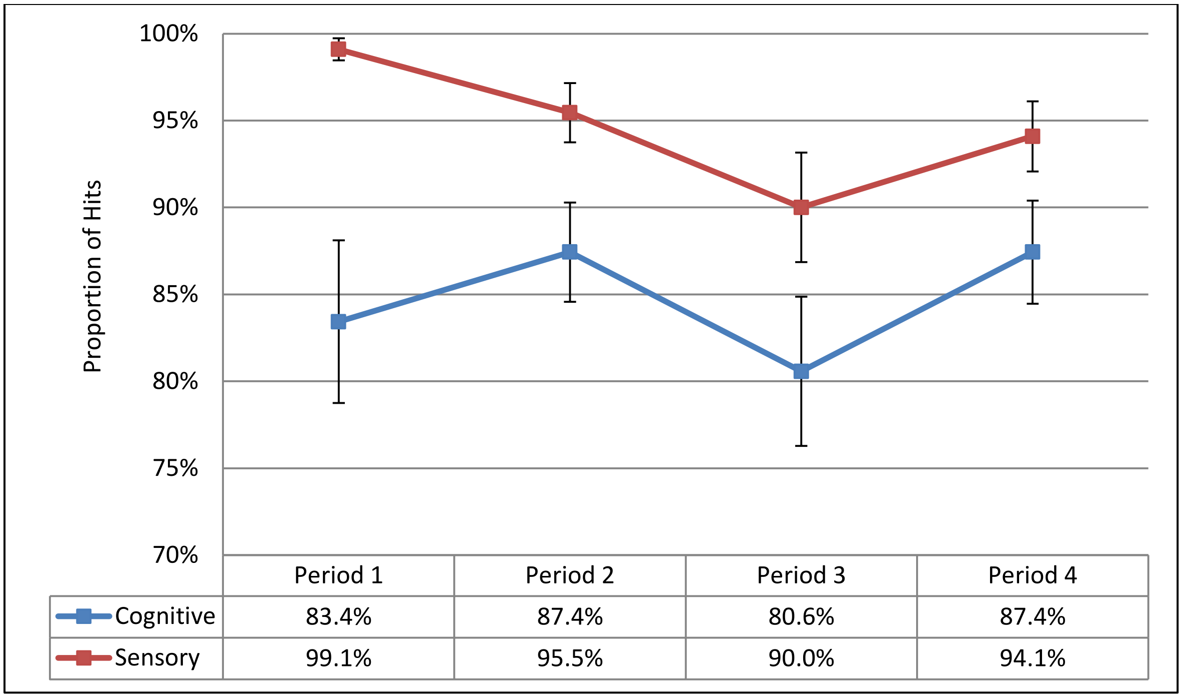
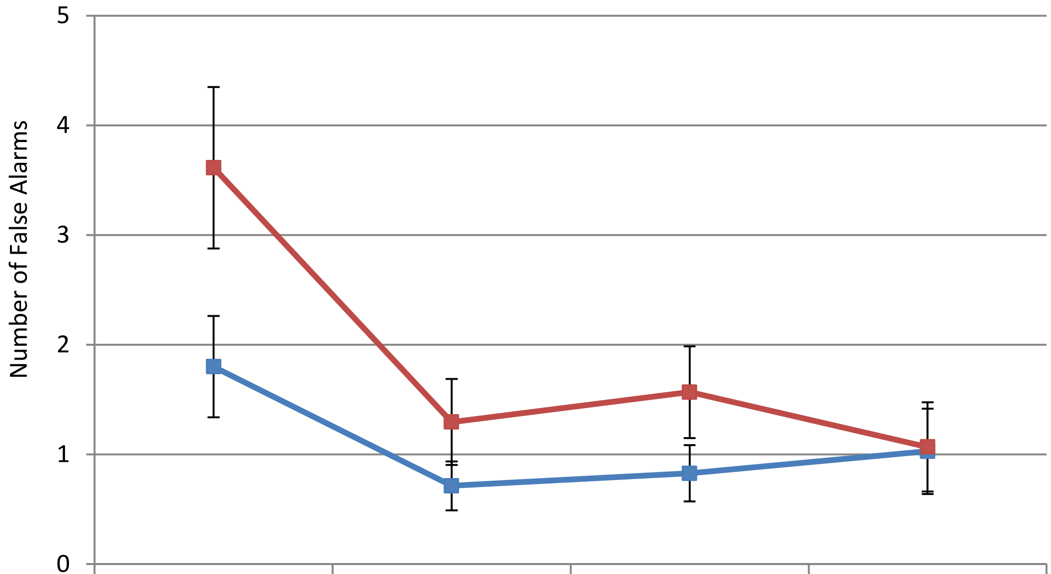


Figure 9. The average proportion of hits with standard errors bars are reported for the sensory and cognitive conditions for Experiment One.

Participants in the cognitive task tended to report fewer false alarms than participants in the sensory condition. Participants in the cognitive task also tended to report fewer false alarms as time on task increased.

When AuM was entered as the covariate into the mixed-measures ANCOVA, there was a significant main effect of period on watch on number of false alarms committed, $F(3, 225) = 3.41$, $p = .039$, $\eta_p^2 = .043$, $\varepsilon = .619$. There was a significant decline in the number of false alarms committed as a function of period on watch. There were no additional significant main effects or interactions to report for this analysis. There were no significant main effects or interactions observed when AchM was entered into the mixed-measures ANCOVA. The average number of false alarms committed over time is reported in Figure 10.



	Period 1	Period 2	Period 3	Period 4
Cognitive	1.8000	.7143	.8286	1.0286
Sensory	3.6136	1.2955	1.5682	1.0682

Figure 10. The number of false alarms with standard error bars are reported for the sensory and cognitive conditions for Experiment One (N = 79).

Participants in the sensory task reported lower response times for each period on watch, compared to participants in the cognitive task. This finding is not unexpected given that the cognitive task requires symbolic processing (i.e., performing simple subtraction) and the sensory task requires perceptual processing (i.e., discriminating between larger and smaller digits).

There was a nearly significant main effect of AuM when it was entered into the mixed-measures ANCOVA as the covariate, $F(1, 75) = 3.57$, $p = .063$, $\eta_p^2 = .046$. Average response time tended to decrease as autonomous motivation scores increased, according to correlation analyses, which were albeit non-significant. There were no significant main effects or interactions for response time when AchM was entered into the mixed-measures ANCOVA. The means and standard deviations for response time are reported in Figure 11.

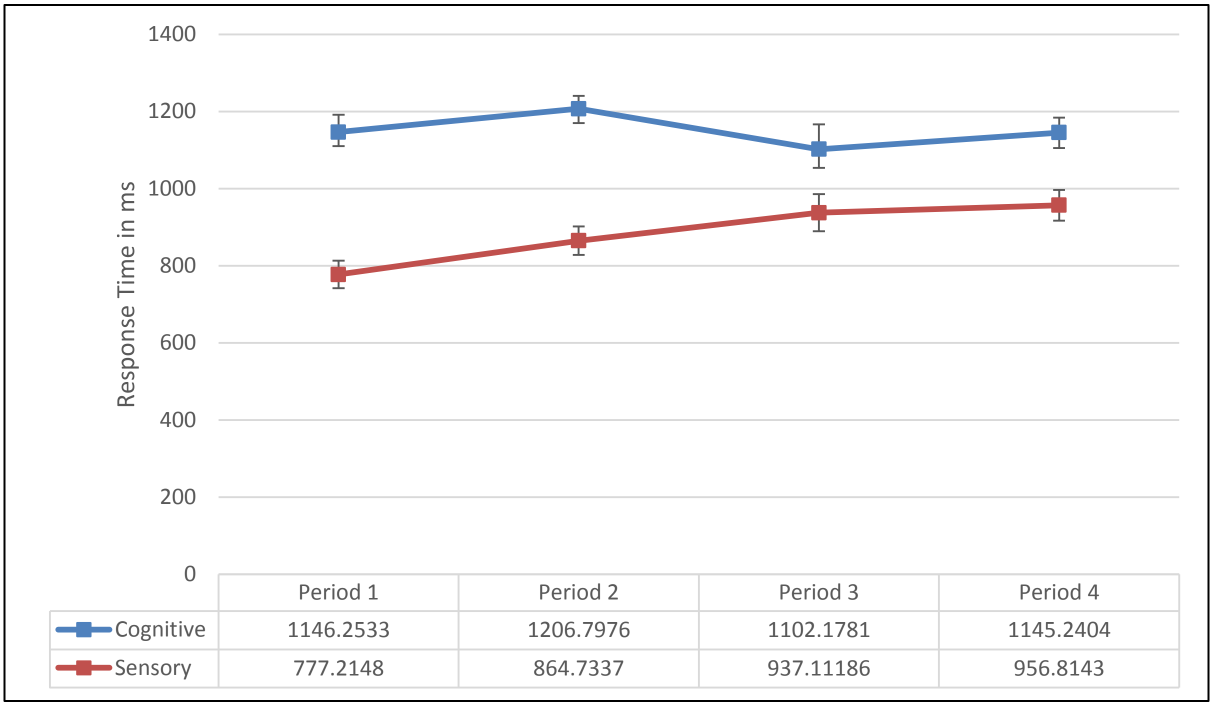


Figure 11. The figure above includes the means and standard errors for the average response time between conditions (*N* = 79). *Note*. Response time is reported in milliseconds.

<u>Sensitivity and Response Bias</u>

The proportion of correct detections and false alarms were used to compute indices of sensitivity (*d'*; reported in Figure 12) and response bias (*c*; reported in Figure 13; See et al., 1995). Separate mixed-measures ANCOVA with task type as the between-subjects variable, period on watch as the within-subjects variable, and AchM or AuM as the covariate were performed for sensitivity and response bias. While the cognitive and sensory task stimuli have been psychophysically equated previously in the literature, it cannot be determined if they are equated in the present Experiment. There were significant differences between the two task types in terms of response bias, but both groups generally trended toward more conservative responding over time.

There was a main effect of watch period, but not task type or AchM, on sensitivity, $F(3, 73) = 2.60$, $p = .053$, $\eta_p^2 = .033$. Pairwise comparisons indicated that there was a significant difference in sensitivity between Periods 1 and 2 ($p < .001$), Periods 1 and 4 ($p = .587$), Periods 2 and 3 ($p = .006$), and Periods 3 and 4 ($p = .003$). The results indicated that sensitivity increased between Periods 1 and 2 and then Periods 3 and 4, but decreased between Periods 2 and 3.There were no other significant pairwise comparisons for period of watch. There were no other significant main effects or interactions to report for these analyses. Achievement motivation was not significantly correlated with sensitivity.

There were no significant main effects, interactions, or correlations to report for period on watch, task type, or AchM on response bias. Achievement motivation was not significantly correlated with response bias. Response bias tended to increase for both conditions, which indicates that participants were more conservative in their responses over time.

There were no significant main effects, interactions, or correlations to report for period on watch, task type, or AuM on sensitivity or response bias. Correlations are reported in Appendix H.

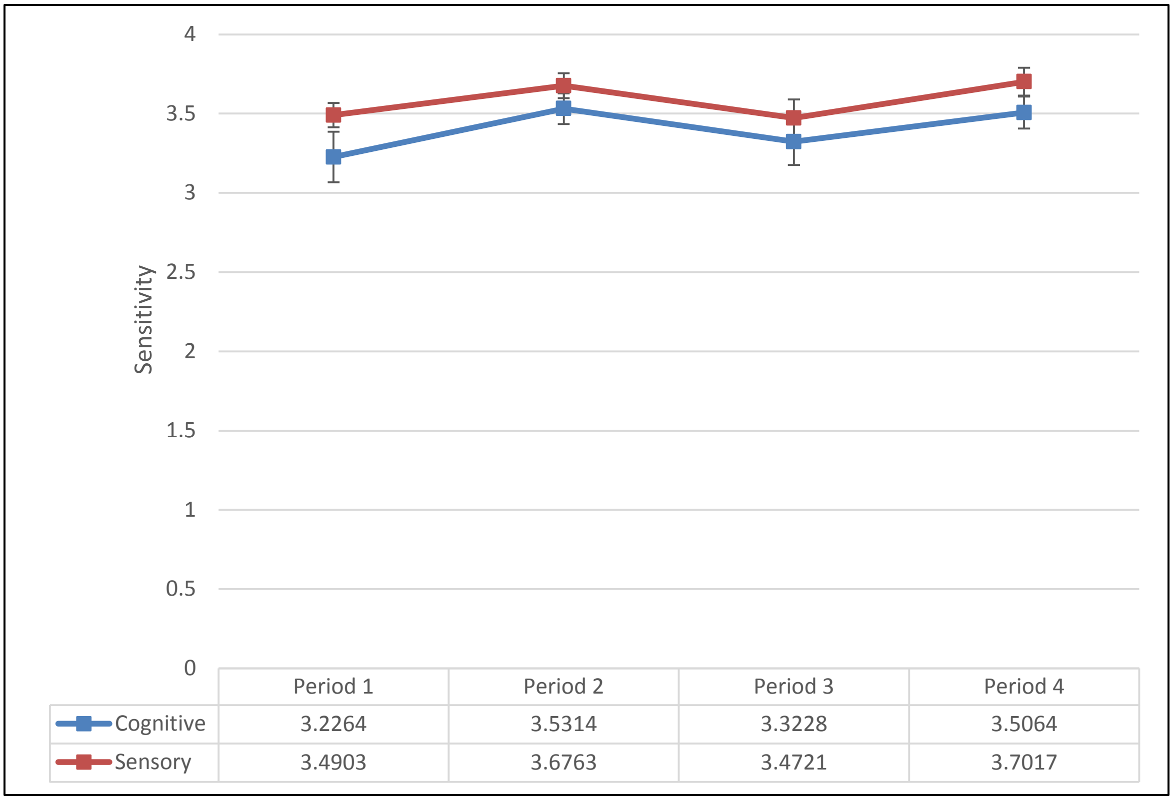


Figure 12. The figure above includes the means and standard errors for changes in sensitivity across conditions and over time (*N* = 79).

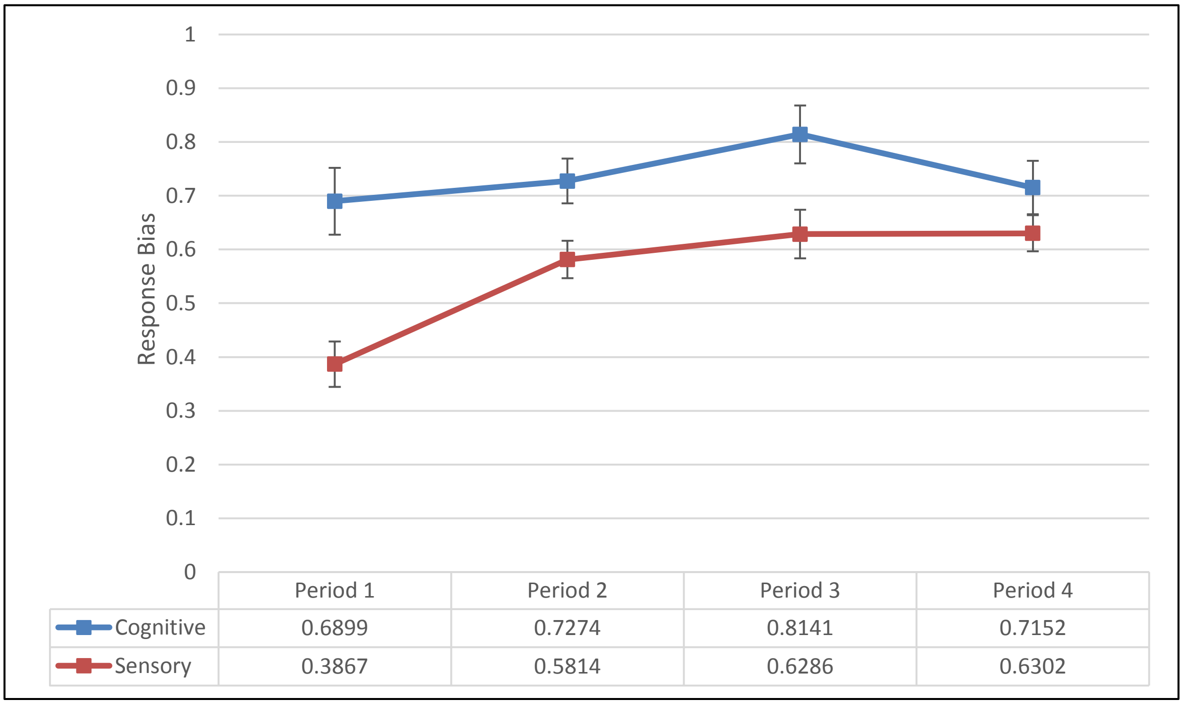


Figure 13. The figure above includes the means and standard errors for changes in response bias across conditions and over time (N = 79).

Discussion

Engagement and Motivation

The results of Experiment One indicated that motivation is not necessarily a unified construct; rather specific types of motivation may influence specific components of vigilance performance. For example, achievement motivation was negatively related to energetic arousal at pre-task and post-task, but autonomous motivation was not. However, achievement motivation and autonomous motivation were both related to post-task cognitions, or post-task unrelated thoughts. This implies that achievement motivation and autonomous motivation likely change perceptions of the task once it is completed, or dictate the amount of energy required of the individual prior to beginning the vigilance task. The following three experiments included in this dissertation will test this claim.

One issue identified in Experiment One was the lack of convergence between achievement motivation and success motivation. Theoretically, both measures of motivation should indicate a moderate, positive, and significant correlation, despite one measure being a state measure and the other being a trait measure. However, this was not the case in Experiment One. This finding calls into question the validity and reliability of the selected measure of achievement motivation, the Ray Achievement Motivation Scale. To further elucidate the reliability of this measure, it will be utilized in Experiments Two and Three to establish reliability across two new samples of undergraduate students. It is important to note that it is unlikely that success motivation in the DSSQ is operationalized poorly due the robust item selection procedures that were utilized in the generation of the original DSSQ (Matthews et al., 2002). It is suspected that the Ray Achievement Motivation Scale may have issues because it has not been cross-culturally validated in a North American sample and the short version of the scale has received less testing and validation than the long form. In a reliability analysis, the Achievement Motivation Scale (Ray, 1979) demonstrated a Cronbach's alpha of .530 (14 items), which is not indicative of a strong reliability. Furthermore, participant data indicated a slight negative skew in achievement motivation, which indicates that participants in the sample in fact reported lower scores for this trait measure (this is potentially a restriction of range issue).

In relation to the theories of information processing, the evidence demonstrated an increase in post-task task-related thoughts, which indicates that participants were concerned about their performance and cogitating on that performance at post-task. Anecdotally, many participants were interested to know how they performed when the task concluded and asked the researcher if they could see their results. This desire to have knowledge of their results is not particularly unexpected considering performance feedback was not provided during this study.

The findings related to cognitive engagement (i.e., post-task task-related and unrelated-thoughts) do not align with the assumptions of mind-wandering theory, which suggests that participants either actively or passively disengage during a vigilance task causing the decrement. These findings also do not support the mindlessness theory of vigilance, which suggests the mind is thoughtless during vigilance performance and this results in the performance decrement. No such decrement, as it is traditionally defined in the vigilance literature, was observed in either task. In order to support mind-wandering theory, an increase in task-related thoughts at post-task should not be observed; rather an increase in task-unrelated thoughts at post-task would need to be observed. To conclude, preliminary evidence suggests that motivation could offset some performance declines associated with vigilance performance, albeit it may not be a significant effect of motivation on performance.

Stress and Workload

Participants in the cognitive task did not report significantly more global workload than participants in the sensory condition. However, there was a significant difference between task types in the amount of perceived mental effort that the task required. As hypothesized, participants in the cognitive condition reported that the task was moderately effortful (Grier, 2015). These results support resource theory in that more resources are required for processing due to the effortful nature of the cognitive task.

There were no significant correlations between achievement motivation and any of the stress and workload measures. This is indicates that achievement motivation is unlikely to be related to perceiving and coping with stress. However, as previously noted, the selected measure of achievement motivation may have not been appropriate as it has not been normed in a North American sample.

Interestingly, autonomous motivation was significantly related to post-task tense arousal, hedonic tone, and anger/frustration, which implies that autonomous motivation may affect the stress and workload that are perceived post-vigil. Autonomous motivation appeared to moderately correlate with lower tense arousal and anger/frustration at pre-task and post-task. It is possible that autonomous motivation may act as a coping mechanism, which serves to lower anger and frustration toward the task. However, additional studies are required to test this claim. This finding is important for informing Experiment Three as motivation should further offset the negative aspects of the vigilance task when compounded with task instructions that support autonomy.

To summarize, achievement motivation does not appear to be helpful in coping with the stress and workload associated with the task and has some limited involvement with engagement in vigilance. The evidence seems to indicate that participants higher in autonomous motivation may be more resilient to the demand and stress associated with vigilance tasks. It is likely the case that autonomous motivation is a coping mechanism for the negative aspects of the vigilance task, but Experiments Two, Three, and Four are required to test this idea.

Performance

In terms of performance, it was clear that the cognitive task was more challenging to perform than the sensory task. Participants in the cognitive condition exhibited longer response times, less correct detection, and tended to commit more false alarms than participants in the sensory task. Furthermore, the signal detection analyses indicate an increase in response bias over periods on watch, which implies a shift toward more conservative responses over time for both groups. Analysis of sensitivity scores indicated that the two groups were equivalent in their ability to distinguish critical signals from neutral events. While the cognitive task may have required more information processing and was perceived as more mentally demanding and frustrating, the sensory task was not immune to the vigilance decrement (at least in terms of correct detections reported for Periods 1 through 3 on watch). The lack of challenge associated with the detection of perceptual stimuli resulted in a vigilance decrement during these periods of watch.

To summarize, the results of the data from Experiment One related to engagement, stress, workload, and performance tend to support to the resource-depletionist account of vigilance, which suggests that cognitive resources are required to maintain vigilance. The respective effects of achievement motivation and autonomous motivation suggest that motivation changes these aspects of vigilance, which could explain the sporadic improvements in performance in the cognitive condition and an increase in performance toward the end of the vigil in the sensory condition.

CHAPTER SIX: EXPERIMENT TWO

Experiment Two extended the work of Experiment One by increasing the information processing requirements of the task by incorporating source complexity (i.e., increasing the number of displays) into the task design. One purpose of this study was to understand the role of motivation in varyingly complex vigilance tasks. Experiment Two demonstrated how changes in task type and source complexity interact with motivational differences. This experiment tested the idea that individual differences in motivation can offset or potentially eliminate the vigilance decrement.

In addition to studying how motivation affects performance, another goal of this study is to manipulate task design to elicit a vigilance decrement. In this study, it was possible to test the claim that vigilance is a psychological phenomenon afforded by the task (Hancock, 2013; Hancock et al., 2016). To conclude, in Experiment Two participants were randomly assigned to monitor one, two, or four displays and were randomly assigned to the two types of vigilance tasks (e.g., cognitive or sensory).

Hypotheses

Engagement and Motivation Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) should be significantly related to the level of engagement and motivation at post-task. Task engagement and motivation will be measured by energetic arousal, concentration, success motivation, intrinsic motivation, task-related thoughts (TRTs), and task-unrelated

thoughts (TUTs). Cognitive task engagement will be measured using concentration, TRTs, and TUTs.

2) Specific hypotheses related to cognitive engagement were developed given the three theories of information processing:

    a. Under the resource theory account of vigilance, AchM and AuM should be significantly related to concentration at post-task, but not under the mindlessness or mind-wandering account.

    b. If cognitively engaged with the task, AchM or AuM should be significantly related to increased TRTs at post-task under the resource-depletion account.

    c. According to mindlessness theory, there should be few if any TRTs.

    d. Under the mind-wandering assumption, there will be high TRTs at pre-task and low TRTs at post-task, regardless of the type of motivation involved in vigilance.

    e. Assuming a resource theory perspective, if individuals are engaged with the task, participants AchM or AuM should be related to a significant decrease in TUTs at post-task.

f. According to mindlessness theory, there should be more TUTs as the mind drifts away from the task because vigilance tasks afford this behavior.

g. Under the mind-wandering assumption, there will be high TUTs if disengaged with the task, especially at post-task as inward or outward task-unrelated thoughts increase during the vigil.

Stress and Workload Measures

3) Achievement motivation (AchM) and autonomous motivation (AuM) may affect stress and workload. Stress and workload will be measured by tense arousal, hedonic tone, anger/frustration, and global workload. Thus, the hypotheses are as follows:

   a. AchM and AuM should be significantly related to tense arousal. Participants lower in motivation will lack effective coping strategies to overcome the monotony associated with the task.

   b. AchM and AuM should be significantly related to higher hedonic tone because these individual differences are related to finding enjoyment in the task.

   c. AchM and AuM should be significantly related to anger/frustration. Participants lower in motivation will lack effective coping strategies related to managing perceived anger and frustration.

4) It is hypothesized that the cognitive task will be perceived as more work than the sensory task based on previous evidence from the existing literature on vigilance.

    a. However, participants high in AchM and AuM may be significantly related to global workload. It is possible that participants high in AchM or AuM will approach the cognitive task as if it is a complex challenge, which may reduce overall perceived workload.

<u>Performance Measures</u>

1) Proportion of correct detections, number of false alarms, average response time, and the signal detection theory measures of sensitivity and response bias.

2) AchM and AuM should be significantly related to the proportion of correct detections because individuals high in these differences want to strive toward success and perceive control over their performance.

3) Similarly, AchM and AuM should be significantly related to the number of false alarms because individuals high in these differences want to strive toward success and perceive control over their performance, thus reporting a low number of false alarms over time.

4) AchM and AuM may be significantly related to mean response time because previous literature has demonstrated that motivation is linked to attention.

Participants

An *a priori* power analysis was conducted for Experiment Two using G*Power Version 3.1 with a medium effect size and conventional criteria (α = 0.05, 1-β = 0.80; Faul et al., 2007) to estimate power and effect sizes prior to data collection. Following this analysis, approximately 130 participants needed to be recruited from the University of Central Florida's psychology research participation system (SONA) to achieve the desired statistical power. ANCOVA was utilized for statistical analyses because the covariates AchM and AuM are continuous variables.

To qualify for participation in Experiment Two, participants reported normal or corrected-to-normal vision and were at least 18 years of age or older. Participants were not allowed to participate in multiple forms of this study, meaning if participants completed Experiment One, they were not able to participate in Experiments Two, Three, or Four. A new sample of SONA participants was obtained for each experiment in this dissertation. Participants indicated that they did not consume caffeine 24 hours prior to the study.

Data Cleaning and Final Sample

One hundred and thirty participants were collected from the SONA study pool for Experiment Two. Six of these participants were removed from the sample for incomplete SuperLab data.

The inclusion criteria were as follows: participants achieved a minimum score of 70% correct detections (i.e., hits) in the first watch period and did not commit more than ten false alarms in any given watch period, and participants had not previously participated in Experiment One. The same rationale from Experiment One for the use of this performance cutoff applies to Experiment Two.

After data cleaning, the final sample for this study consisted of 105 undergraduate students. Nineteen participants were removed from this sample because of performance deviations that did not meet the inclusion criteria. More specifically, three participants were removed from the sensory one display condition, two participants were removed from the sensory two display condition, five participants were removed from the sensory four display condition, three participants were removed from the cognitive one display condition, one participant was removed from the cognitive two display condition, and five participants were removed from the cognitive four display condition.

Design

In Experiment Two, participants were randomly assigned to either the cognitive or sensory task and were required to monitor one, two, or four displays (randomized and counterbalanced) to increase the complexity of the task to facilitate changes in processing demand and observe the effect of motivation in a much more complex vigilance task (see Table 7).

Table 7. The table below indicates the conditions to which participants were randomly assigned in Experiment Two.

Task Type	Source Complexity	Number of Participants Assigned to Each Condition
Cognitive	One Display	13
	Two Displays	20
	Four Displays	9
Sensory	One Display	20
	Two Displays	26
	Four Displays	17

Task Stimuli and Environment

The task stimuli and experimental environment used in Experiment Two were identical to participants used in Experiment One.

Measures

The same measures from Experiment One were used in Experiment Two. The reliabilities of these measures for Experiment Two are reported in Appendix I.

Procedure

The procedure for Experiment Two was the same as Experiment One, with one exception. Participants were randomly assigned to one of six conditions: 1) a cognitive task with one display, 2) a cognitive task with two displays, 3) a cognitive task with four displays, 4) a sensory task with one display, 5) a sensory task with two displays, or, 6) a sensory task with four displays.

Descriptive Statistics

One hundred and five undergraduate students (68 females; 35 males; 2 transgender) were recruited from the SONA psychology research pool at the University of Central Florida for Experiment Two. Of participants who participated, 63.1% were freshmen, 15.2% were sophomores, 13.2% were juniors, and 8.5% were seniors. The average age of participants was 19.44 years (*Median* = 19.00 years, *SD* = 2.40 years). The oldest student in this sample was 32-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants indicated that they did not to consume caffeine 24 hours prior to this study.

The participants included in the present study did not differ substantially from those excluded from Experiment Two (based on inclusion criteria). For example, the average age of participants that were excluded was 19.74 years of age (*Range*: 18 – 29), 5 male participants were removed, and 14 female participants were removed. There was only one significant difference between participants that were included and those that were excluded from analyses.

Participants differed significantly across pre-task concentration; participants excluded from the present analyses reported a higher average pre-task concentration score, which had a relatively large effect. The complete engagement, motivation, stress, and workload scores for the participants removed from Experiment Two are listed in Appendix J. The effect sizes for analyses on the excluded data are included in Appendix K.

Results

<u>Engagement and Motivation Measures</u>

The average AchM score was 21.92 (*SD* = 3.40; *Range:* 17.00 – 32.00) and the average AuM score was 35.47 (*SD* = 9.35; *Range:* 13.00 – 49.00) across all conditions. There was a moderate negative skew for achievement motivation scores and a robust positive skew for autonomous motivation scores, which indicates that many participants in this sample reported being high in this state motivation.

A two (condition) x three (number of displays) ANCOVA with AchM or AuM as the covariate was performed on all dependent measures related to motivation and engagement (note:

the same measures from Experiment One were used). Separate ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of these measures across task types are reported in Table 8. The means and standard deviations of these measures across number of displays are reported in Table 9. Correlations of AchM and AuM with the engagement and motivation measures are reported in Appendix C.

Table 8. The table below includes the means and standard deviations for all measures of motivation and engagement across task type (N = 105).

	Cognitive Task (N = 42)		Sensory Task (N = 63)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	22.40 (3.43)		21.60 (3.37)		21.94 (3.39)	
AuM	34.07 (9.56)		36.41 (9.17)		35.37 (9.37)	
Success Motivation	12.36 (7.57)	16.95 (6.90)	14.92 (8.28)	19.94 (6.42)	13.92 (8.03)	18.79 (6.74)
Intrinsic Motivation	21.86 (4.63)	11.74 (4.66)	21.03 (5.07)	11.60 (5.23)	21.32 (4.88)	11.63 (4.97)
Energetic Arousal	15.95 (3.72)	17.19 (4.07)	16.98 (4.03)	17.22 (4.30)	16.56 (3.91)	17.18 (4.18)
Concentration	21.88 (5.49)	9.36 (6.34)	21.82 (6.35)	6.63 (6.73)	21.78 (6.00)	7.71 (6.65)
TRTs	10.93 (8.66)	21.21 (7.17)	11.37 (8.28)	20.75 (5.51)	11.25 (8.38)	20.94 (6.17)
TUTs	9.76 (8.99)	14.19 (7.17)	9.95 (8.64)	16.06 (6.63)	9.93 (8.72)	15.25 (6.88)

Note. Numbers in parentheses represent standard deviations.

Table 9. The table below includes the means and standard deviations for all measures of motivation and engagement across the number of displays (*N* = 105).

	One Display (*N* = 33)		Two Displays (*N* = 46)		Four Displays (*N* = 26)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	22.24 (2.86)		21.67 (3.54)		21.96 (3.93)	
AuM	35.42 (9.65)		34.63 (9.53)		37.44 (8.74)	
Success Motivation	14.21 (9.13)	19.52 (7.65)	14.13 (7.43)	17.83 (5.12)	13.00 (8.14)	19.80 (7.92)
Intrinsic Motivation	21.03 (4.21)	11.06 (5.28)	21.85 (4.94)	12.28 (4.81)	20.72 (5.67)	11.20 (5.05)
Energetic Arousal	16.06 (3.95)	16.48 (4.66)	17.23 (3.65)	17.73 (3.62)	16.08 (4.39)	17.44 (4.43)
Concentration	21.64 (6.57)	7.82 (7.25)	20.82 (5.99)	8.13 (5.99)	24.08 (4.38)	6.76 (7.36)
TRTs	10.21 (9.05)	19.06 (6.04)	12.00 (7.43)	21.26 (5.27)	11.12 (9.46)	22.96 (7.46)
TUTs	9.36 (8.26)	14.00 (6.78)	10.76 (8.05)	15.08 (6.78)	8.96 (10.53)	17.38 (6.95)

Note. Numbers in parentheses represent standard deviations.

There was a significant interaction between task type and number of displays, but not AchM, on post-task task-related thoughts, $F(2, 93) = 3.40$, $p = .038$, $\eta_p^2 = .068$. Participants in the cognitive condition observing four displays reported the greatest number of post-task task-related thoughts ($M = 24.75$, $SD = 9.59$), whereas participants in the sensory condition observing only one display reported the fewest post-task task-related thoughts ($M = 19.52$, $SD = 4.59$).

There was a significant three-way interaction between condition, number of displays, and AuM, on post-task energetic arousal, $F(2, 93) = 3.43$, $p = .037$, $\eta_p^2 = .069$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task energetic arousal, only one result was significant. There was a significant effect of the covariate AuM on post-task energetic arousal in the cognitive task wherein participants monitored only one display, $F(1, 11) = 4.92$, $p = .049$, $\eta_p^2 = .309$.

Participants in the sensory condition observing only one display ($M = 16.38$, $SD = 4.05$) and four displays ($M = 16.23$, $SD = 4.29$) reported the lowest levels of energetic arousal at post-task. There was also a significant main effect of number of displays on post-energetic arousal, $F(2, 93) = 4.59$, $p = .012$, $\eta_p^2 = .089$. Participants in the cognitive task observing two ($M = 17.40$, $SD = 2.96$) or four displays ($M = 18.75$, $SD = 4.33$) reported the most energetic arousal at post-task. Participants in the sensory task displayed some of the lowest energetic arousal at post-task, which is similar to what was observed at pre-task.

There was also a significant main effect of task type on post-task concentration, $F(1, 93) = 3.41$, $p = .068$, $\eta_p^2 = .035$. Participants in the cognitive task reported more concentration at post-task than participants in the sensory condition.

There was a significant correlation between autonomous motivation and post-task success motivation ($r = .227$, $p < .05$), pre-task intrinsic motivation ($r = .344$, $p < .01$), post-task intrinsic motivation ($r = .355$, $p < .01$), and pre-task concentration ($r = .217$, $p < .05$). No additional significant correlations, main effects, or interactions were observed with autonomous motivation as a covariate.

Stress and Workload Measures

A two (condition) x three (number of displays) ANCOVA with either AchM or AuM as the covariate was performed on all outcome measures related to stress and workload. Separate

ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of these measures by task type are reported in Table 10. The means and standard deviations of these measures by number of displays are reported in Table 11. The means and standard deviations for the full DSSQ and NASA-TLX are reported in Appendix D. The correlations between measures of stress and workload and the covariates are included in Appendix F.

Table 10. The table below includes the means and standard deviations for all measures of stress and workload across task types (*N* = 105).

	Cognitive Task (*N* = 42)		Sensory Task (*N* = 63)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	12.14 (3.40)	15.50 (5.92)	13.02 (3.41)	15.13 (4.42)	12.65 (3.40)	15.29 (5.03)
Hedonic Tone	25.21 (4.02)	21.74 (3.64)	25.67 (4.14)	22.62 (4.10)	25.46 (4.07)	22.22 (3.94)
Anger/ Frustration	7.24 (2.66)	10.52 (4.44)	8.56 (3.72)	10.89 (4.02)	8.00 (3.38)	10.83 (4.25)
Global Workload		41.45 (13.23)		31.17 (24.05)		39.25 (12.84)
Mental Demand		43.26 (27.63)		32.35 (25.36)		36.61 (26.71)
Temporal Demand		34.38 (28.54)		23.68 (22.50)		28.26 (25.58)
Physical Demand		11.05 (15.45)		8.76 (8.50)		9.96 (12.07)
Perceived Performance		60.45 (31.92)		48.62 (32.84)		53.75 (32.93)
Effort		35.74 (27.88)		25.22 (22.33)		29.91 (25.47)
Frustration		30.81 (29.53)		33.24 (30.79)		32.81 (30.55)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

Table 11. The table below includes the means and standard deviations for all measures of stress and workload across number of displays (N = 105).

	One Display (N = 33)		Two Displays (N = 46)		Four Displays (N = 26)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	12.46 (2.89)	13.54 (4.29)	12.72 (3.99)	15.59 (4.53)	12.80 (2.97)	17.20 (6.13)
Hedonic Tone	25.06 (4.37)	22.57 (4.24)	25.30 (4.18)	22.02 (4.00)	26.32 (3.38)	22.08 (3.49)
Anger/ Frustration	8.26 (3.18)	11.26 (4.83)	7.89 (3.68)	10.34 (4.01)	7.84 (3.16)	11.12 (3.89)
Global Workload		39.59 (9.33)		35.49 (13.20)		45.09 (13.86)
Mental Demand		38.37 (27.12)		31.61 (25.17)		44.19 (27.86)
Temporal Demand		23.83 (22.77)		23.78 (20.43)		42.81 (31.89)
Physical Demand		12.14 (13.79)		9.98 (12.81)		6.81 (6.49)
Perceived Performance		43.46 (33.89)		61.72 (32.74)		53.73 (28.27)
Effort		29.27 (23.90)		28.63 (26.71)		31.04 (24.60)
Frustration		24.45 (27.51)		37.02 (30.59)		33.77 (31.78)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

There was a significant main effect of condition on post-task tense arousal, $F(1, 93)$ = 6.32, p = .014, η_p^2 = .063. Participants in the cognitive condition (M = 19.50, SD = 7.03) and sensory condition (M = 16.12, SD = 5.56) observing four displays reported the greatest post-task tense arousal across the groups. Participants observing only one display in either the sensory or cognitive condition reported the lowest levels of post-task tense arousal. No additional main effects or interactions were observed with achievement motivation as a covariate. No significant correlations between AchM and the workload and stress measures were observed.

There was a significant main effect of AuM on post-task hedonic tone, $F(1, 93) = 3.62$, $p < .001$, $\eta_p^2 = .131$. Similar post-task hedonic tone was reported across participants in the sensory conditions, regardless of the number of displays. Participants in the cognitive condition monitoring two ($M = 21.25$, $SD = 2.84$) or four displays ($M = 21.87$, $SD = 3.72$) reported the lowest post-task hedonic tone. Participants in the sensory condition observing only one display reported the most anger/frustration at post-task ($M = 11.90$, $SD = 4.47$).

There was a significant correlation between AuM and pre-task hedonic tone ($r = -.212$, $p < .05$), post-task hedonic tone ($r = .402$, $p < .01$), pre-task anger/frustration ($r = -.277$, $p < .05$), and post-task anger/frustration ($r = -.212$, $p < .05$). It is possible that participants high in autonomy may have found the lack of autonomy in the study stressful before completing the task. However, the correlation between post-task hedonic tone and AuM reversed direction. No further significant correlations, main effects, or interactions were observed with autonomous motivation as a covariate.

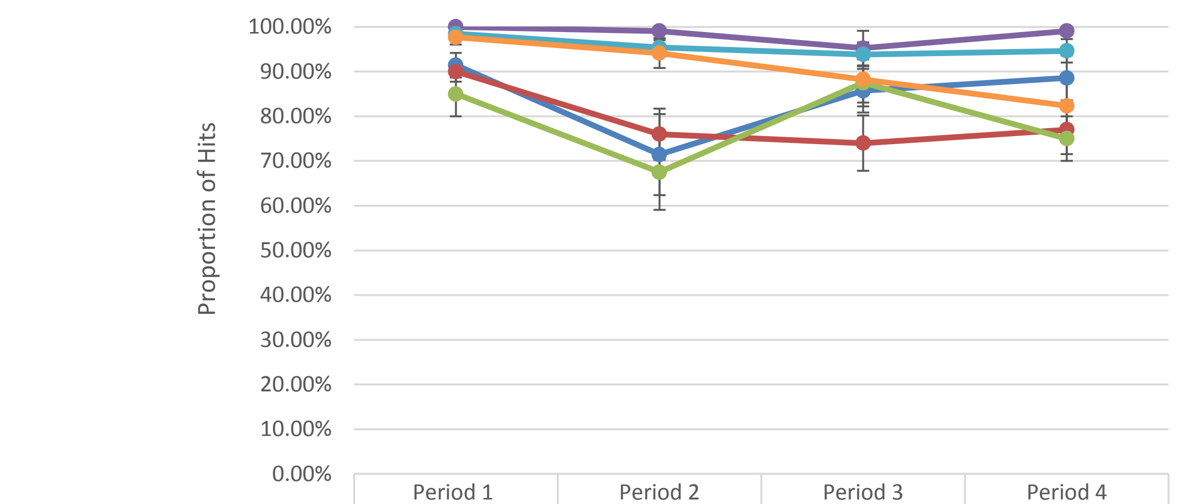
Performance Measures

Mixed-measures ANCOVAs with task type and number of displays as the between-subjects factor, period on watch as the within-subjects factor, and AchM or AuM as the covariate were performed on all measures related to. Separate ANCOVAs were performed for each of these dependent measures. Performance varied greatly based on task type and number of displays. Correlations between the measures of performance and the covariates are included in

Appendix G. The means and standard deviations of the proportion of correct detections are reported in Figures14, 15, and 16.

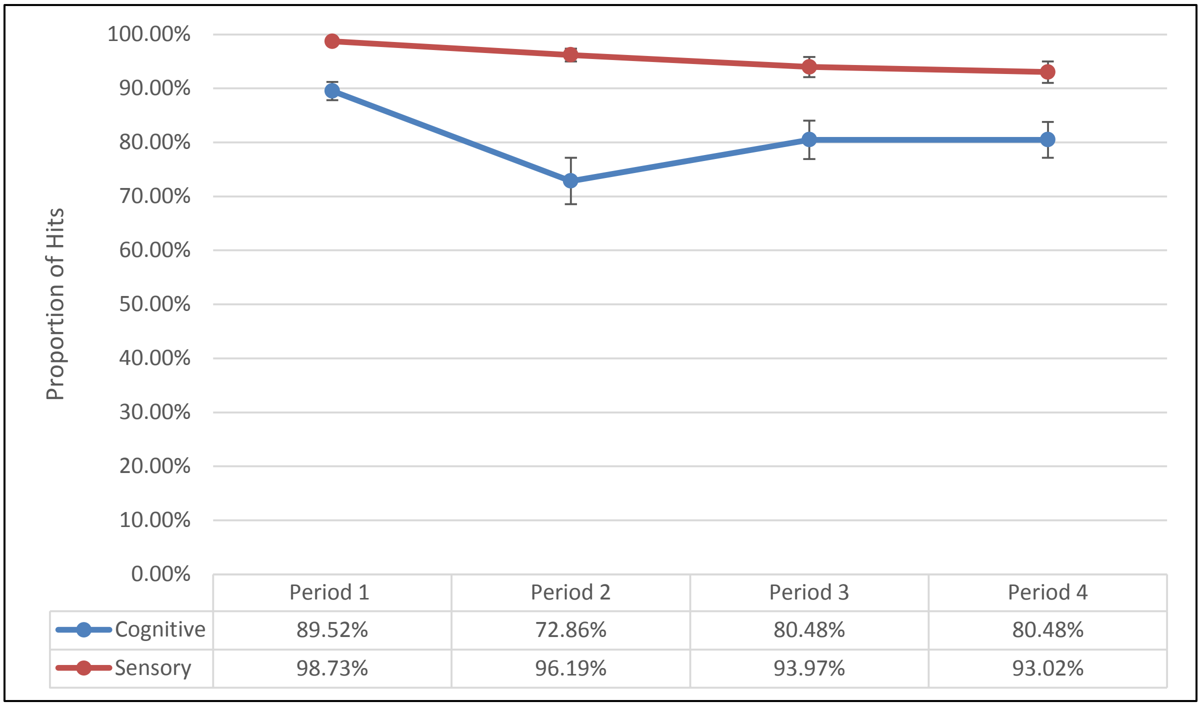
There was a nearly significant interaction between task type and period, but not AuM, on proportion of correct detections, $F(3, 279) = 2.62$, $p = .051$, $\eta_p^2 = .027$. There was also a significant main effect of period on watch on proportion of correct detections, $F(3, 279) = 3.944$, $p = .009$, $\eta_p^2 = .041$. Participants in the sensory condition detected significantly more targets than participants in the cognitive condition over time. There was also a significant correlation between AuM and the proportion of correct detections in Period 3 of watch ($r = .306$, $p < .01$) and overall correct detections ($r = .208$, $p < .05$). No additional significant main effects, interactions, or correlations could be reported when AuM was entered as the covariate.

There were no significant main effects or interactions to report when AchM was entered into the ANCOVAs as the covariate in analyses performed on proportion of correct detections.



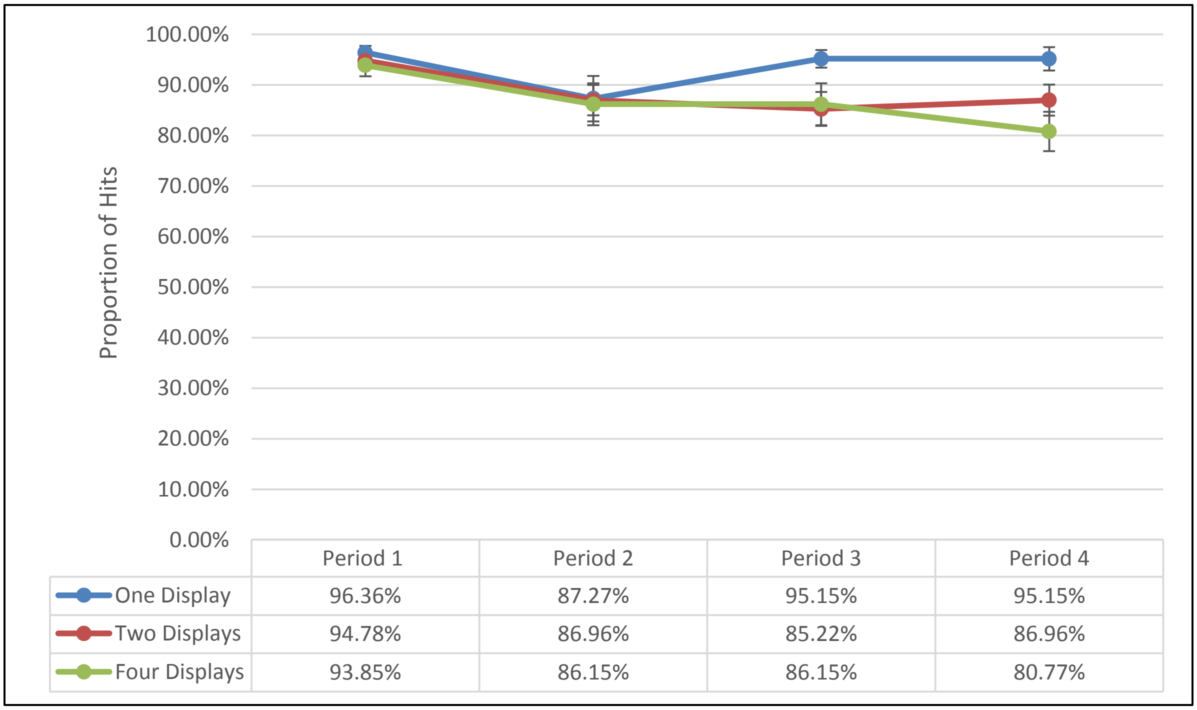
	Period 1	Period 2	Period 3	Period 4
Cognitive - One Display	91.43%	71.43%	85.71%	88.57%
Cognitive - Two Displays	90.00%	76.00%	74.00%	77.00%
Cognitive - Four Displays	85.00%	67.50%	87.50%	75.00%
Sensory - One Display	100.00%	99.05%	95.24%	99.05%
Sensory - Two Displays	98.46%	95.38%	93.85%	94.62%
Sensory - Four Displays	97.65%	94.12%	88.24%	82.35%

Figure 14. The average proportion of correct detections with standard errors bars are reported for each of the conditions in Experiment Two.



	Period 1	Period 2	Period 3	Period 4
Cognitive	89.52%	72.86%	80.48%	80.48%
Sensory	98.73%	96.19%	93.97%	93.02%

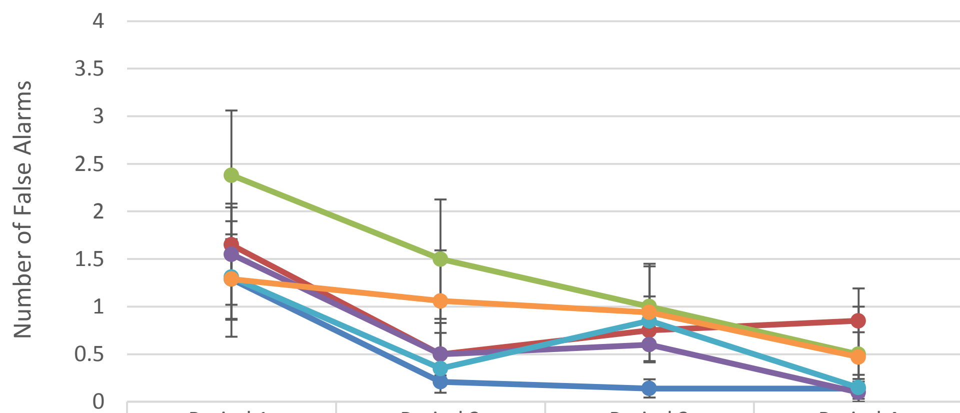
Figure 15. The average proportion of correct detections with standard errors bars are reported across task type for Experiment Two.



	Period 1	Period 2	Period 3	Period 4
One Display	96.36%	87.27%	95.15%	95.15%
Two Displays	94.78%	86.96%	85.22%	86.96%
Four Displays	93.85%	86.15%	86.15%	80.77%

Figure 16. The average proportion of correct detections with standard errors bars are reported across source complexity for Experiment Two.

The means and standard deviations of the number of false alarms demonstrated in Experiment Two are reported in Figures 17, 18, and 19. There was a significant main effect of period, but not number of displays, or AchM on the number of false alarms, $F(3, 279) = 2.87$, $p = .037$, $\eta_p^2 = .030$. Participants observing four displays demonstrated higher false alarm rates over time, regardless of assignment to the four display sensory condition or cognitive condition. No additional significant main effects, interactions, or correlations for AuM or AchM could be reported.



	Period 1	Period 2	Period 3	Period 4
Cognitive - One Display	1.29	0.21	0.14	0.14
Cognitive - Two Displays	1.65	0.5	0.75	0.85
Cognitive - Four Displays	2.38	1.5	1	0.5
Sensory - One Display	1.55	0.5	0.6	0.1
Sensory - Two Displays	1.31	0.35	0.85	0.15
Sensory - Four Displays	1.29	1.06	0.94	0.47

Figure 17. The average number of false alarms with standard errors bars are reported for each of the conditions in Experiment Two.

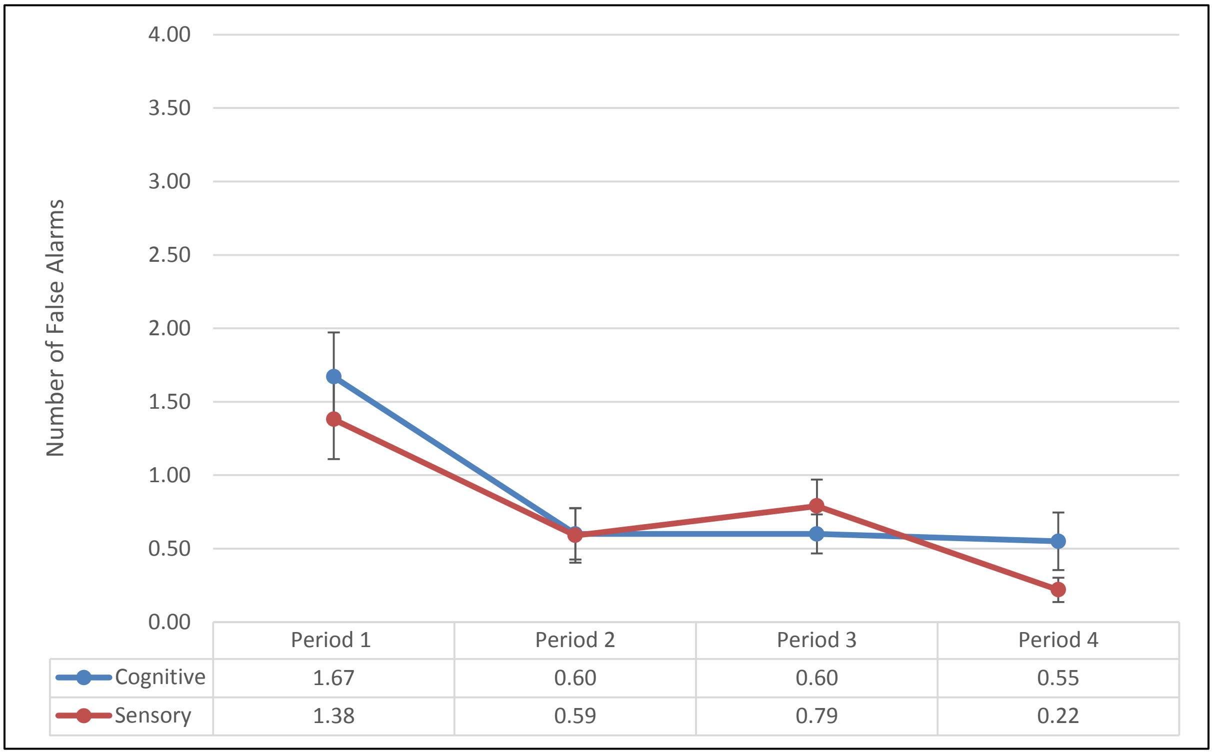
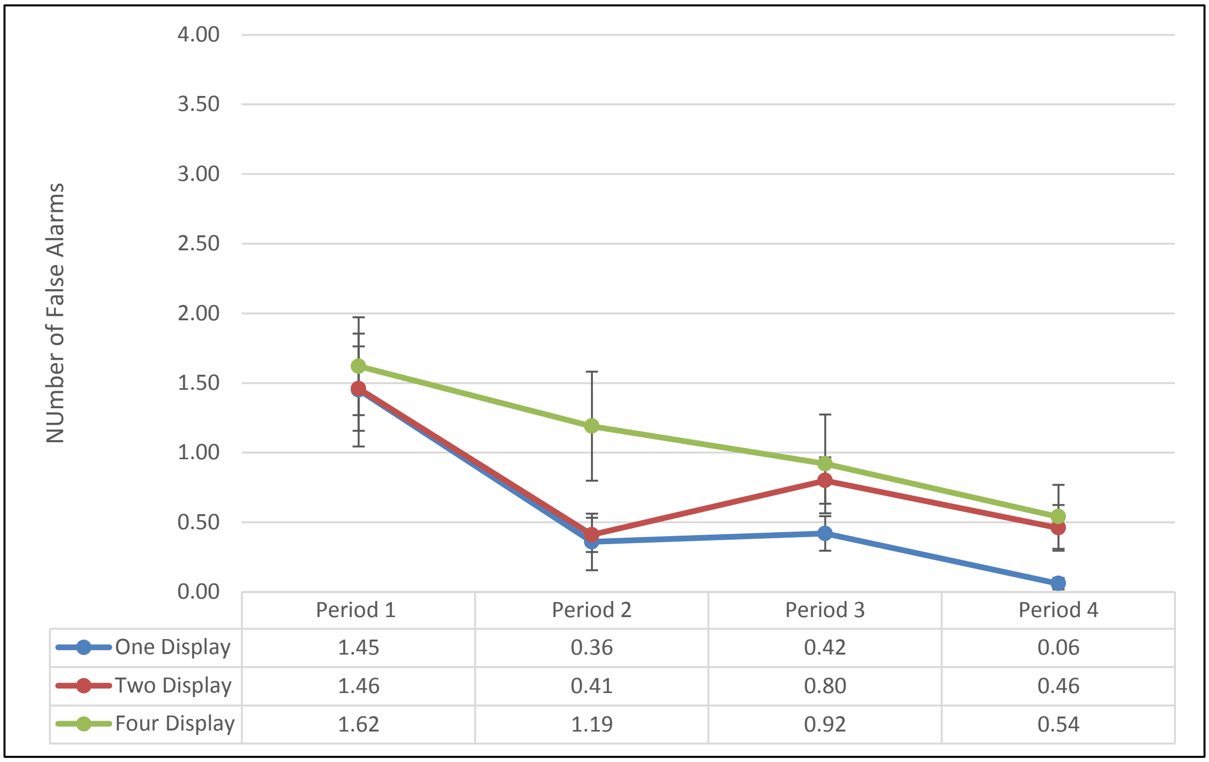


Figure 18. The average number of false alarms with standard errors bars are reported across task type in Experiment Two.

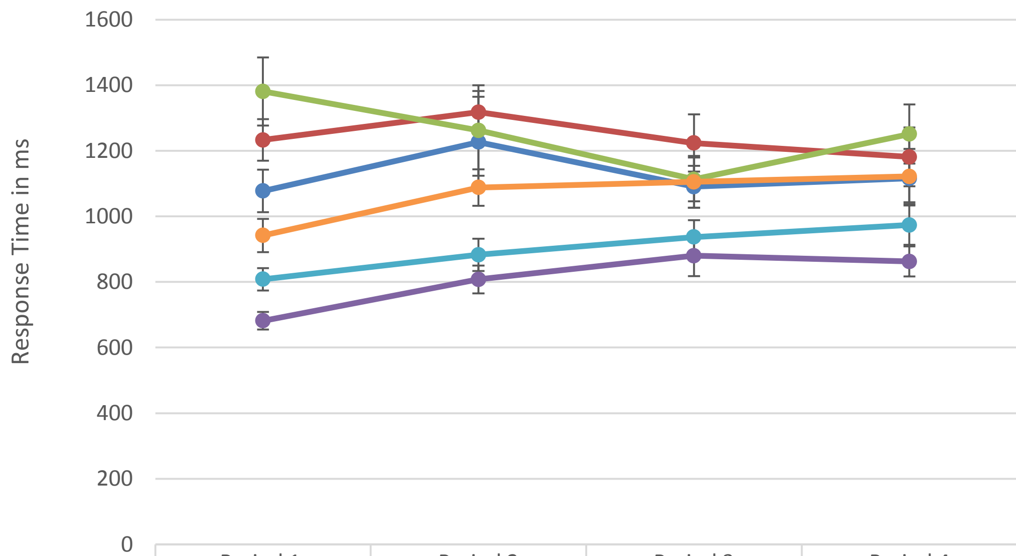


	Period 1	Period 2	Period 3	Period 4
One Display	1.45	0.36	0.42	0.06
Two Display	1.46	0.41	0.80	0.46
Four Display	1.62	1.19	0.92	0.54

Figure 19. The average number of false alarms with standard errors bars are reported across source complexity in Experiment Two.

There was a significant three-way interaction between period, number of displays, and the covariate AuM on response time, $F(6, 279) = 2.19$, $p = .044$, $\eta_p^2 = .045$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AuM, only one result reached significance. There was a main effect of period on mean response time for participants randomly assigned to the sensory task with one display to monitor, $F(3, 16) = 8.68$, $p = .001$, $\eta_p^2 = .325$, ε = .728. There was also a significant interaction between period and AuM on mean response time for participants in the sensory task with one display to monitor, $F(3, 16) = 4.42$, $p = .016$, $\eta_p^2 = .197$, ε = .728. Based on the data from participants assigned to this condition, the results of a linear regression indicated that as autonomy motivation increased; mean response time decreased over period on watch. But, AuM was not significantly correlated with the average response time across any of the periods on watch for participants assigned who monitored one display in the sensory task (*r* for Period 1 = .288, *r* for Period 2 = -.251, *r* for Period 3 = -.372, *r* for Period 4 = -.193).

There were no additional significant correlations, main effects, or interactions to report for these analyses or for ANCOVAs performed utilizing AchM as the covariate. The average response times across each period of watch are included in Figures 20, 21, and 22.



	Period 1	Period 2	Period 3	Period 4
Cognitive - One Display	1077.54	1226.52	1090.76	1115.77
Cognitive - Two Displays	1232.72	1317.76	1223.8	1181.41
Cognitive - Four Displays	1381	1261.89	1112.95	1251.04
Sensory - One Display	681.83	807.67	880.19	862.37
Sensory - Two Displays	808.21	883.03	936.87	973.76
Sensory - Four Displays	941.85	1087.96	1105.27	1121.66

Figure 20. The average response time with standard errors bars are reported for each of the conditions in Experiment Two. Note response time was not recorded for one participant in Period 2.

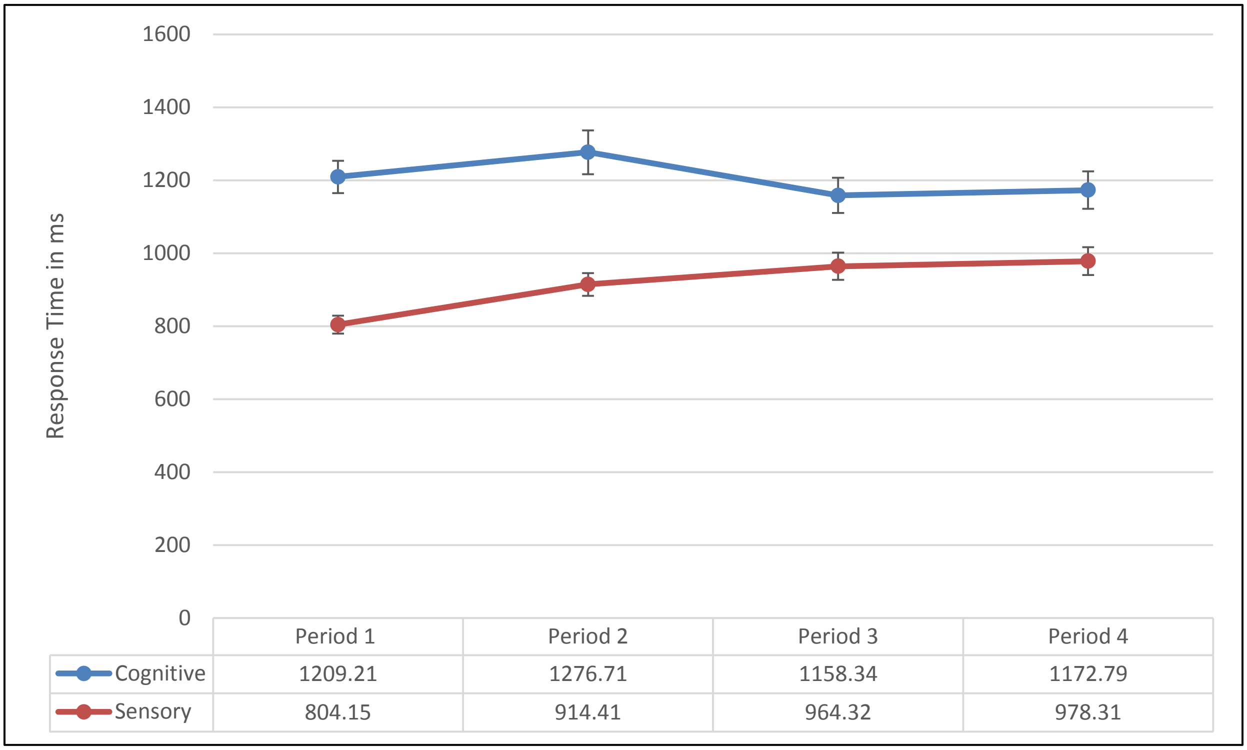
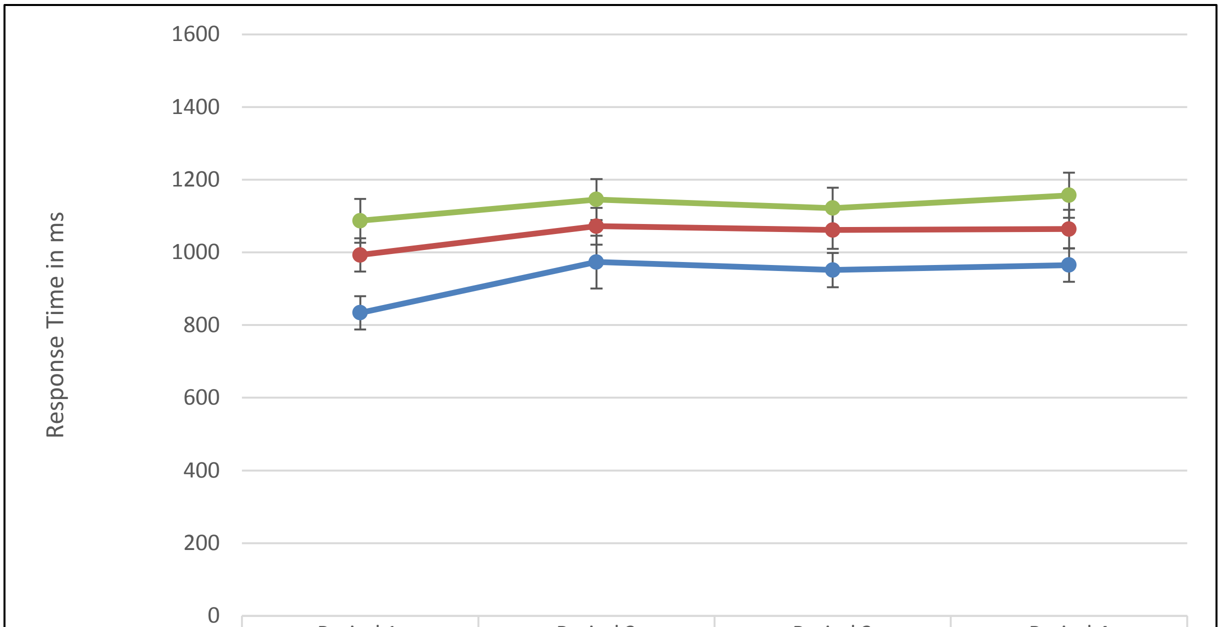


Figure 21. The average response time with standard errors bars are reported across task type in Experiment Two.



	Period 1	Period 2	Period 3	Period 4
One Display	833.98	973.64	951.54	965.32
Two Display	992.78	1072.05	1061.62	1064.05
Four Display	1086.89	1145.57	1121.8	1157.27

Figure 22. The average response time with standard errors bars are reported across source complexity in Experiment Two.

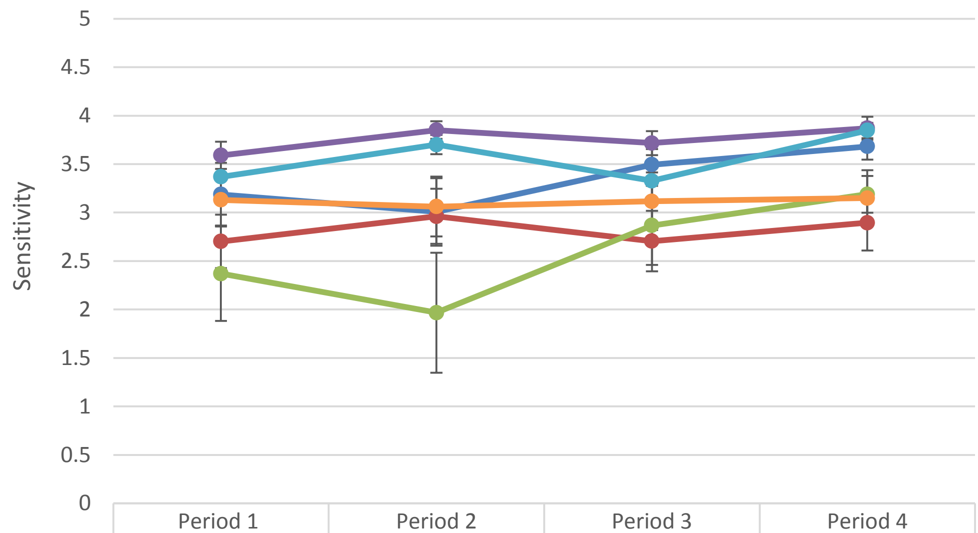
Sensitivity and Response Bias

The proportion of correct detections and false alarms were used to compute indices of sensitivity (*d'*; reported in Figures 23-25) and response bias (*c*; reported in Figure 26-28; See et al., 1995). Response bias tended to increase over time, indicating that participants were becoming more conservative in their response to stimuli across each period on watch.

Mixed-measures ANCOVAs with task type and number of displays as the between-subjects variables, period on watch as the within-subjects variable, and AchM or AuM as the covariate were performed on all measures related to these indices. Separate ANCOVAs were performed for each of these dependent variables. Correlations between the measures of sensitivity, response bias, and the covariates are included in Appendix H.

There was a significant main effect of task type on sensitivity, $F(1, 93) = 5.03$, $p = .027$, $\eta_p^2 = .051$, but not achievement motivation. There were no additional significant main effects, interactions, or correlations to report for these analyses. There were no significant main effects, interactions, or correlations when AchM was entered as the covariate for analyses related to response bias. There were no significant main effects or interactions when AuM was entered as the covariate in the analyses on sensitivity.

There was a significant two-way interaction between period and AuM on response bias, $F(3, 279) = 3.21$, $p = .023$, $\eta_p^2 = .033$. There was a significant main effect of period on response bias, $F(3, 279) = 4.95$, $p = .002$, $\eta_p^2 = .051$. There was a significant difference in response bias between Periods 1, 2, 3, and 4. There was a significant correlation between AuM and Period 2 ($r = -.201$, $p < .05$), and Period 3 ($r = -.222$, $p < .05$), in terms of response bias. There were no additional significant main effects, interactions, or correlations to report for these analyses.



	Period 1	Period 2	Period 3	Period 4
Cognitive - One Display	3.187	3.0067	3.4947	3.6822
Cognitive - Two Displays	2.7027	2.9619	2.7051	2.8959
Cognitive - Four Displays	2.37	1.9676	2.8671	3.1884
Sensory - One Display	3.5909	3.8508	3.7172	3.8702
Sensory - Two Displays	3.3694	3.7008	3.3270	3.8475
Sensory - Four Displays	3.1315	3.0626	3.1162	3.1491

Figure 23. The figure above includes the means and standard errors for changes in sensitivity across conditions and over time (*N* = 105).

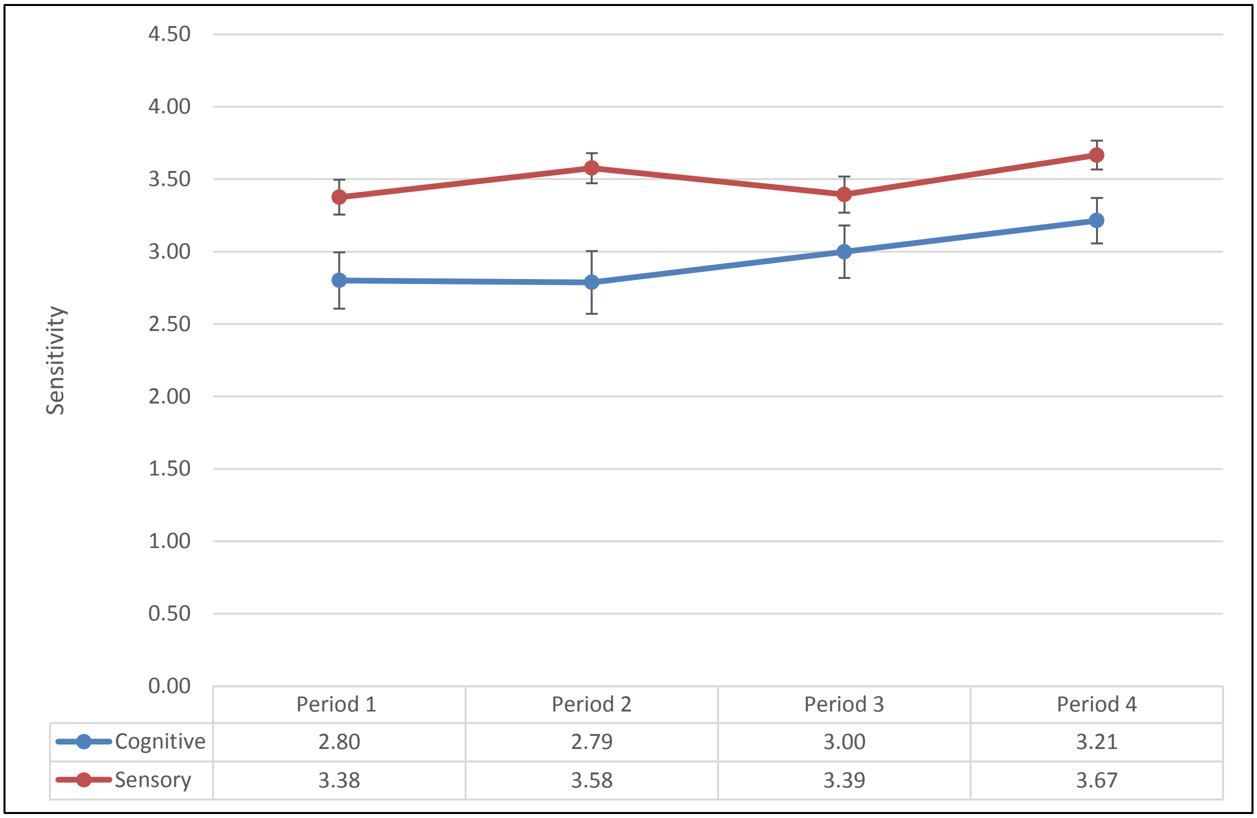
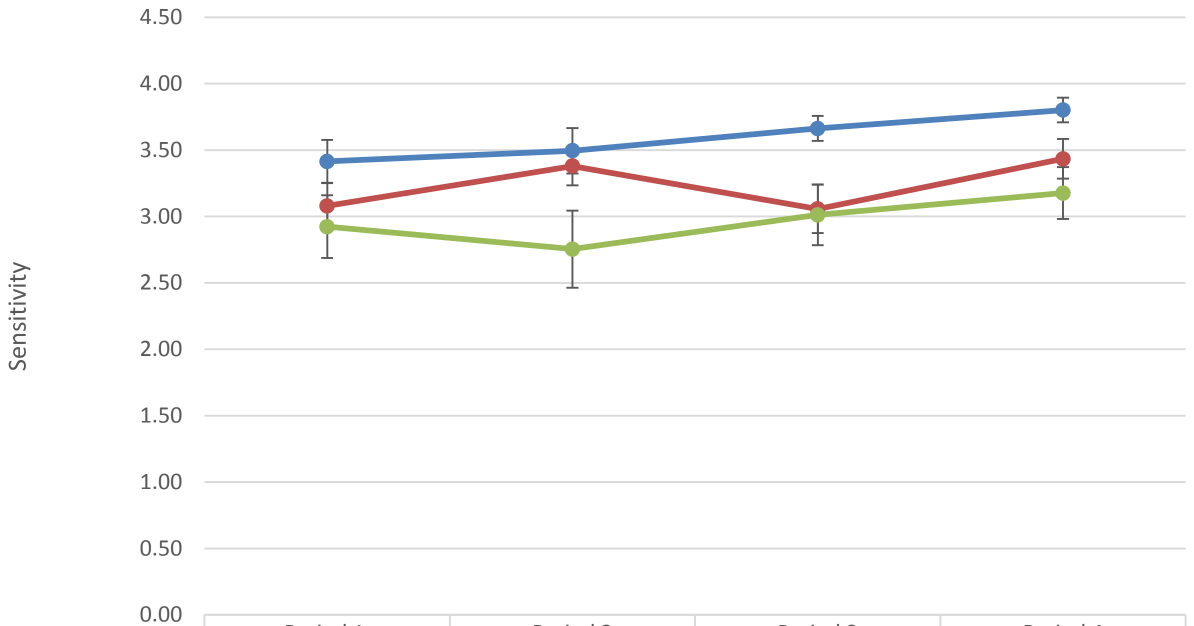
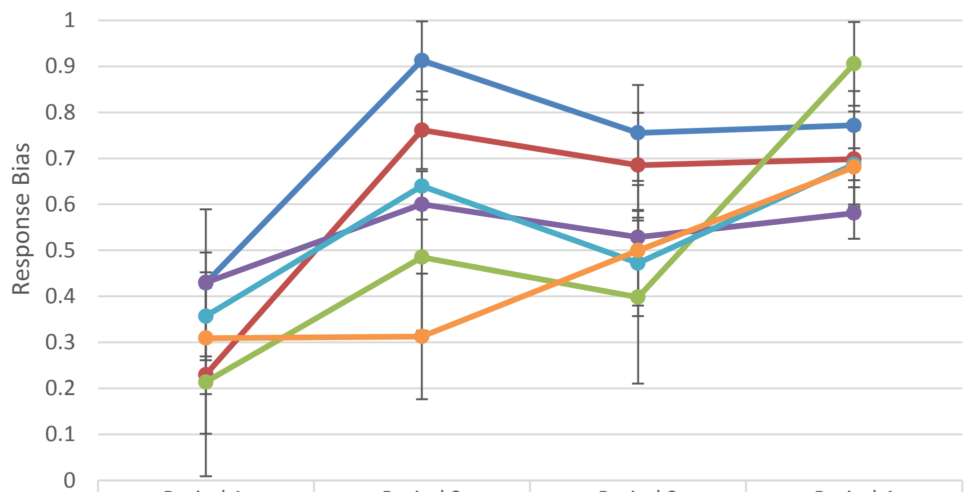


Figure 24. The figure above includes the means and standard errors for changes in sensitivity across task type.



	Period 1	Period 2	Period 3	Period 4
One Display	3.41	3.49	3.66	3.80
Two Display	3.08	3.38	3.06	3.43
Four Display	2.92	2.75	3.01	3.18

Figure 25. The figure above includes the means and standard errors for changes in sensitivity across source complexity.



	Period 1	Period 2	Period 3	Period 4
Cognitive - One Display	0.4294	0.9127	0.7553	0.7717
Cognitive - Two Displays	0.2299	0.7612	0.6852	0.6983
Cognitive - Four Displays	0.2139	0.4851	0.3984	0.9055
Sensory - One Display	0.4303	0.6003	0.5285	0.5811
Sensory - Two Displays	0.3571	0.6398	0.4724	0.6870
Sensory - Four Displays	0.3096	0.313	0.4998	0.6810

Figure 26. The figure above includes the means and standard errors for changes in response bias across conditions and over time (*N* = 105).

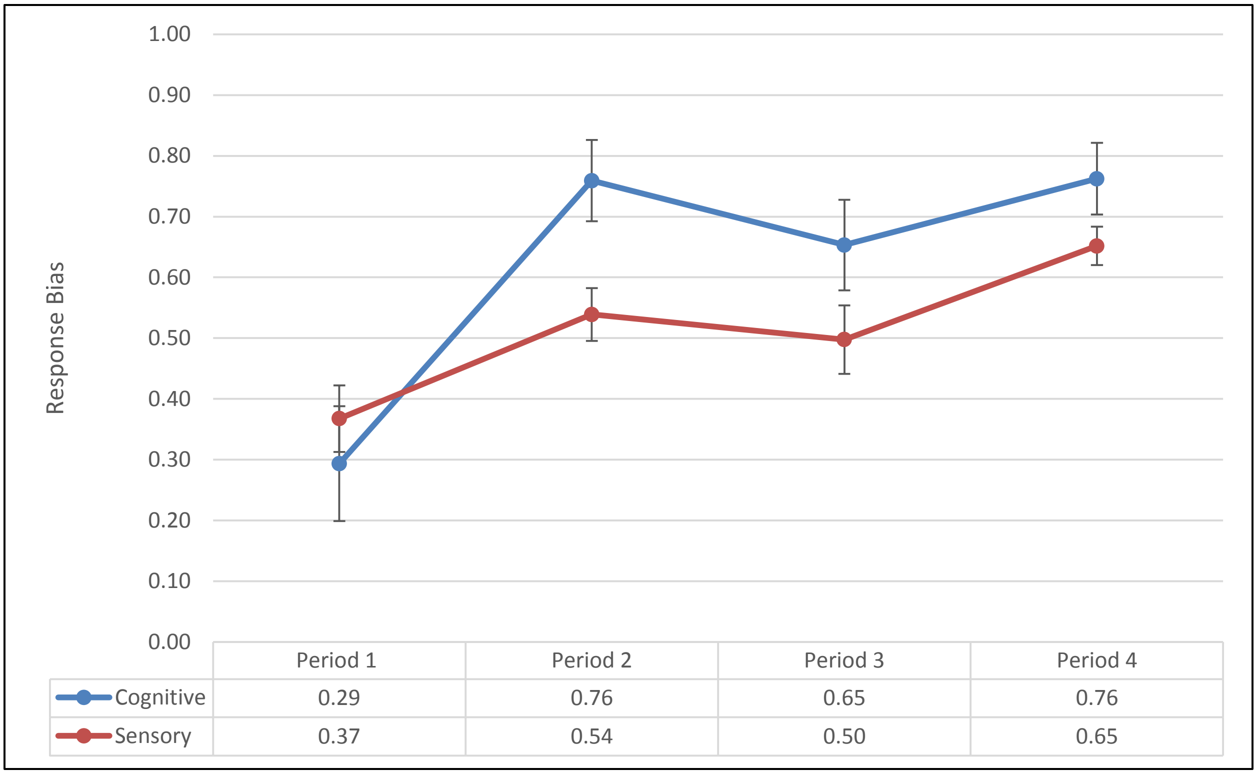
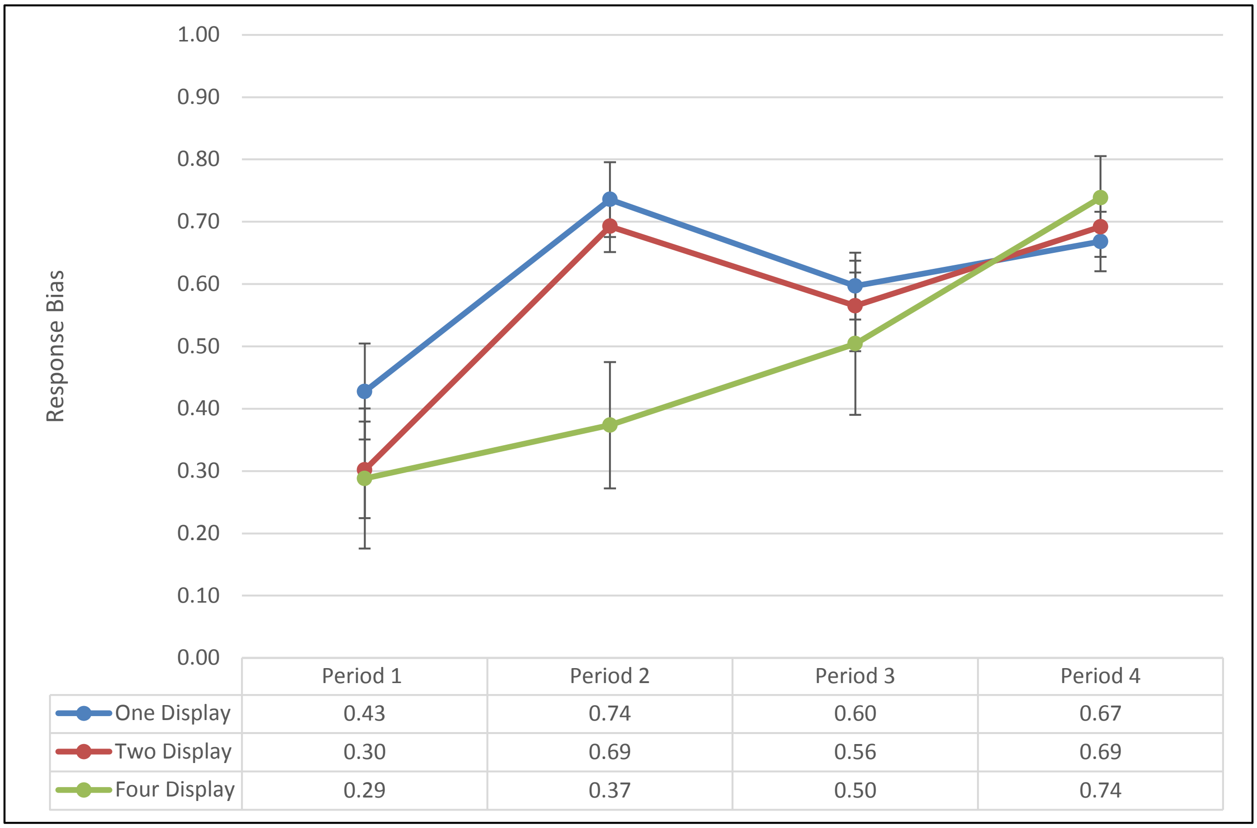


Figure 27. The figure above includes the means and standard errors for changes in response bias across task type.



	Period 1	Period 2	Period 3	Period 4
One Display	0.43	0.74	0.60	0.67
Two Display	0.30	0.69	0.56	0.69
Four Display	0.29	0.37	0.50	0.74

Figure 28. The figure above includes the means and standard errors for changes in response bias across source complexity.

Discussion

Engagement and Motivation

Participants monitoring more displays in the cognitive task tended to report significantly more post-task task-related thoughts than participants assigned to the sensory task. Thus, it could be argued that the sensory condition fails to produce cognitive engagement, or, it is possible that this task does not afford much intellectual engagement. The lower energetic arousal scores reported by participants in the sensory task and participants that only monitored one display during the vigil support this latter claim. In the Matthews et al. (2002; see also Matthews, 2016) instantiation of post-task task-unrelated thoughts, these results could also imply that the cognitive task induces more worry about one's performance.

In terms of motivation, all display conditions indicated lower pre-task achievement motivation, followed by a numerical increase in reported post-task success motivation. However, an inverse relationship occurred for intrinsic motivation. Each condition reported higher intrinsic motivation scores at pre-task with subsequent declines in intrinsic motivation at post-task. A similar trend occurred for pre- and post-task concentration. Clearly, individuals entered the task with initially modest degrees of motivation and concentration; however, upon conclusion of the vigil, motivational resources were significantly depleted.

This claim is supported by the significant three-way interaction observed between autonomous motivation, task type, and number of displays on post-task intrinsic motivation. Participants in the cognitive condition observing four displays demonstrated the highest degree of post-task intrinsic motivation, whereas participants in the sensory conditions reported some of the lowest post-task intrinsic motivation scores. Similarly, participants in the cognitive two- and four-display conditions reported the highest degree of post-task energetic arousal. Participants in the sensory conditions reported some of the lowest post-task energetic arousal scores.

Coupled with the high rate of attrition in the cognitive four-display condition, it is likely the case that complex cognitive vigilance tasks require an autonomously motivated individual to perform, while sensory-based complex tasks may not. Conversely, it is possible that autonomously motivated individuals are prepared to complete a more cognitively demanding task, whereas participants in the sensory conditions perceive more monotony, which is afforded by the nature of the task. Experiments Three and Four seek to further test these claims.

Stress and Workload

Perceived stress scores for pre-task and post-task were similar across the task types and the number of displays, prior to entering achievement motivation and autonomous motivation separately as covariates. There was a significant interaction between task type, number of displays, and achievement motivation on post-task tense arousal. Participants in the cognitive condition observing four displays reported the greatest post-task tense arousal in all conditions. Participants in the sensory condition monitoring only one display reported some of the lowest levels of post-task tense arousal when achievement motivation was covaried with task type and number of displays.

Similar trends in the data were observed when autonomous motivation was entered as the covariate. However, this variable appeared to interact with task type and display for post-task hedonic tone, and to a lesser extent with post-task tense arousal. For example, the significant three-way interaction between task type, number of displays, and autonomous motivation indicated that participants in the cognitive condition monitoring two or four displays reported some of the lowest post-task hedonic tone. In the same vein, the significant three-way interactions observed between task type, number of displays, and autonomous pre- and post-task anger/frustration yielded similar results. Participants in the single display sensory condition reported some of the highest anger/frustration at pre- and post-task. There were also significant correlations between autonomous motivation and post-task hedonic tone and pre-task anger/frustration, respectively, which indicated that participants higher in autonomous motivation perceive more pleasantness (i.e., hedonic tone) associated with the task and less anger/frustration associated with the task. Autonomous motivation may engage effective coping strategies to combat the negative aspects of the vigilance task (i.e., repetition, monotony, etc.).

In terms of global workload, there were no significant differences to report between task types when AchM or AuM were entered as covariates. Although the difference was not significant, participants in the cognitive task reported more global workload than participants in the sensory condition, which indicates that this task type requires more mental work and demand. Participants in the cognitive two-display conditions reported some of the lowest levels of global workload compared to participants monitoring only one display or observing all four displays. This manifests as a sort of "Goldilocks effect," wherein the experimenter is able to create a task that is somewhat engaging, but not overly demanding in terms of workload and stress.

Performance

Similar trends to participants observed in Experiment One were observed in Experiment Two: participants in the sensory task tended to outperform participants in the cognitive task. Participants in the sensory conditions outperformed participants in the cognitive condition, but as previously indicated, there was less motivation and greater stress and workload associated with performing the sensory task. Participants in the sensory single display condition demonstrated nearly perfect performance in correct detections over time; however, this group reported some of the lowest motivation and highest stress and workload upon conclusion of the vigil. Meanwhile, the traditional vigilance decrement was observed only for participants in the sensory four-display condition.

In each instantiation of the cognitive condition, temporal effects on performance tended to be variable in terms of the proportion of correct detections with these values decreasing, and then increasing over time. This could in part be due to the nature of the cognitive task. However, this trend is most likely attributed to autonomous motivation, which was significantly correlated with period on watch. It is possible that cognitive task may afford more cognitive engagement and when combined with an individual difference such as high autonomous motivation, participants strive to perform as well as possible, rather than submit to the boredom and monotony associated with the vigilance task. The same conclusions cannot be formulated for the sensory task. It should be noted that these results do not necessarily align with some of the extant literature (for a meta-analysis see See et al., 1995), which states that cognitive tasks may yield better performance than sensory tasks. The reason for this difference could be in part due to the event rate being relatively high.

In terms of false alarms, there was a significant effect of period on watch, but not motivation. There were trends in the data that indicated as the number of displays increased, the number of false alarms also increased. This makes sense given that participants were required to monitor an increased amount of information in the four-display condition and may be more likely to commit false alarms. Participants in the four display conditions reported more false alarms over time than any other condition. It is likely the case that as source complexity increases, false alarm-related performance becomes more error prone. This claim is supported by significant interactions between time, number of displays, and achievement motivation. These findings support the claim that the vigilance decrement could be a manifestation of both individual differences influencing performance, as well as a symptom of the boredom and monotony associated with performing the vigil.

In terms of response time, response time tended to become increasingly laggard over time, with one exception. The average response time of participants assigned to the two-display cognitive task demonstrated a decrease in response time as time on task increased. This finding is not typically observed in vigilance research. However, this result could be due to the significant relationship between autonomous motivation, time, and the optimal amount of information to process (i.e., two displays in the cognitive task). While it is argued that the vigilance decrement is iatrogenically created, these results provide preliminary evidence indicating that the same can be said for cognitive engagement in vigilance tasks, which implies that the level of engagement could be caused by the task's design.

CHAPTER SEVEN: EXPERIMENT THREE

Experiment Three extended the results of Experiment One by manipulating the type of task instructions participants received. Instructions were adapted to facilitate the experience of greater perceived autonomy (i.e., autonomy-supportive motivation) or less perceived autonomy (i.e., controlled motivation). It was demonstrated in pilot work and a handful of previous vigilance studies (Dember et al., 1992; Isard & Szalma, 2015) that manipulations to task instruction types could influence engagement in the vigilance task at pre- and post-task. It was hypothesized that autonomy-supportive instructions would result in an increased motivation to perform the task.

Hypotheses

Engagement and Motivation Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) should be significantly related to the level of engagement and motivation at post-task. Task engagement and motivation will be measured by energetic arousal, concentration, success motivation, intrinsic motivation, task-related thoughts (TRTs), and task-unrelated thoughts (TUTs). Cognitive task engagement will be measured using concentration, TRTs, and TUTs.

2) Specific hypotheses related to cognitive engagement were developed given the three theories of information processing:

    a. Under the resource theory account of vigilance, AchM and AuM should be significantly related to concentration at post-task, but not under the mindlessness or mind-wandering account.

    b. If cognitively engaged with the task, AchM or AuM should be significantly related to increased TRTs at post-task under the resource-depletion account.

    c. According to mindlessness theory, there should be few if any TRTs.

    d. Under the mind-wandering assumption, there will be high TRTs at pre-task and low TRTs at post-task, regardless of the type of motivation involved in vigilance.

    e. Assuming a resource theory perspective, if individuals are engaged with the task, participants AchM or AuM should be related to a significant decrease in TUTs at post-task.

    f. According to mindlessness theory, there should be more TUTs as the mind drifts away from the task because vigilance tasks afford this behavior.

g. Under the mind-wandering assumption, there will be high TUTs if disengaged with the task, especially at post-task as inward or outward task-unrelated thoughts increase during the vigil.

3) Instruction manipulations to motivation should exacerbate engagement in the vigilance task, as well as increase motivation to perform the task when instructions are autonomy-supportive. Perceived choice in the activity will increase motivation to perform the activity, thus there should be a significant relationship between the covariates measuring motivation and the type of instructions participants receive.

Stress and Workload Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) may affect stress and workload. Stress and workload will be measured by tense arousal, hedonic tone, anger/frustration, and global workload. Thus, the hypotheses are as follows:

    a. AchM and AuM should be significantly related to tense arousal. Participants lower in motivation will lack effective coping strategies to overcome the monotony associated with the task.

    b. AchM and AuM should be significantly related to higher hedonic tone because these individual differences are related to finding enjoyment in the task.

c. AchM and AuM should be significantly related to anger/frustration. Participants lower in motivation will lack effective coping strategies related to managing perceived anger and frustration.

2) It is hypothesized that the cognitive task will be perceived as more work than the sensory task based on previous evidence from the existing literature on vigilance.

   a. However, participants high in AchM and AuM may be significantly related to global workload. It is possible that participants high in AchM or AuM will approach the cognitive task as if it is a complex challenge, which may reduce overall perceived workload.

Performance Measures

1) Proportion of correct detections, number of false alarms, average response time, and signal detection theory measures of sensitivity and response bias will serve as measures of performance.

2) AchM and AuM should be significantly related to the proportion of correct detections because individuals high in these differences want to strive toward success and perceive control over their performance.

   a. Instruction manipulations to motivation should exacerbate engagement in the vigilance task, which should also manifest in changes to performance, meaning autonomous motivation, achievement motivation, and task instructions (i.e., autonomy-supportive instructions) should be significantly related to improved performance in terms of proportion of correct detections.

3) Similarly, AchM and AuM should be significantly related to the number of false alarms because individuals high in these differences want to strive toward success and perceive control over their performance, thus reporting a low number of false alarms over time.

    a. Instruction manipulations to motivation should exacerbate engagement in the vigilance task, which should also manifest in changes to performance, meaning autonomous motivation, achievement motivation, and task instructions (i.e., autonomy-supportive instructions) should be significantly related to a lower rate of false alarms

4) AchM and AuM may be significantly related to mean response time because previous literature has demonstrated that motivation is linked to attention.

    a. Instruction manipulations to motivation should exacerbate engagement in the vigilance task, which should also manifest in changes to performance, which would result in a significant interaction between either AchM or AuM, period on watch, and instruction type on mean response time. If instructions facilitate participant engagement in the task, they should respond more quickly to correct detections and report fewer false alarms, which effect average response time.

Participants

An *a priori* power analysis was conducted for Experiment Three using G*Power Version 3.1 using a medium effect size and conventional criteria ($\alpha = 0.05$, $1-\beta = 0.80$; Faul et al., 2007) to estimate power and effect sizes prior to data collection. Following this analysis, approximately 112 participants were recruited from the University of Central Florida's psychology research participation system (SONA).

To qualify for participation in the present study, participants reported normal or corrected-to-normal vision and were at least 18 years of age or older. Participants who completed either Experiments One or Experiment Two were not able to participate in Experiments Three or Four. Participants were asked not to consume caffeine 24 hours prior to the study.

Data Cleaning and Final Sample

One hundred and twelve participants were collected from the SONA study pool for Experiment Three. Five of these participants were removed from the sample for incomplete SuperLab data and three participants were removed for incomplete survey data.

The inclusion criteria were as follows: participants achieved a minimum score of 70% correct detections (i.e., hit rate) in the first watch period and did not commit more than ten false alarms in any given watch period. The same rationale from the previous experiments applies to the use of this cutoff criteria for Experiment Three.

After further data cleaning based on inclusion criteria, the final sample for this study consisted of 93 undergraduate students. Eleven participants were removed from this sample because of performance deviations that did not meet the inclusion criteria. More specifically, data from eight participants in the cognitive task receiving controlling instructions and three participants from the sensory task receiving controlling instructions were eliminated from the following analyses. Interestingly, no participants removed from the autonomy-supportive instruction conditions in terms of performance-based inclusion criteria.

Design

In Experiment Three, participants were randomly assigned to either the cognitive or sensory vigilance task and receive either autonomy-supportive instructions or controlling instructions (see Table 12). Participants were required to monitor one specific quadrant at a time. The quadrant, which participants monitored, was randomized across conditions to control for any effects related to the location of the quadrant (i.e., top, bottom, left, right). No such location effects were observed.

Table 12. The table below indicates the conditions to which participants were randomly assigned in Experiment Three.

Task Type	Instruction Type	Number of Participants Assigned to Each Condition
Cognitive	Autonomy-Supportive	19
	Controlling	22
Sensory	Autonomy-Supportive	20
	Controlling	32

Autonomy-supportive instructions read (by the participant on a computer and aloud by a research assistant) as follows (note this example is worded for the cognitive condition): "In the following experiment, you will be asked to attend to 1, 2, or 4 displays (described on the next slide). Each display will contain a 2-digit number (shown below). You will watch the display for a ***critical signal***. A ***critical signal*** appears when the difference between the 2 digits is **-1, 0, or 1**. For example, 23 (2 minus 3 equals -1), 55 (minus 5 equals 0) and 10 (1 minus 0 equals 1) could all be possible critical signals. But, 91 (9 minus 1 equals 8), 04 (0 minus 4 equals -4), and 68 (6 minus 8 equals -2) would **<u>not</u>** be critical signals. *When you are ready, please press any key to continue*." The last sentence of the instructions appeared on all subsequent instruction slides to facilitate the perception of autonomy. Instructions were not present when the vigil began. Participants could ask questions to the researcher, if they had any, prior to beginning the vigil.

The controlling instructions were read (by the participant on a computer and aloud by a research assistant) as follows (note this example is worded for the cognitive condition): "In the following experiment, you will be asked to attend to 1, 2, or 4 displays (described on the next slide). Each display will contain a 2-digit number (shown below). You will watch the display for a ***critical signal***. A ***critical signal*** appears when the difference between the 2 digits is **-1, 0, or 1**. For example, 23 (2 minus 3 equals -1), 55 (minus 5 equals 0) and 10 (1 minus 0 equals 1) could all be possible critical signals. But, 91 (9 minus 1 equals 8), 04 (0 minus 4 equals -4), and 68 (6 minus 8 equals -2) would **not** be critical signals. *Press the spacebar to continue*." This last sentence of the instructions appeared on all subsequent instruction slides to decrease the perception of autonomy or choice in the activity. Instructions were not present when the vigil began. Participants could ask questions to the researcher, if they had any, prior to beginning the vigil.

Task Stimuli and Environment

The task stimuli and environment of Experiment Three were identical to participants used in Experiment One.

Measures

The same measures from Experiment One were used in Experiment Three. The reliabilities of these measures for Experiment Three are reported in Appendix I.

Procedure

The procedure for Experiment Three was the same as Experiment One, with one exception. Participants were assigned to one of four conditions: 1) a cognitive task with autonomy-supportive instructions, 2) a cognitive task with controlling instructions, 3) a sensory task with autonomy-supportive instructions, or, 4) a sensory task with controlling instructions.

Descriptive Statistics

Data from 93 undergraduate students (53 females; 39 males; 1 transgender) was collected from the SONA pool for Experiment Three. Of participants who participated, 68.9% were freshmen, 15.2% were sophomores, 9.7% were juniors, and 6.2% were seniors. The average age of participants was 19.11 years (*Median* = 18.00 years, *SD* = 1.96 years). The oldest student in this sample was 29-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants indicated that they did not to consume caffeine 24 hours prior to this study.

The participants included in the present study did not differ substantially from those excluded from Experiment Three (based on inclusion criteria). For example, the average age of participants that were excluded was 20.73 years of age (*Range*: 18 – 34), 2 male participants were removed, and 9 female participants were removed. There were two significant differences between participants that were included and those that were excluded from these analyses.

Participants differed significantly across pre- and post-task intrinsic motivation, which are a part of the task engagement factor of the DSSQ. Participants excluded from the present analyses reported both higher pre- and post-task intrinsic motivation scores than those included in the present sample, which is a finding accompanied by a very large effect and large effect, respectively. The complete engagement, motivation, stress, and workload scores for the participants removed from Experiment Three are listed in Appendix J. The effect sizes for analyses on the excluded data are included in Appendix K.

Results

Engagement and Motivation Measures

The average AchM score was 21.84 (*SD* = 3.40; *Range*: 16.00 – 30.00). The average AuM score was 34.97 (*SD* = 9.16; *Range*: 7.00 – 49.00). There was a strong positive skew for the autonomous motivation scores, which indicates that many participants self-reported being high in this state measure. Furthermore, there was a moderate negative skew for the achievement motivation scores, which indicates that participants tended to self-report being somewhat lower in achievement motivation.

AchM or AuM scores were used as covariates, and task type and instruction type were used as independent variables to perform separate ANCOVAs on all engagement and motivation outcome measures. Separate ANCOVAs were performed for each pre-task and post-task measure. ANCOVA was used because the covariates are continuous variables.

The means and standard deviations for the measures of engagement and motivation by task type are reported in Table 13. The means and standard deviations for the measures of engagement and motivation by instruction type are reported in Table 14. Correlations of AchM and AuM with the engagement and motivation measures are reported in Appendix C.

Table 13. The table below includes the means and standard deviations for all measures of motivation and engagement across the type of task (*N* = 93).

	Cognitive Task (*N* = 41)		Sensory Task (*N* = 52)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	21.05 (3.32)		22.46 (3.36)		21.84 (3.40)	
AuM	36.22 (9.32)		33.98 (9.00)		34.97 (9.16)	
Success Motivation	19.41 (9.07)	20.17 (6.79)	20.50 (6.56)	18.77 (7.18)	20.02 (7.74)	19.39 (7.01)
Intrinsic Motivation	18.51 (4.48)	11.46 (4.22)	17.69 (4.53)	12.88 (4.37)	18.05 (4.50)	12.26 (4.34)
Energetic Arousal	17.83 (4.21)	18.39 (5.16)	16.33 (3.96)	16.92 (4.91)	16.99 (4.12)	17.57 (5.05)
Concentration	18.68 (6.94)	10.19 (6.49)	16.37 (5.91)	7.63 (7.27)	17.39 (6.46)	8.76 (7.02)
TRTs	15.07 (8.20)	19.61 (7.09)	16.13 (7.54)	18.88 (5.31)	15.67 (7.81)	19.20 (6.13)
TUTs	13.29 (8.41)	12.92 (6.96)	14.25 (7.56)	15.40 (6.59)	13.83 (7.91)	14.31 (6.83)

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations.

Table 14. The table below includes the means and standard deviations for all measures of motivation and engagement across instruction type (*N* = 93).

	Autonomy-Supportive Instructions (*N* = 42)		**Controlling Instructions (*N* = 51)**	
	Pre	**Post**	**Pre**	**Post**
AchM	21.98 (3.61)		21.73 (3.24)	
AuM	34.79 (9.58)		35.12 (8.90)	
Success Motivation	21.36 (7.31)	19.64 (6.42)	18.92 (7.98)	19.18 (7.52)
Intrinsic Motivation	17.95 (3.39)	12.05 (4.49)	18.14 (5.28)	12.43 (4.25)
Energetic Arousal	16.83 (4.76)	17.45 (5.95)	17.12 (3.55)	17.67 (4.22)
Concentration	17.31 (6.01)	9.21 (5.94)	17.45 (6.86)	8.39 (7.83)
TRTs	16.60 (7.14)	20.26 (6.20)	14.90 (8.32)	18.33 (5.99)
TUTs	14.74 (7.79)	13.64 (5.46)	13.08 (8.00)	14.86 (7.79)

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations.

There was a significant interaction between the covariate AchM and task type on post-task intrinsic motivation, $F(1, 85) = 7.91$, $p = .006$, $\eta_p^2 = .085$, as well as pre-task concentration, $F(1, 85) = 5.05$, $p = .027$, $\eta_p^2 = .056$. Participants in the sensory condition reported the highest post-task intrinsic motivation scores ($M = 12.88$, $SD = 4.37$), but reported the lowest pre-task concentration scores ($M = 16.37$, $SD = 5.91$) relative to the cognitive condition ($M = 18.68$, $SD = 6.94$).

There was also a significant interaction between instruction type and task type on pre-task concentration, $F(1, 85) = 4.32$, $p = .041$, $\eta_p^2 = .048$, and pre-task task-unrelated thoughts, $F(1, 85) = 7.04$, $p = .009$, $\eta_p^2 = .077$. Participants in the cognitive condition receiving autonomy-supportive instructions reported the highest degree of pre-task concentration ($M = 19.27$, $SD = 4.57$), whereas participants in the sensory condition receiving autonomy-supportive instructions reported the lowest pre-task concentration ($M = 15.15$, $SD = 6.75$).

There was a significant main effect of the covariate AchM, but not task type or instruction type, on pre-task energetic arousal, $F(1, 85) = 10.82$, $p = .001$, $\eta_p^2 = .113$, and post-task energetic arousal, $F(1, 85) = 8.00$, $p = .006$, $\eta_p^2 = .086$. There was a significant correlation between AchM and post-task success motivation ($r = -.295$, $p < .004$), pre-energetic arousal ($r = -.385$, $p < .004$), and post-energetic arousal ($r = -.326$, $p < .004$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant three-way interaction between instruction type, task type, and the covariate AuM on pre-task concentration, $F(1, 85) = 5.94$, $p = .017$, $\eta_p^2 = .065$, as well as a significant interaction between instruction type and autonomous motivation on pre-task concentration, $F(1, 85) = 4.18$, $p = .044$, $\eta_p^2 = .047$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on pre-task concentration, several results reached significance. There was a significant effect of the covariate AuM on pre-task concentration in both sensory tasks, which includes participants receiving autonomy-supportive instructions, $F(1, 18) = 5.87$, $p = .026$, $\eta_p^2 = .246$, and participants receiving controlling instructions, $F(1, 30) = 6.21$, $p = .018$, $\eta_p^2 = .171$. There was also a significant effect of the covariate AuM on pre-task concentration in the cognitive task when participants were given controlling instructions, $F(1, 17) = 17.61$, $p = .001$, $\eta_p^2 = .509$. When AuM was entered as the covariate in these analyses, participants in the cognitive condition receiving autonomy-supportive instructions reported the highest pre-task concentration (*M* = 19.27, *SD* = 4.57), whereas participants in the sensory condition receiving autonomy-supportive instructions reported the lowest amount of pre-task concentration (*M* = 15.15, *SD* = 6.75).

There was also a significant interaction between autonomous motivation and instruction type on post-task task-unrelated thoughts, $F(1, 85) = 4.58$, $p = .035$, $\eta_p^2 = .051$. Participants receiving controlling instructions reported fewer post-task task-unrelated thoughts, whereas participants in the sensory condition receiving autonomy-supportive instructions reported the most post-task task-unrelated thoughts (*M* = 16.35, *SD* = 6.29).

There was a significant main effect of the covariate AuM, but not task type or instruction type, on pre-task energetic arousal, $F(1, 85) = 5.39$, $p = .023$, $\eta_p^2 = .060$, post-task energetic arousal, $F(1, 85) = 12.18$, $p = .001$, $\eta_p^2 = .125$, post-task success motivation, $F(1, 85) = 9.28$, $p = .003$, $\eta_p^2 = .098$, pre-task intrinsic motivation, $F(1, 85) = 7.39$, $p = .008$, $\eta_p^2 = .080$, pre-task concentration, $F(1, 85) = 24.24$, $p < .001$, $\eta_p^2 = .222$, post-task concentration, $F(1, 85) = 10.20$, $p = .002$, $\eta_p^2 = .107$, pre-task task-unrelated thoughts, $F(1, 85) = 7.54$, $p = .007$, $\eta_p^2 = .082$, and post-task task-unrelated thoughts, $F(1, 85) = 12.55$, $p = .001$, $\eta_p^2 = .129$.

There was a significant interaction between instruction type and task type on pre-task concentration, $F(1, 85) = 6.70$, $p = .011$, $\eta_p^2 = .073$, and pre-task task-unrelated thoughts, $F(1, 85) = 4.88$, $p = .030$, $\eta_p^2 = .054$. As well, there was a significant main effect of instruction type on pre-task concentration when AuM was entered as the covariate, $F(1, 85) = 3.98$, $p = .049$, $\eta_p^2 = .045$, and post-task task-unrelated thoughts, $F(1, 85) = 5.38$, $p = .023$, $\eta_p^2 = .060$. There was a significant correlation between AuM and post-task success motivation ($r = .330$, $p < .004$), pre-task concentration ($r = .497$, $p < .004$), post-task concentration ($r = .347$, $p < .004$), pre-task task-unrelated thoughts ($r = -.321$, $p < .004$), and post-task task-unrelated thoughts ($r = -.396$, $p < .004$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

Stress and Workload Measures

An ANCOVA with task type and instruction type as the independent variables, and AchM or AuM as the covariate, was performed on all outcome measures related to stress and workload. Separate ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of stress and workload measures by task type are reported in Table 15. The means and standard deviations for the measures of stress and workload measures by instruction type are reported in Table 16. The means and standard deviations for the full DSSQ are reported in Appendix D. The means and standard deviations for the full NASA-TLX are reported in Appendix E.

Table 15. The table below includes the means and standard deviations for all measures of stress and workload across task type (N = 93).

	Cognitive Task (N = 41)		Sensory Task (N = 52)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	11.95 (3.02)	13.97 (4.29)	13.48 (3.46)	15.38 (3.74)	12.81 (3.35)	14.76 (4.04)
Hedonic Tone	26.24 (4.13)	23.15 (4.18)	24.69 (4.87)	22.02 (4.20)	25.38 (4.60)	22.52 (4.21)
Anger/ Frustration	7.34 (2.85)	9.63 (4.20)	8.32 (3.95)	11.04 (4.27)	7.89 (3.53)	10.42 (4.28)
Global Workload		41.72 (14.03)		36.01 (13.52)		38.53 (13.96)
Mental Demand		43.63 (29.33)		28.37 (25.60)		35.10 (28.20)
Temporal Demand		29.83 (26.03)		22.40 (21.93)		25.67 (23.98)
Physical Demand		13.49 (19.94)		11.83 (16.39)		12.56 (17.96)
Perceived Performance		47.46 (34.91)		45.90 (32.71)		46.59 (33.52)
Effort		35.63 (29.87)		29.25 (23.74)		32.06 (26.66)
Frustration		27.17 (30.35)		34.94 (31.58)		31.52 (31.12)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

Table 16. The table below includes the means and standard deviations for all measures of stress and workload across instruction type (*N* = 93).

	Autonomy-Supportive Instructions (*N* = 42)		Controlling Instructions (*N* = 51)	
	Pre	**Post**	**Pre**	**Post**
Tense Arousal	12.31 (3.22)	14.69 (4.09)	13.22 (3.43)	14.82 (4.03)
Hedonic Tone	25.26 (4.75)	22.38 (4.37)	25.47 (4.52)	22.63 (4.11)
Anger/ Frustration	7.64 (3.22)	10.40 (4.58)	8.10 (3.78)	10.43 (4.06)
Global Workload		39.76 (14.33)		37.51 (13.72)
Mental Demand		37.02 (28.04)		33.51 (28.51)
Temporal Demand		24.12 (19.13)		26.96 (27.46)
Physical Demand		8.98 (11.34)		15.51 (21.64)
Perceived Performance		45.33 (34.41)		47.63 (33.08)
Effort		36.79 (27.14)		28.18 (25.87)
Frustration		36.12 (32.43)		27.73 (29.77)

There was a significant interaction between instruction type, task type, and AchM on global workload, $F(1, 85) = 6.79$, $p = .011$, $\eta_p^2 = .074$. There was a significant interaction between instruction type and task type on global workload, $F(1, 85) = 5.59$, $p = .020$, $\eta_p^2 = .062$, and significant interaction between instruction type and AchM on global workload, $F(1, 85) = 7.10$, $p = .009$, $\eta_p^2 = .077$. There was a significant main effect of instruction type on global workload, $F(1, 85) = 5.17$, $p = .026$, $\eta_p^2 = .057$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on global workload, two results reached significance. There was a significant effect of the covariate AchM on global workload in the cognitive task where participants received autonomy-supportive instructions, $F(1, 20) = 5.76$, $p = .026$, $\eta_p^2 = .223$, and in the cognitive task where participants received controlling instructions, $F(1, 5) = 6.62$, $p = .020$, $\eta_p^2 = .280$. Participants receiving autonomy-supportive instructions reported more global workload in both the sensory task ($M = 38.15$, $SD = 12.54$) and cognitive task ($M = 41.21$, $SD = 15.94$) relative to participants receiving controlling instructions.

There was a significant main effect of AchM on pre-task hedonic tone, $F(1, 85) = 7.10$, $p = .009$, $\eta_p^2 = .077$, as well as post-task hedonic tone, $F(1, 85) = 6.18$, $p = .015$, $\eta_p^2 = .068$. There was a significant correlation between AchM and pre-task hedonic tone ($r = -.320$, $p < .003$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant main effect of AuM on post-task tense arousal, $F(1, 85) = 7.10$, $p = .009$, $\eta_p^2 = .077$, pre-task hedonic tone, $F(1, 85) = 8.37$, $p = .005$, $\eta_p^2 = .090$, post-task hedonic tone, $F(1, 85) = 16.80$, $p < .001$, $\eta_p^2 = .165$, pre-task anger/frustration, $F(1, 85) = 5.57$, $p = .021$, $\eta_p^2 = .061$, and post-task anger/frustration, $F(1, 85) = 8.60$, $p = .004$, $\eta_p^2 = .092$. There was a significant correlation between AuM and post-task tense arousal ($r = -.295$, $p < .01$), pre-task hedonic tone ($r = .314$, $p < .003$), post-task hedonic tone ($r = .427$, $p < .003$), pre-task anger/frustration ($r = -.274$, $p < .01$), and post-task anger/frustration ($r = -.343$, $p < .003$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

Performance Measures

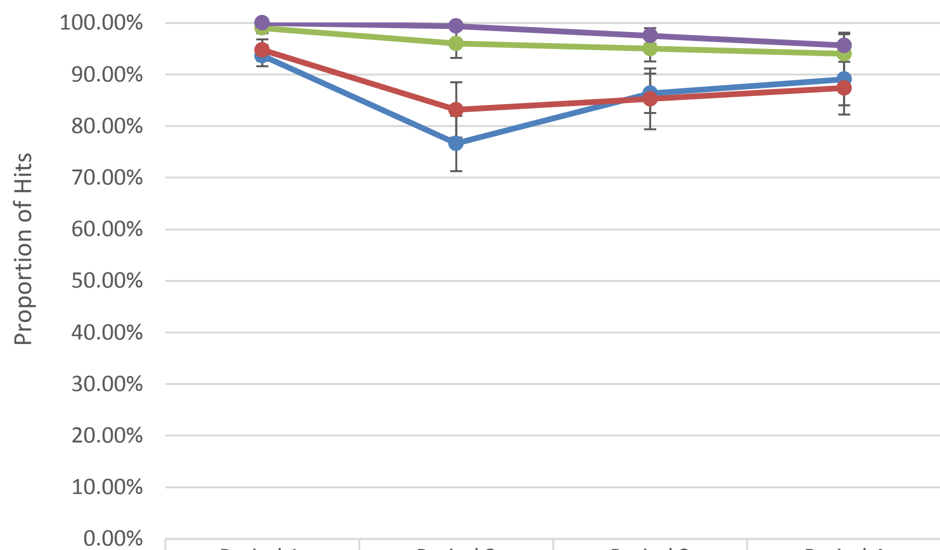
Mixed-measures ANCOVAs with task type and instruction type as the between-subjects factor, period on watch as the within-subjects factor, and AchM or AuM as the covariate were performed on all outcome measures related to performance. Separate ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of the proportion of correct detections are reported in Figures 29-31. The means and standard deviations of the number of false alarms are reported in Figures 32-34. The average response times per each period on watch are included in Figures 35-37. The correlations between motivation and correct detections, false alarms, and mean response time are reported in Appendix G.

There was a significant three-way interaction between instruction type, task type, and AuM on proportion of correct detections, $F(1, 85) = 4.27$, $p = .042$, $\eta_p^2 = .048$. There was also a significant interaction between instruction type and task type on proportion of correct detections, $F(1, 85) = 4.26$, $p = .042$, $\eta_p^2 = .048$, as well as instruction type and AuM on proportion of correct detections, $F(1, 85) = 4.00$, $p = .049$, $\eta_p^2 = .045$. There was a significant main effect of instruction type on proportion of correct detections, $F(1, 85) = 4.27$, $p = .042$, $\eta_p^2 = .048$. There was also a significant main effect of period on watch, but not AuM, on proportion of correct detections, $F(3, 255) = 3.06$, $p = .029$, $\eta_p^2 = .035$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AuM, only one result reached significance. There was a significant main effect of AuM on proportion of correct detections for participants assigned to the cognitive task who received autonomy-supportive instructions, $F(1, 20) = 7.82$, $p = .011$, $\eta_p^2 = .281$. When correct detection performance was plotted against AuM scores, there was a trend which indicated as

AuM motivation increased, there was also a slight increase in the proportion of correct detections over periods. Interestingly, observers in the sensory task receiving controlling instructions reported the greatest proportion of correct detections over time. Participants in the cognitive task demonstrated a decrease in performance during the second period on watch, but then demonstrated an increase in performance during periods three and four (which is similar to what was observed in Experiments One and Two). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There were no significant correlations, main effects, or interactions to report for the proportion of correct detections when AchM was entered into the ANCOVA as the covariate.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive	93.64%	76.63%	86.36%	89.09%
Cognitive - Controlling	94.74%	83.16%	85.26%	87.37%
Sensory- Autonomy-Supportive	99.00%	96.00%	95.00%	94.00%
Sensory - Controlling	100.00%	99.38%	97.50%	95.63%

Figure 29. The average proportion of correct detections with standard errors bars are reported for each of the conditions in Experiment Three.

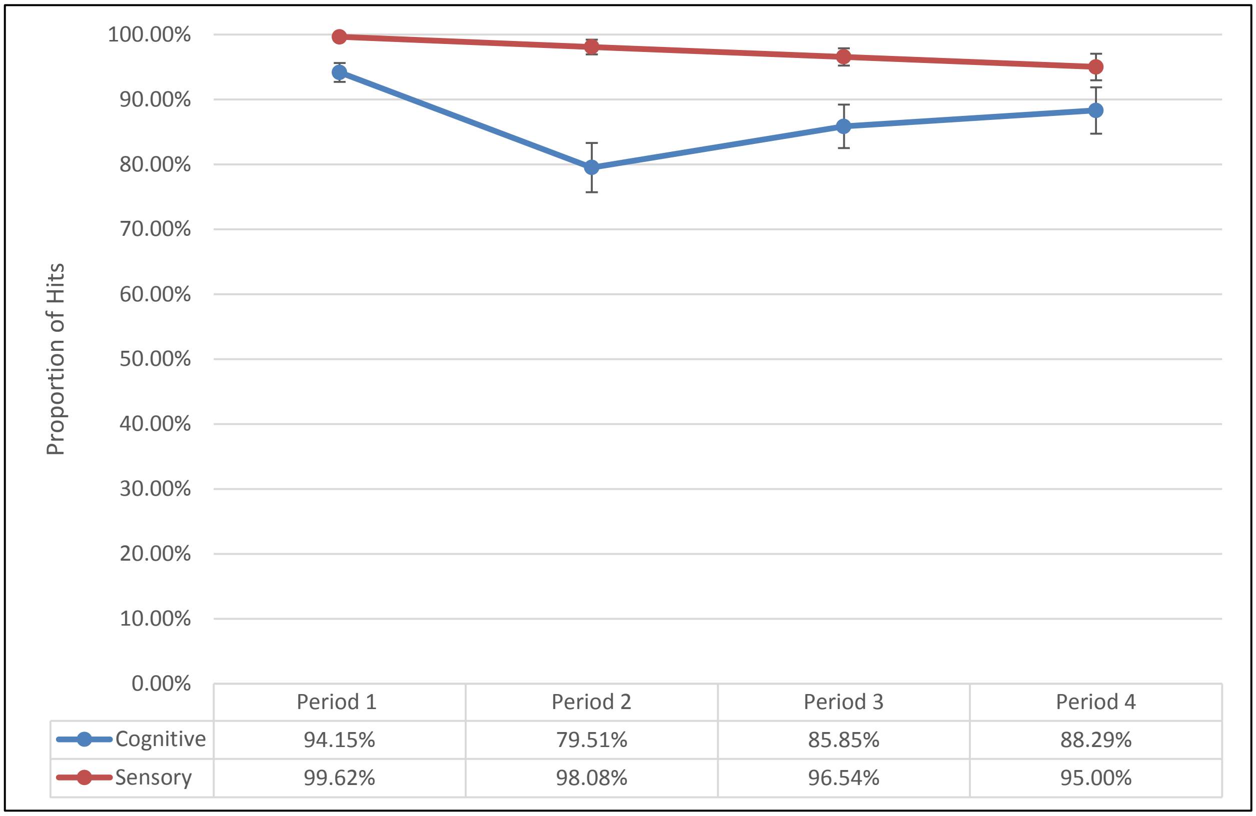


Figure 30. The average proportion of correct detections with standard errors bars are reported across task type in Experiment Three.

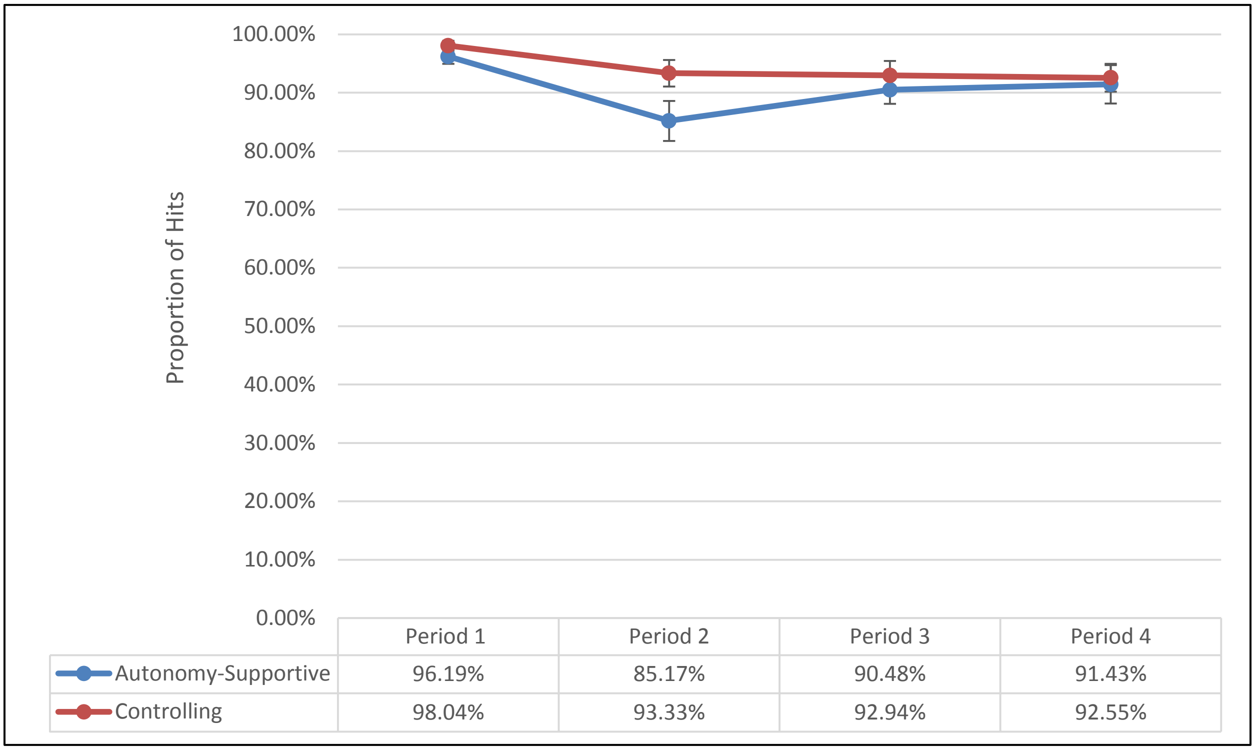
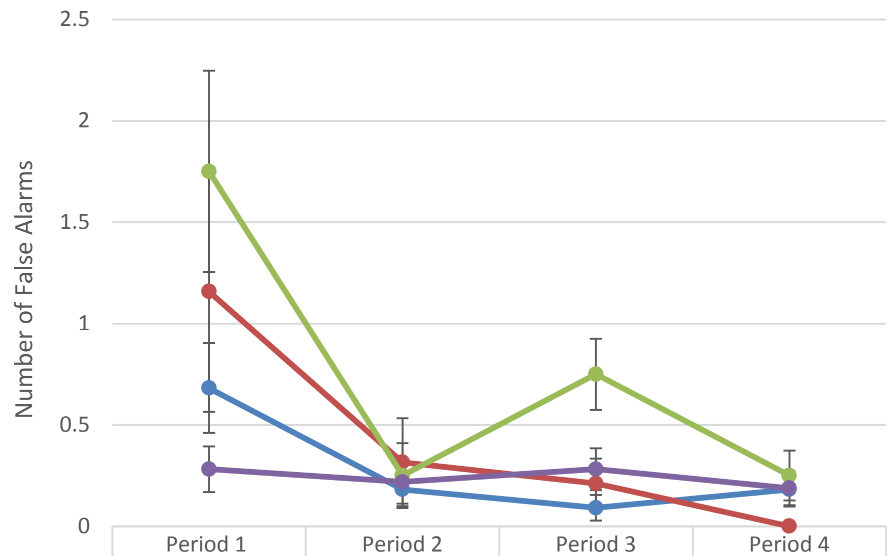


Figure 31. The average proportion of correct detections with standard errors bars are reported across instruction type in Experiment Three.

There was a significant interaction between instruction type and period on watch, but not AchM, on the number of false alarms, $F(3, 255) = 2.71$, $p = .046$, $\eta_p^2 = .031$. Participants in the sensory condition receiving autonomy-supportive instructions demonstrated some of the most variable performance in terms of the number of false alarms reported over time. There were no additional significant main effects, interactions, or correlations to report for the number of false alarms when AchM was entered as the covariate.

There were no significant main effects, interactions, or correlations to report for the number of false alarms when AuM was entered into the ANCOVA as the covariate.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive	0.6818	0.1818	0.0909	0.1818
Cognitive - Controlling	1.1579	0.3158	0.2105	0.0000
Sensory- Autonomy-Supportive	1.7500	0.2500	0.7500	0.2500
Sensory - Controlling	0.2813	0.2188	0.2813	0.1875

Figure 32. The average number of false alarms with standard errors bars are reported for each of the conditions in Experiment Three.

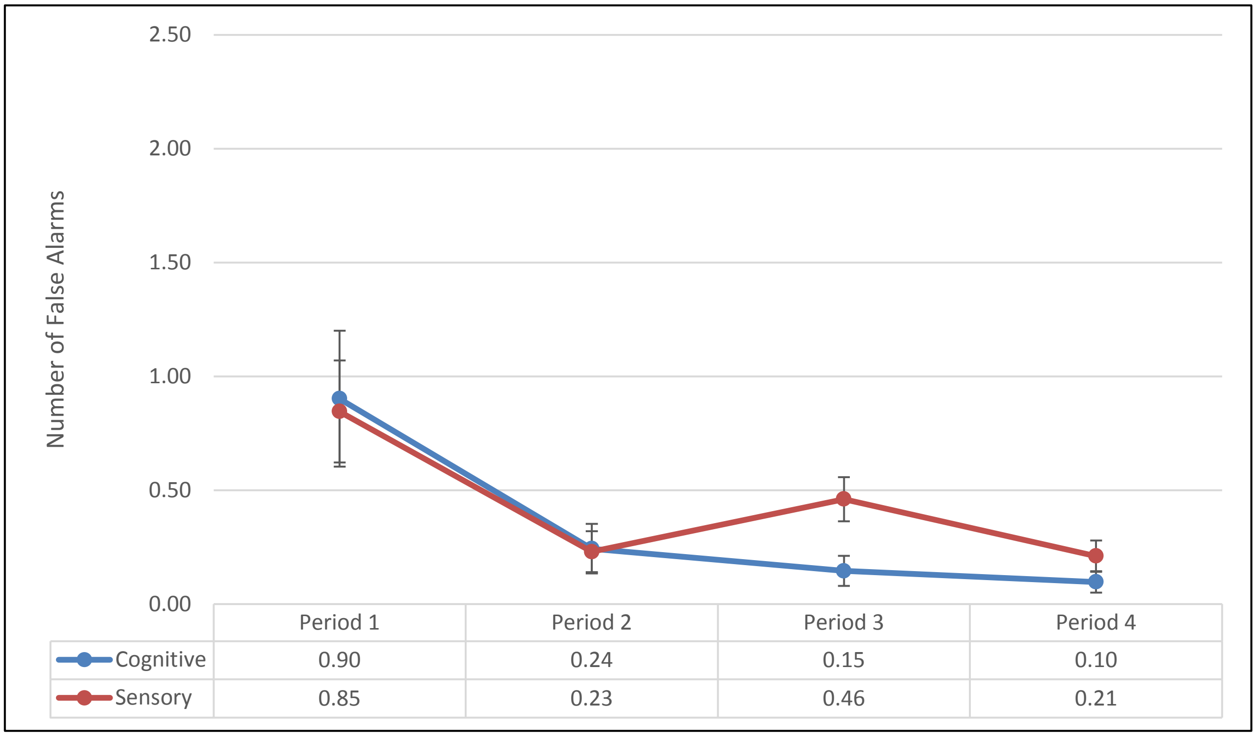


Figure 33. The average number of false alarms with standard errors bars are reported across task type in Experiment Three.

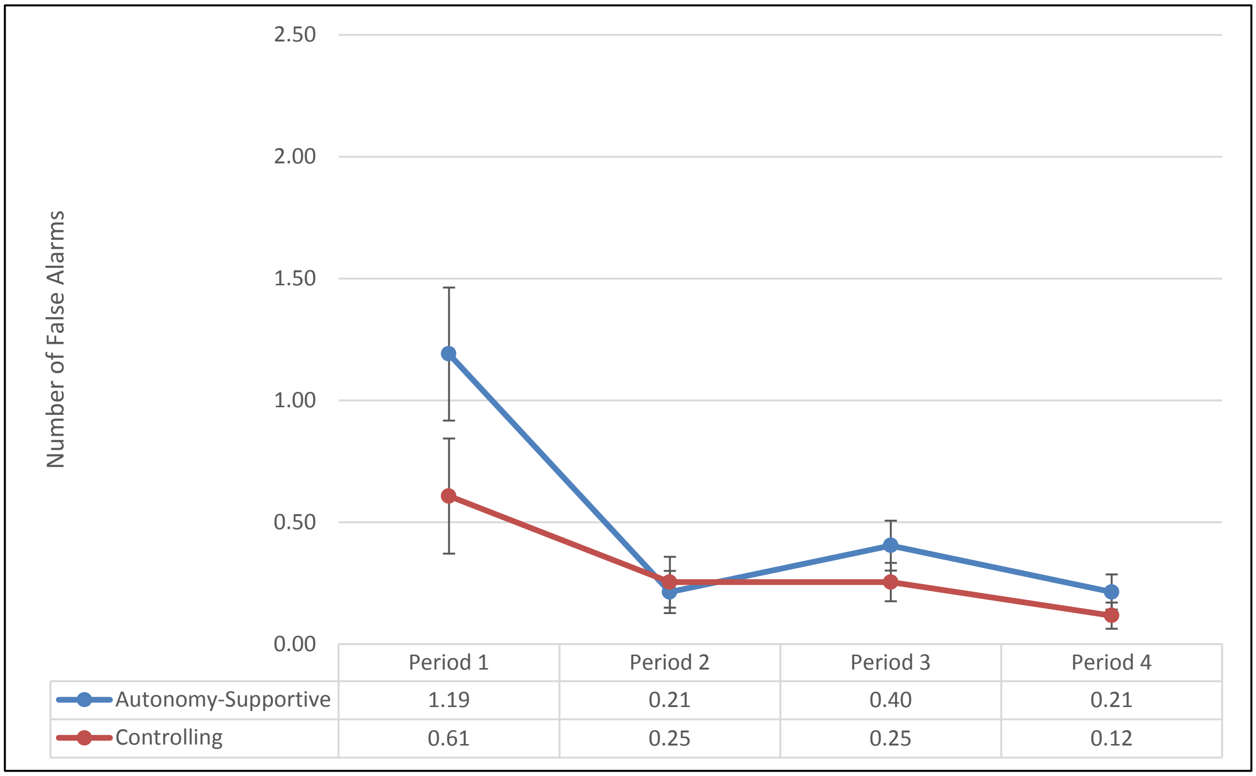
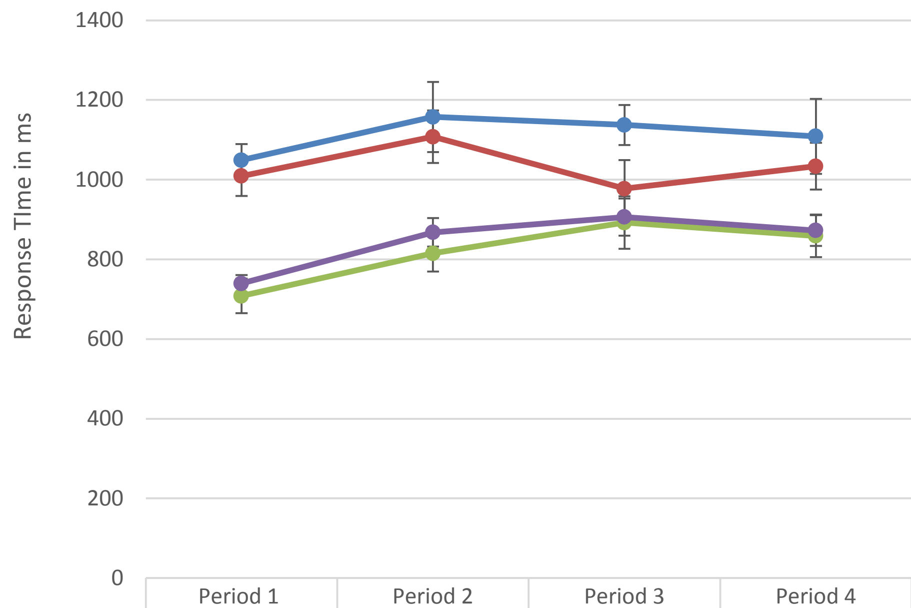


Figure 34. The average number of false alarms with standard errors bars are reported across instruction type in Experiment Three.

There were no significant main effects, interactions, or correlations to report for mean response time when AchM was entered into the ANCOVA as the covariate. There were no significant main effects, interactions, or correlations to report for average response time when AuM was entered into the ANCOVA as the covariate.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive	1049.0386	1157.4136	1137.3363	1108.7947
Cognitive - Controlling	1009.2289	1107.8526	977.4438	1033.9289
Sensory- Autonomy-Supportive	708.2025	815.1598	892.105	858.83
Sensory - Controlling	739.55	867.9031	906.3042	872.4364

Figure 35. The average response time with standard errors bars are reported for each of the conditions in Experiment Three.

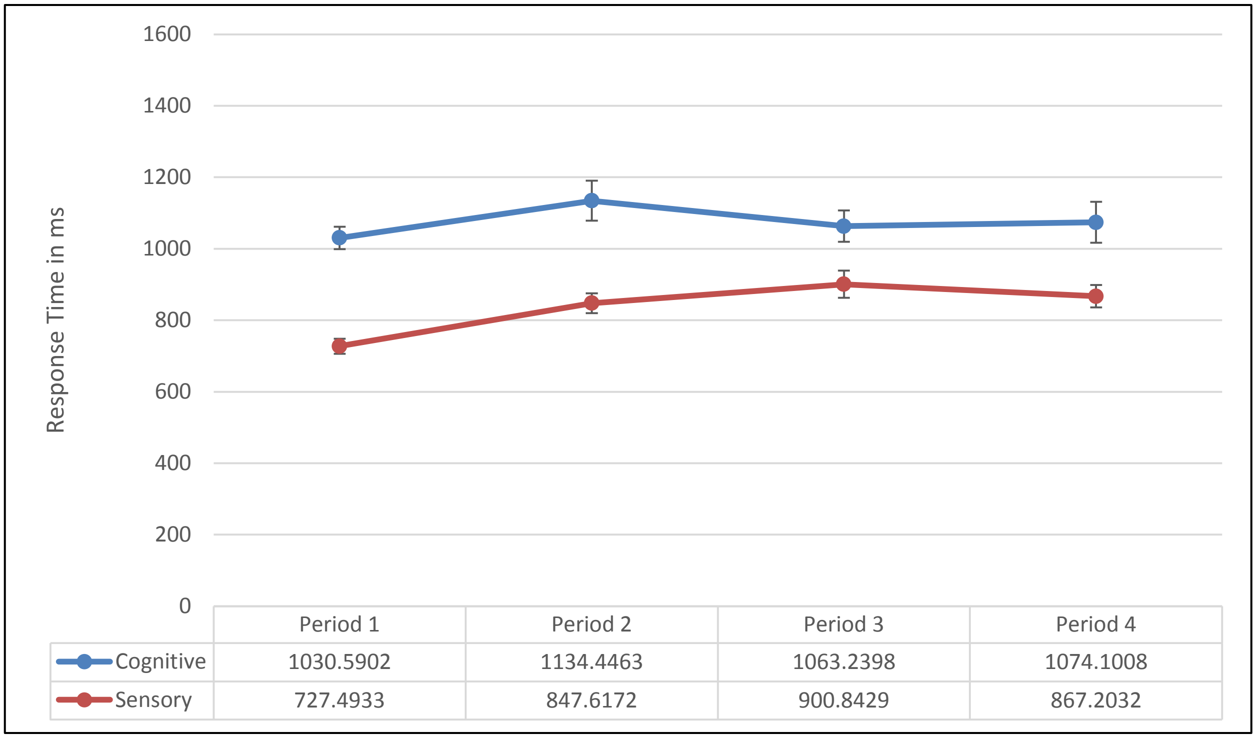


Figure 36. The average response time with standard errors bars are reported across task type in Experiment Three.

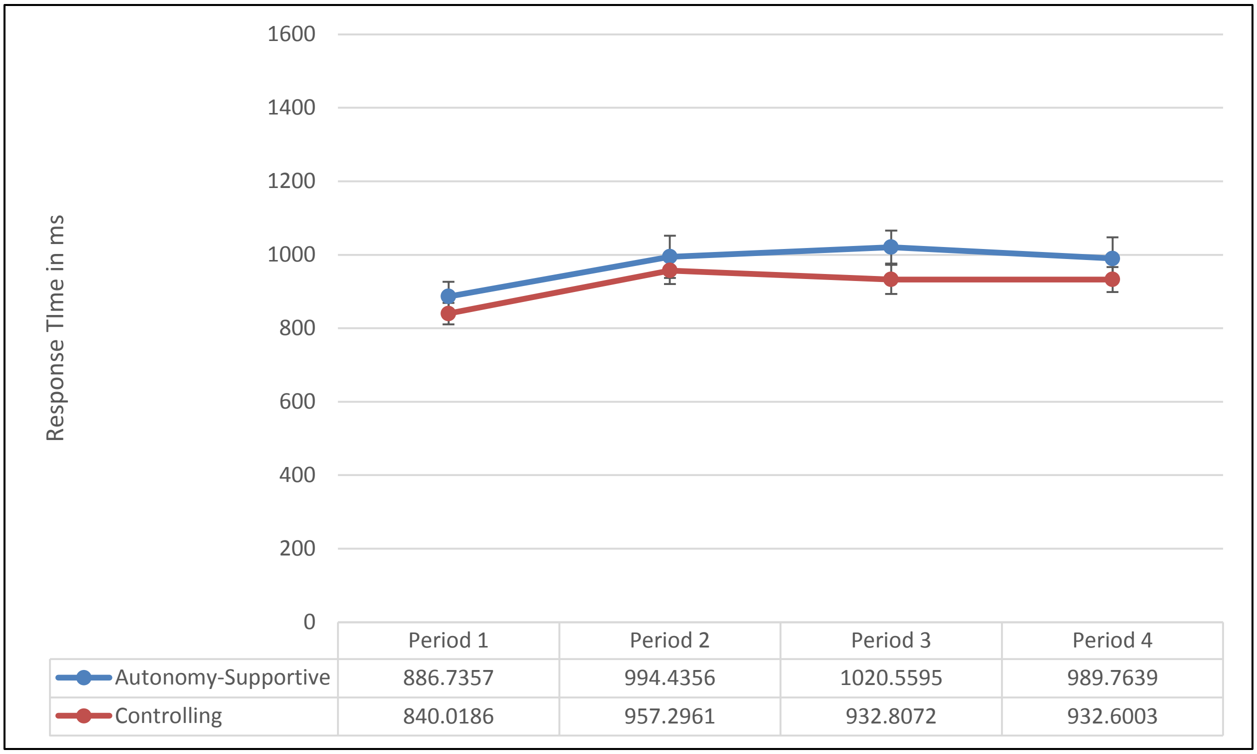


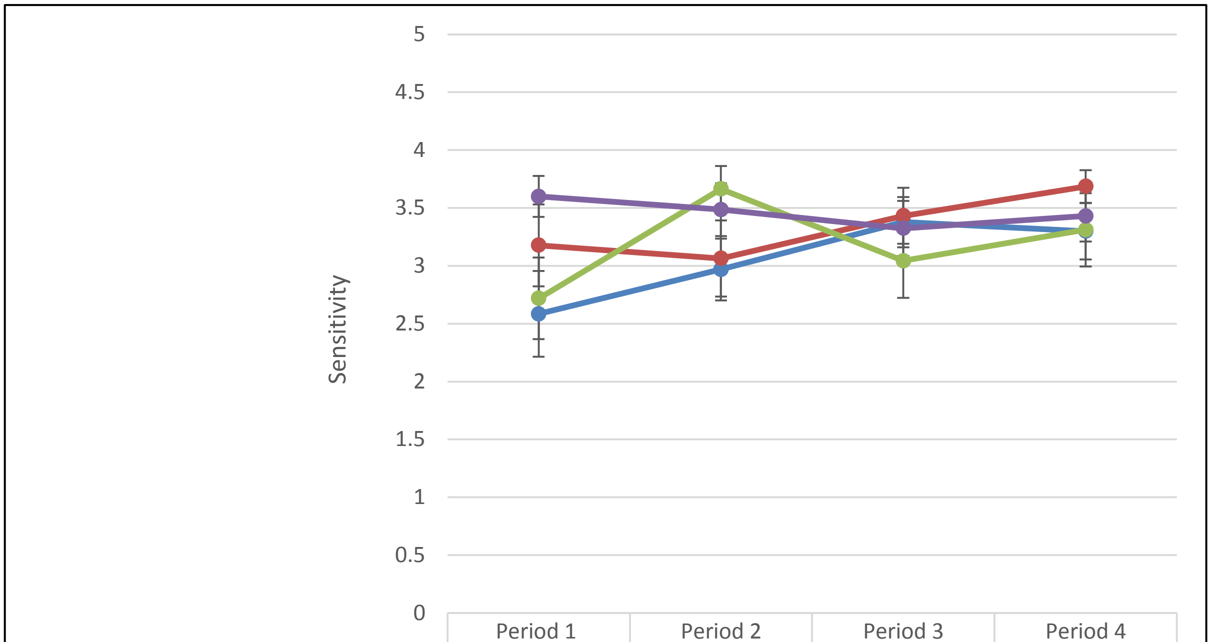
Figure 37. The average response time with standard errors bars are reported across instruction type in Experiment Three.

<u>Sensitivity and Response Bias</u>

The proportion of correct detections and number of false alarms were used to compute indices of sensitivity (*d'*; reported in Figures 38-40) and response bias (*c*; reported in Figures 41-43; See et al., 1995). Response bias tended to increase over time across task type, which indicates that participants in both condition types were becoming more conservative in their responding across each period on watch.

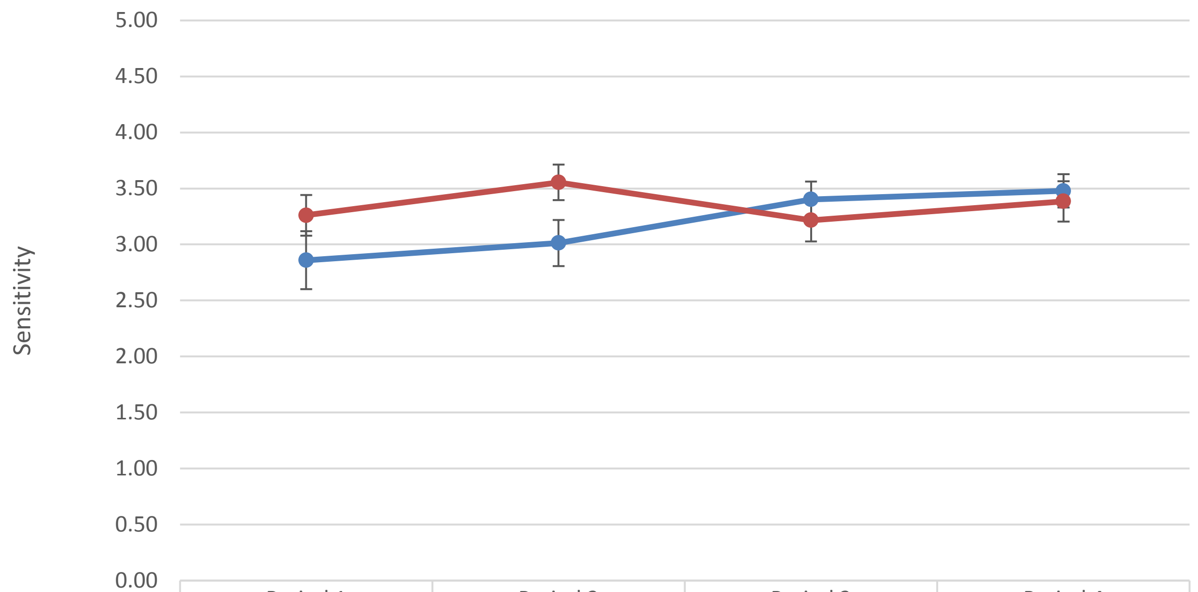
Mixed-measures ANCOVAs with task type and instruction type as the between-subjects variables, period on watch as the within-subjects variable, and AchM or AuM as the covariate were performed on all dependent measures related to these indices. Separate ANCOVAs were performed for each of these indices. Correlations between the measures of sensitivity and response bias, and the covariates are included in Appendix H.

There were no significant main effects, interactions, or correlations to report for sensitivity or response bias when AchM or AuM was entered into the ANCOVA as the covariate.



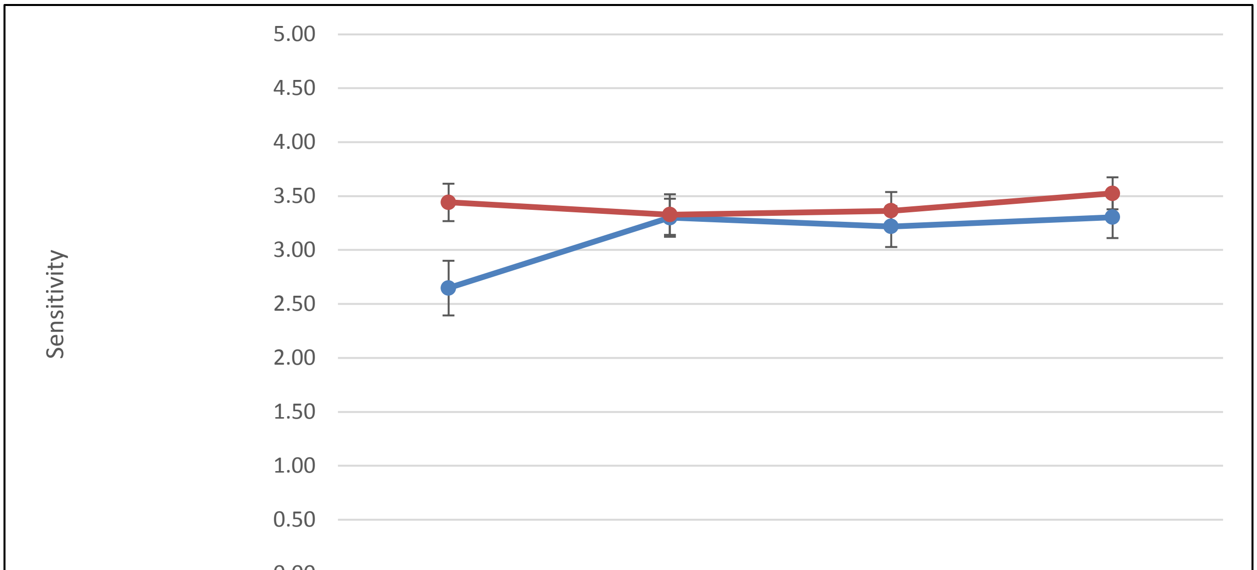
	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive	2.5837	2.9689	3.3772	3.2986
Cognitive - Controlling	3.1768	3.064	3.4316	3.6867
Sensory- Autonomy-Supportive	2.719	3.6636	3.043	3.311
Sensory - Controlling	3.5995	3.4853	3.3242	3.4305

Figure 38. Average sensitivity over time with standard errors bars is reported for each of the conditions in Experiment Three.



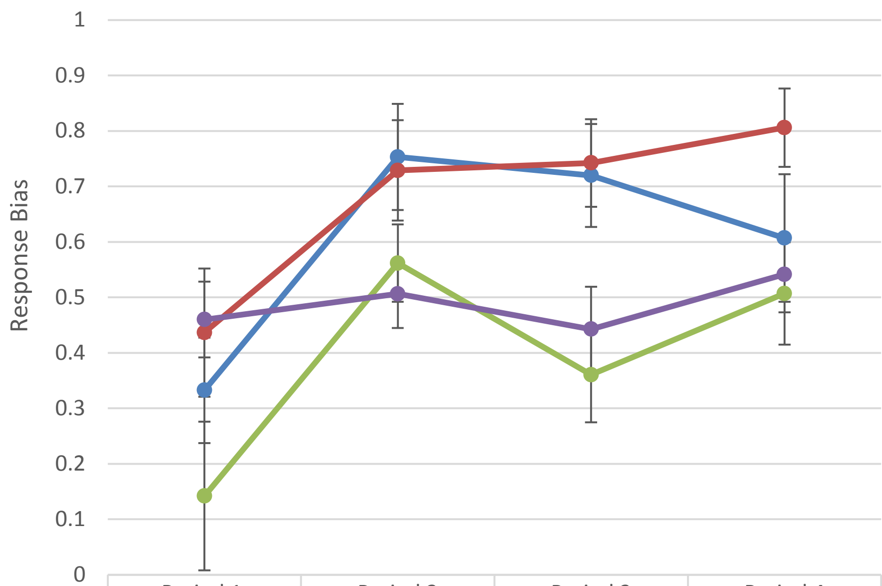
	Period 1	Period 2	Period 3	Period 4
Cognitive	2.86	3.01	3.40	3.48
Sensory	3.26	3.55	3.22	3.38

Figure 39. Average sensitivity over time reported across task type in Experiment Three.



	Period 1	Period 2	Period 3	Period 4
Autonomy-Supportive	2.65	3.30	3.22	3.30
Controlling	3.44	3.33	3.36	3.53

Figure 40. Average sensitivity over time reported across instruction type in Experiment Three.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive	0.3326	0.753	0.7199	0.6068
Cognitive - Controlling	0.4365	0.7288	0.7422	0.8060
Sensory- Autonomy-Supportive	0.1419	0.5618	0.3606	0.5070
Sensory - Controlling	0.4600	0.5062	0.4426	0.5415

Figure 41. Average response bias over time with standard errors bars is reported for each of the conditions in Experiment Three.

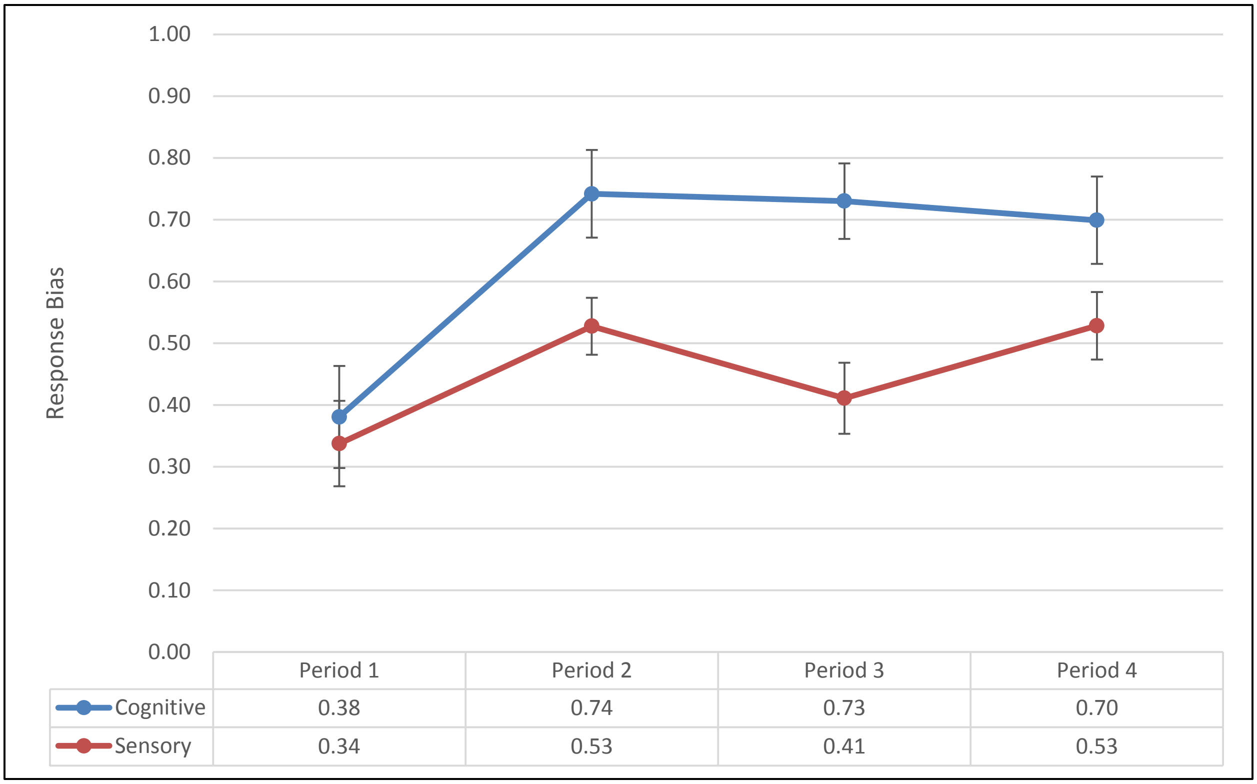
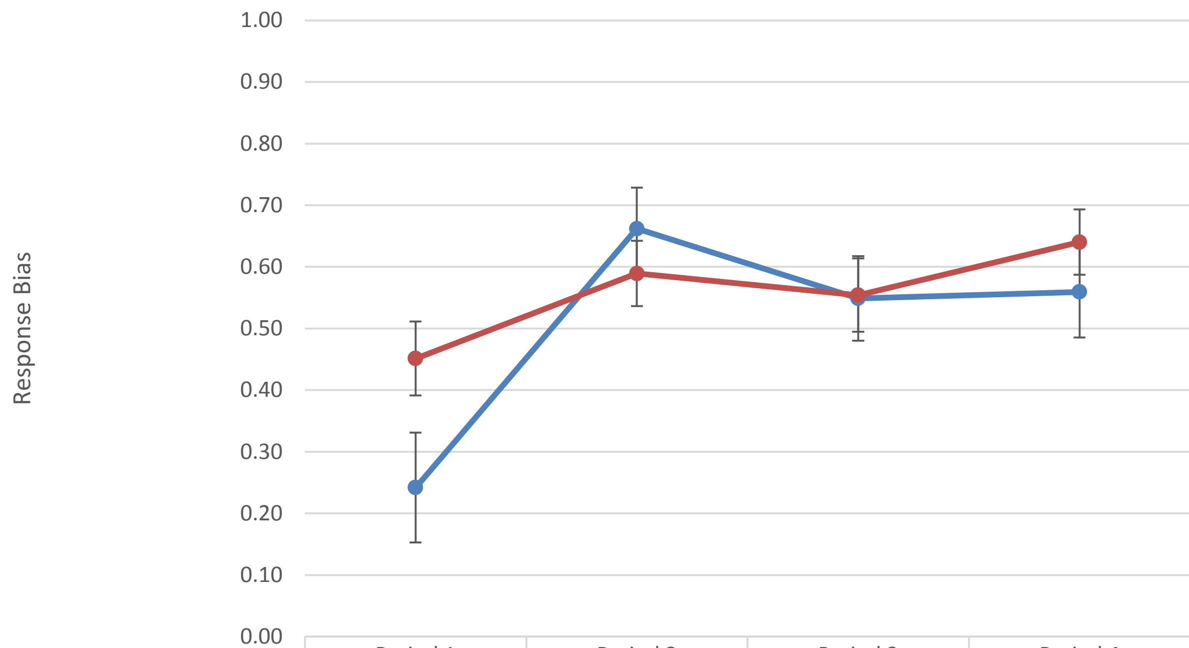


Figure 42. Average response bias over time across task type in Experiment Three.



	Period 1	Period 2	Period 3	Period 4
Autonomy-Supportive	0.24	0.66	0.55	0.56
Controlling	0.45	0.59	0.55	0.64

Figure 43. Average response bias over time across instruction type in Experiment Three.

Discussion

Engagement and Motivation

For achievement motivation there were significant effects on both pre- and post-task measures of engagement and motivation. Achievement motivation was significantly related to pre-task energetic arousal, post-task energetic arousal, post-task intrinsic motivation, and pre-task concentration. Participants in the cognitive task reported more intrinsic motivation at pre-task, however participants in the sensory task reported slightly more intrinsic motivation at post-task (there was a significant decline in intrinsic motivation between pre- and post-task).

Participants in the cognitive task receiving autonomy-supportive instructions reported the highest degree of pre-task concentration.

It is important to note that this finding could be an artefact of the cleaning that occurred. For example, to meet the inclusion criteria for data analyses, individuals in the cognitive condition may have remained in the dataset due to unique individual differences in trait motivation or state motivation (i.e., achievement motivation and autonomous motivation). The results indicated that achievement motivation likely affects perception of the task at baseline (i.e., pre-task), which in turn affects post-task success and intrinsic motivation.

Autonomous motivation significantly affected several measures of task engagement and task-related motivation including concentration, intrinsic motivation, success motivation, and task-unrelated thoughts. Autonomous motivation appeared to have more of an impact on the engagement and motivation (compared to achievement motivation), which was evidenced by a number of significant interactions with this covariate. These achievement motivation and autonomous motivation could affect the engagement and motivation measures differently in vigilance task, thus both achievement motivation and autonomous motivation will be retained in the fourth experiment in this dissertation. It is also worth noting at this time that autonomous motivation has been the more reliable measure of the two measures motivation and this is important to bear in mind when reflecting on the present findings.

Instruction type and task type also affected task-related and task-unrelated thoughts. For example, participants in the sensory task reported some of the highest rates of post-task task-unrelated thoughts, while observers in the cognitive task reported the fewest post-task task-unrelated thoughts. Participants in the sensory condition receiving autonomy-supportive instructions reported the most task-unrelated thoughts at post-task. In this vein, it could be argued that task-related and task-unrelated thoughts are not necessarily a product of mindlessness or mind-wandering which occur during vigilance, rather these task-based cognitions which are afforded by task type and task instructions. Thus, mind-wandering and mindlessness are not symptoms of vigilance per se, but byproducts of an iatrogenically created state induced by the researcher.

Stress and Workload

Achievement motivation and autonomous motivation impact the stress and workload associated with vigilance differently. For example, achievement motivation tended to predominantly affect hedonic tone, whereas autonomous motivation was implicated in tense arousal, hedonic tone, and anger/frustration. Lower achievement motivation scores were inversely correlated with hedonic tone, which implied that as achievement motivation increased, pleasantness associated with the task decreased. However, autonomous motivation scores were positively correlated with hedonic tone, which indicated that as autonomous motivation increased, there was more pleasantness associated with the vigilance task at pre-task and post-task. Participants higher in autonomous motivation also reported less anger/frustration toward the task at pre- and post-task, as well as less tense arousal at post-task. Based on these findings, it appears that autonomous motivation may have an ameliorative effect on some of the more 'negative' aspects of vigilance performance such as anger, frustration, tense arousal, or unpleasantness, which facilitates better coping with the vigilance task overall.

Interestingly, autonomous motivation did not have an effect on global workload, but achievement motivation significantly affected workload in Experiment Three. Instruction type also influenced perceptions of workload associated with the task. For example, participants in the autonomy-supportive instruction condition reported significantly higher global workload than participants in the controlling instruction condition. Participants in the cognitive task reported more global workload than participants in the sensory task, which was expected given the results of Experiments One and Two.

Performance

Achievement motivation did not influence vigilance performance in terms of proportion of correct detections, number of false alarms, average response time, sensitivity, or response bias. Thus, specific hypotheses related to performance and AchM generally went unsupported for Experiment Three.

In addition to task type and instruction type, autonomous motivation was significantly related to the proportion of correct detections detected over time. Participants in the sensory task outperformed participants in the cognitive task, which is likely due to the fact that the cognitive task requires symbolic processing and the sensory task requires perceptual processing. However, participants in the sensory task demonstrated a decline in proportion of correct detections over time. Participants in the cognitive task actually indicated a cognitive increment in performance over time, albeit there was a significant decline in performance between Periods 1 and 2 of watch for participants in either cognitive task, but a substantial increase in performance between Periods 3 and 4. This improvement in performance is likely due to a combination of factors: an important individual difference (i.e., autonomous motivation) and task design (i.e., the cognitive task affords more cognitive engagement). Interestingly, autonomous motivation did not influence false alarm rates, response time, sensitivity, or response bias in Experiment Three.

Instruction type did influence false alarm performance in Experiment Three. Participants assigned to the sensory condition receiving autonomy-supportive instructions responded more liberally to false alarms in Periods 1 and 3, which implies that autonomy-supportive instructions may shift the response criteria of observers. Participants in the cognitive condition receiving autonomy-supportive instructions demonstrated a numerical, liberal shift in responding between Periods 3 and 4 of watch, which could have influenced their improvement in performance toward the end of the task. That said, there was a shift toward better discrimination between critical signals and non-signals, as well as a general trend toward more conservatism in response to critical signals over time.

CHAPTER EIGHT: EXPERIMENT FOUR

Experiment Four extended the results of Experiments One, Two, and Three by varying the vigilance task across three factors: 1) source complexity, 2) task type, and 3) instruction type. In Experiment Four, participants were randomly assigned to one of twelve conditions: 1) a cognitive task with autonomy-supportive instructions and one display, 2) a cognitive task with autonomy-supportive instructions and two displays, 3) a cognitive task with autonomy-supportive instructions and four displays, 4) a cognitive task with controlling instructions and one display, 5) a cognitive task with controlling instructions and two displays, 6) a cognitive task with controlling instructions and four displays, 7) a sensory task with autonomy-supportive instructions and one display, 8) a sensory task with autonomy-supportive instructions and two displays, 9) a sensory task with autonomy-supportive instructions and four displays, 10) a sensory task with controlling instructions and one display, 11) a sensory task with controlling instructions and two displays, or 12) a sensory task with controlling instructions and four displays.

Hypotheses

Engagement and Motivation Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) should be significantly related to the level of engagement and motivation at post-task. Task engagement and motivation will be measured by energetic arousal, concentration, success motivation, intrinsic motivation, task-related thoughts (TRTs), and task-unrelated

thoughts (TUTs). Cognitive task engagement will be measured using concentration, TRTs, and TUTs.

2) Specific hypotheses related to cognitive engagement were developed given the three theories of information processing:

    a. Under the resource theory account of vigilance, AchM and AuM should be significantly related to concentration at post-task, but not under the mindlessness or mind-wandering account.

    b. If cognitively engaged with the task, AchM or AuM should be significantly related to increased TRTs at post-task under the resource-depletion account.

    c. According to mindlessness theory, there should be few if any TRTs.

    d. Under the mind-wandering assumption, there will be high TRTs at pre-task and low TRTs at post-task, regardless of the type of motivation involved in vigilance.

    e. Assuming a resource theory perspective, if individuals are engaged with the task, participants AchM or AuM should be related to a significant decrease in TUTs at post-task.

f. According to mindlessness theory, there should be more TUTs as the mind drifts away from the task because vigilance tasks afford this behavior.

g. Under the mind-wandering assumption, there will be high TUTs if disengaged with the task, especially at post-task as inward or outward task-unrelated thoughts increase during the vigil.

Stress and Workload Measures

1) Achievement motivation (AchM) and autonomous motivation (AuM) may affect stress and workload. Stress and workload will be measured by tense arousal, hedonic tone, anger/frustration, and global workload. Thus, the hypotheses are as follows:

    a. AchM and AuM should be significantly related to tense arousal. Participants lower in motivation will lack effective coping strategies to overcome the monotony associated with the task.

    b. AchM and AuM should be significantly related to higher hedonic tone because these individual differences are related to finding enjoyment in the task.

    c. AchM and AuM should be significantly related to anger/frustration. Participants lower in motivation will lack effective coping strategies related to managing perceived anger and frustration.

2) It is hypothesized that the cognitive task will be perceived as more work than the sensory task based on previous evidence from the existing literature on vigilance.

    a. However, participants high in AchM and AuM may be significantly related to global workload. It is possible that participants high in AchM or AuM will approach the cognitive task as if it is a complex challenge, which may reduce overall perceived workload.

Performance Measures

1) Proportion of correct detections, number of false alarms, average response time, and signal detection measures of sensitivity and response bias will serve as measures of performance.

2) AchM and AuM should be significantly related to the proportion of correct detections because individuals high in these differences want to strive toward success and perceive control over their performance.

3) Similarly, AchM and AuM should be significantly related to the number of false alarms because individuals high in these differences want to strive toward success and perceive

control over their performance, thus reporting a low number of false alarms over time.

4) AchM and AuM may be significantly related to mean response time because previous literature has demonstrated that motivation is linked to attention.

Participants

An *a priori* power analysis was conducted for Experiment Four using G*Power Version 3.1 with a medium effect size and conventional criteria (α = 0.05, 1-β = 0.80; Faul et al., 2007) to estimate power and effect sizes prior to data collection. Following this analysis, approximately 158 participants were recruited from the University of Central Florida's research participation system (SONA).

To qualify for participation in this study, participants must have normal or corrected-to-normal vision and were at least 18 years of age or older. Participants who participated in Experiments One, Two, or Three are not eligible for participation in Experiment Four. Participants were asked to not consume caffeine 24 hours prior to the study.

Data Cleaning and Final Sample

One hundred and fifty-eight participants were collected from the SONA study pool for Experiment Four. Six of these participants were removed from the sample for incomplete SuperLab data and four participants were removed for incomplete survey data.

The inclusion criteria were as follows: participants achieved a minimum score of 70% correct detections (i.e., hit rate) in the first watch period and did not commit more than ten false alarms in any given watch period. The same rationale for the cutoff criteria, which was used in the previous studies, applies here as well.

After data cleaning based on the inclusion criteria for analysis, the final sample for this study consisted of 121 undergraduate students. Twenty-seven participants were removed from this sample because of performance deviations that did not meet the inclusion criteria. More specifically, one participant was removed from the one-display cognitive task with controlling instructions, four participants were removed from the two-display cognitive task with controlling instructions, four participants were removed from the four-display cognitive task with controlling instructions, four participants were removed from the two-display cognitive task with autonomy-supportive instructions, four participants were removed from the four-display cognitive task with autonomy-supportive instructions, one participant was removed from the one-display sensory task with controlling instructions, two participants were removed from the two-display sensory task with controlling instructions, one participant was removed from the four-display sensory task with controlling instructions, three participants were removed from the two-display sensory task with autonomy-supportive instructions, and one participant was removed from the four-display sensory task with autonomy-supportive instructions.

Design

In Experiment Four, participants were randomly assigned to either the cognitive or sensory task and received either autonomy-supportive instructions or controlling instructions condition and were required to monitor one, two, or four displays (see Table 17).

Table 17. The table below indicates the conditions to which participants were randomly assigned in Experiment Four.

Task Type	Instruction Type	Source Complexity	Participants Assigned to each Condition
Cognitive	Autonomy-Supportive	One display	11
		Two displays	7
		Four displays	7
Cognitive	Controlling	One display	7
		Two displays	7
		Four displays	9
Sensory	Autonomy-Supportive	One display	17
		Two displays	11
		Four displays	6
Sensory	Controlling	One display	20
		Two displays	8
		Four displays	11

Task Stimuli and Environment

The task stimuli and environment of Experiment Four were identical to participants used in Experiments One, Two, and Three.

Measures

The same measures from Experiment One were used in Experiment Four. The reliabilities of these measures for Experiment Four are reported in Appendix I.

Procedure

The procedure for Experiment Four was the same as that used in previous experiments, with the exception that participants could be randomly assigned to one of the twelve conditions.

Descriptive Statistics

Data from 121 undergraduate students (81 females; 39 males; 1 student preferred to not disclose) was collected from the SONA pool at the University of Central Florida for Experiment Four. Of participants who participated, 68.5% were freshmen, 13.2% were sophomores, 12.4% were juniors, and 4.2% were seniors. The average age of participants was 19.03 years (*Median* =

18.00 years, *SD* = 1.73 years). The oldest student in this sample was 29-years-old and the youngest student was 18 years of age. All participants reported normal or corrected-to-normal vision. Participants indicated that they did not to consume caffeine 24 hours prior to this study.

The participants included in the present study did not differ substantially from those excluded from Experiment Four (based on inclusion criteria). For example, the average age of participants that were excluded was 18.67 years of age (*Range*: 18 – 21), 6 male participants were removed, and 21 female participants were removed. There were two significant differences between participants that were included and those that were excluded from these analyses.

Participants differed significantly in pre-task intrinsic motivation and autonomous motivation, which was one of the covariates included in the present study. Participants excluded from the present analyses reported both higher pre-task intrinsic motivation and autonomous motivation scores than those included in the present sample, which is a finding accompanied by very large effect sizes. The complete engagement, motivation, stress, and workload scores for the participants removed from Experiment Four are listed in Appendix J. The effect sizes for analyses on the excluded data are included in Appendix K.

Results

Engagement and Motivation Measures

The average AchM score was 21.92 (*SD* = 3.71; *Range*: 16.00 – 34.00). The average AuM score was 34.36 (*SD* = 9.08; *Range*: 13.00 – 49.00). There was a strong negative skew for the achievement motivation scores, which implies that participants in this sample self-reported lower achievement motivation than in previous samples. There was a slight positive skew for autonomous motivation, which indicates a trend toward higher autonomous motivation scores being reported throughout the sample.

AchM or AuM scores were used as covariates, and task type, number of displays, and instruction type were used as independent variables to conduct separate ANCOVAs for all measures of motivation and engagement. Separate ANCOVAs were performed for each pre-task and post-task measure. ANCOVAs were used to perform the analyses in the present experiment because the covariates are continuous variables.

The means and standard deviations for the engagement and motivation measures across task types are reported in Table 18. The means and standard deviations for the measures of engagement and motivation by instruction type are reported in Table 19. The means and standard deviations for the measures of engagement and motivation by number of displays are reported in Table 20. Correlations of AchM and AuM with the engagement and motivation measures are reported in Appendix C.

Table 18. The table below includes the means and standard deviations for all measures of motivation and engagement across task type (*N* = 121).

	Cognitive Task (*N* = 48)		**Sensory Task (*N* = 73)**		**Overall**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	21.13 (3.32)		22.44 (3.88)		21.92 (3.71)	
AuM	34.50 (8.47)		34.26 (9.52)		34.36 (9.08)	
Success Motivation	19.96 (7.31)	20.48 (6.64)	20.42 (6.33)	19.68 (6.99)	20.24 (6.71)	20.00 (6.83)
Intrinsic Motivation	18.15 (5.39)	12.44 (4.50)	17.07 (4.18)	12.54 (4.93)	17.50 (4.71)	12.50 (4.75)
Energetic Arousal	18.06 (3.82)	18.71 (4.21)	17.60 (3.76)	18.08 (4.58)	17.79 (3.78)	18.33 (4.43)
Concentration	17.65 (5.90)	8.54 (6.04)	14.60 (6.56)	6.53 (7.42)	15.81 (6.45)	7.33 (6.95)
TRTs	17.94 (8.16)	21.90 (6.45)	17.62 (8.50)	19.71 (7.31)	17.74 (8.34)	20.58 (7.04)
TUTs	16.10 (9.48)	15.50 (7.19)	17.52 (9.09)	16.68 (8.07)	16.96 (9.23)	16.21 (7.72)

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations.

Table 19. The table below includes the means and standard deviations for all measures of motivation and engagement across instruction type (N = 121).

	Autonomy-Supportive Instructions (N = 59)		**Controlling Instructions (N = 62)**	
	Pre	**Post**	**Pre**	**Post**
AchM	21.78 (3.23)		22.05 (4.13)	
AuM	35.31 (8.61)		33.45 (9.49)	
Success Motivation	20.00 (7.18)	19.61 (6.64)	20.47 (6.29)	20.38 (7.05)
Intrinsic Motivation	17.20 (4.42)	12.05 (4.71)	17.77 (4.99)	12.93 (4.78)
Energetic Arousal	18.10 (2.95)	18.83 (4.67)	17.48 (4.43)	17.85 (4.16)
Concentration	16.51 (6.49)	7.14 (7.24)	15.15 (6.40)	7.52 (6.71)
TRTs	17.56 (9.13)	20.69 (7.72)	17.92 (7.58)	20.48 (6.37)
TUTs	17.39 (10.28)	17.03 (8.61)	16.55 (8.18)	15.41 (6.73)

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations.

Table 20. The table below includes the means and standard deviations for all measures of motivation and engagement across number of displays (N = 121).

	One (N = 55)		Two (N = 33)		Four (N = 33)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
AchM	22.15 (3.36)		21.45 (3.50)		22.00 (4.47)	
AuM	34.75 (8.42)		31.79 (9.24)		36.27 (9.66)	
Success Motivation	20.18 (6.49)	19.42 (6.31)	20.27 (7.11)	20.91 (6.16)	20.30 (6.88)	20.06 (8.32)
Intrinsic Motivation	17.02 (4.38)	11.95 (3.97)	17.24 (4.39)	12.55 (5.33)	18.55 (5.47)	13.41 (5.31)
Energetic Arousal	17.67 (3.54)	18.22 (4.39)	18.18 (3.81)	19.03 (4.38)	17.58 (4.18)	17.81 (4.60)
Concentration	16.04 (6.13)	6.84 (7.16)	15.61 (6.48)	8.06 (6.76)	15.64 (7.12)	7.44 (6.90)
TRTs	17.85 (8.35)	19.44 (5.97)	18.82 (7.46)	22.03 (7.01)	16.48 (9.20)	21.06 (8.51)
TUTs	16.95 (8.77)	15.49 (7.13)	16.94 (8.50)	17.12 (7.69)	17.00 (10.85)	16.50 (8.79)

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. Numbers in parentheses represent standard deviations.

There was a significant four-way interaction between the covariate AchM, instruction type, task type, and number of displays, on pre-task intrinsic motivation, $F(2, 97) = 3.11$, p = .049, η_p^2 = .060. There was also a significant interaction between AchM and instruction type on pre-task intrinsic motivation, $F(1, 97) = 8.57$, p = .004, η_p^2 = .081. In follow-up ANCOVAs exploring the effects of each level of the independent variables on pre-task intrinsic motivation, only one result reached significance. There was a significant effect of the covariate AchM on pre-task intrinsic motivation in the sensory task that required participants to monitor one display and when these participants received autonomous instructions, $F(1, 15) = 5.85$, p = .029, η_p^2 =

.281. Participants in the cognitive condition with controlling instructions monitoring four displays reported the highest pre-task intrinsic motivation scores (*M* = 22.00, *SD* = 4.87). Participants in the sensory condition monitoring four displays and receiving autonomy-supportive instructions also reported high pre-task intrinsic motivation (*M* = 19.86, *SD* = 5.70).

It is important to note that this finding is likely an atrefact of data cleaning. For example, in order to be included in the present analyses observers had to perform well enough to remain in the sample and likely had an individual difference that enabled them to be included in the present analyses. In this case, that individual difference was achievement motivation. This could be a limitation to this study, but it does support the idea of accounting for individual differences, especially in the implicit assumption that all participants are motivated to perform the task.

There was a significant four-way interaction between the covariate AchM, instruction type, task type, and number of displays, on post-task concentration, $F(2, 97) = 3.15$, $p = .047$, $\eta_p^2 = .062$. There was a significant three-way interaction between task type, number of displays, and AchM, on post-task concentration, $F(2, 97) = 5.15$, $p = .008$, $\eta_p^2 = .097$. There was a significant three-way interaction between instruction type, task type, and number of displays, on post-task concentration, $F(1, 96) = 3.57$, $p = .032$, $\eta_p^2 = .069$, and post-task task-unrelated thoughts, $F(2, 97) = 4.04$, $p = .021$, $\eta_p^2 = .078$. There was significant interaction between task type and number of displays on post-task concentration, $F(2, 97) = 4.82$, $p = .010$, $\eta_p^2 = .091$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task concentration, only one result approached significance. There was a nearly significant effect of the covariate AchM on post-task concentration in the cognitive task wherein participants monitored only one display and received controlling instructions, $F(1, 5) = 6.62$, $p = .050$, $\eta_p^2 = .570$. A similar result was observed for participants in the cognitive task with two displays and controlling instructions, $F(1, 5) = 5.15$, $p = .073$, $\eta_p^2 = .507$. Participants in the cognitive condition receiving controlling instructions and monitoring either two (*M* = 9.29, *SD* = 4.61) or four (*M* = 9.89, *SD* = 5.75) displays reported some of the highest post-task concentration, whereas participants in the sensory condition receiving autonomy-supportive instructions monitoring only one display reported some of the lowest post-task concentration (*M* = 5.71, *SD* = 7.37).

There was a significant four-way interaction between the covariate AchM, instruction type, task type, and number of displays, on post-task task-unrelated thoughts, $F(2, 97) = 3.62$, $p = .030$, $\eta_p^2 = .070$. There was a significant interaction between AchM and the number of displays on post-task task-unrelated thoughts, $F(2, 97) = 6.40$, $p = .002$, $\eta_p^2 = .118$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task task-unrelated thoughts, only one result reached significance. There was a significant effect of the covariate AchM on post-task task-unrelated thoughts in the cognitive task wherein participants monitored two displays and received autonomy-supportive instructions, $F(1, 5) = 8.99$, $p = .030$, $\eta_p^2 = .643$, and in the cognitive task wherein participants monitored two displays and received controlling instructions, $F(1, 5) = 15.67$, $p = .011$, $\eta_p^2 = .758$. Participants in the sensory condition receiving autonomy-supportive instructions monitoring two displays reported the highest degree of post-task task-unrelated thoughts (*M* = 19.45, *SD* = 9.41), whereas participants in the cognitive condition monitoring only one display and receiving either autonomy-supportive instructions (*M* = 13.27, *SD* = 8.32) or controlling instructions (*M* = 14.43, *SD* = 6.75) reported the fewest post-task task-unrelated thoughts.

There was a significant main effect of the covariate AchM, but not task type, instruction type, or number of displays, on post-task success motivation, $F(1, 97) = 8.76$, $p = .004$, $\eta_p^2 =$

.084, pre-task energetic arousal, $F(1, 97) = 4.15$, $p = .044$, $\eta_p^2 = .041$ (note that Levene's Test of the Equality of Error Variances was violated for this analysis, thus this result should be interpreted with caution), and post-task task-related thoughts, $F(1, 97) = 3.93$, $p = .050$, $\eta_p^2 = .039$. There was a significant main effect of the number of displays on post-task task-unrelated thoughts, $F(2, 97) = 6.70$, $p = .002$, $\eta_p^2 = .122$. There was a significant main effect of instruction type on pre-task intrinsic motivation, $F(1, 97) = 8.31$, $p = .005$, $\eta_p^2 = .079$. There was a significant negative correlation between AchM and post-task success motivation ($r = -.327$, $p < .004$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant three-way interaction between instruction type, task type, and AuM on post-task intrinsic motivation, $F(1, 97) = 5.80$, $p = .018$, $\eta_p^2 = .057$. There was a significant interaction between number of displays and AuM on post-task intrinsic motivation, $F(2, 97) = 4.27$, $p = .017$, $\eta_p^2 = .082$. There was a significant interaction between instruction type and task type on post-task intrinsic motivation, $F(1, 97) = 4.77$, $p = .031$, $\eta_p^2 = .047$. There was a significant main effect of number of displays on post-task intrinsic motivation, $F(1, 97) = 4.61$, $p = .012$, $\eta_p^2 = .088$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task intrinsic motivation, three results were significant. There was a significant effect of the covariate AuM on post-task intrinsic motivation in the sensory task wherein participants monitored four displays and received controlling instructions, $F(1, 8) = 8.70$, $p = .018$, $\eta_p^2 = .521$. There was also significant effect of the covariate AuM on post-task intrinsic motivation in the cognitive task wherein participants monitored only one display and received controlling instructions, $F(1, 5) = 8.55$, $p = .033$, $\eta_p^2 = .631$, and in the same task wherein participants monitored two displays and received controlling instructions, $F(1, 5) = 11.18$, $p = .020$, $\eta_p^2 = .691$. Participants in the cognitive condition receiving controlling instructions reported the highest post-task intrinsic motivation scores ($M = 14.56$, $SD = 4.45$; four display condition), whereas participants in the sensory condition receiving autonomy-supportive instructions demonstrated the lowest post-task intrinsic motivation scores ($M = 11.24$, $SD = 4.40$; one display condition).

There was a significant three-way interaction between task type, number of displays, and AuM on post-task energetic arousal, $F(2, 97) = 4.79$, $p = .010$, $\eta_p^2 = .091$. There was a significant interaction between task type and number of displays on post-task energetic arousal, $F(2, 97) = 4.78$, $p = .011$, $\eta_p^2 = .091$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task energetic arousal, two results were significant. There was a significant effect of the covariate AuM on post-task energetic arousal in the cognitive task wherein participants monitored only one display and received autonomy-supportive instructions, $F(1, 9) = 5.69$, $p = .041$, $\eta_p^2 = .387$, and in the same task where participants monitored one display and received controlling instructions, $F(1, 5) = 7.20$, $p = .044$, $\eta_p^2 = .590$. Participants monitoring two displays across conditions reported the most post-task energetic arousal. Participants in the sensory condition monitoring four displays reported the lowest amount of post-task energetic arousal ($M = 14.80$, $SD = 3.46$).

There was also a significant interaction between instruction type and autonomous motivation on pre-task success motivation, $F(1, 97) = 8.13$, $p = .005$, $\eta_p^2 = .077$. Observers in the controlling instruction condition reported slightly higher success motivation prior to completing the task than participants receiving autonomy-supportive instructions.

There was a significant main effect of the covariate AuM, on post-task success motivation, $F(1, 97) = 4.26$, $p = .042$, $\eta_p^2 = .042$, as well as pre-task intrinsic motivation, $F(1, 97) = 8.30$, $p = .005$, $\eta_p^2 = .079$. There was a significant main effect of instruction type on pre-task success motivation, $F(1, 97) = 7.19$, $p = .009$, $\eta_p^2 = .069$, and pre-task energetic arousal, $F(1, 97) = 3.83$, $p = .053$, $\eta_p^2 = .038$. There were no additional significant main effects, interactions, or correlations to report for these analyses.

Stress and Workload Measures

An ANCOVA with task type, number of displays, and type of instructions as the independent variables, and AchM or AuM as the covariate, was performed on all outcome measures related to stress and workload. Separate ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of stress and workload measures by task type are reported in Table 21. The means and standard deviations for the measures of stress and workload measures by instruction type are reported in Table 22. The means and standard deviations for the measures of stress and workload measures by number of displays are reported in Table 23. The means and standard deviations for the full DSSQ are reported in Appendix D. The means and standard deviations for the full NASA-TLX are reported in Appendix E.

Table 21. The table below includes the means and standard deviations for all measures of stress and workload across conditions (N = 121).

	Cognitive Task (N = 48)		Sensory Task (N = 73)		Overall	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	12.38 (3.55)	15.81 (5.21)	13.36 (3.26)	15.64 (4.40)	12.97 (3.40)	15.71 (4.72)
Hedonic Tone	26.56 (4.04)	23.19 (3.53)	25.65 (4.29)	22.44 (4.79)	26.02 (4.20)	22.74 (4.33)
Anger/ Frustration	7.44 (2.86)	9.51 (3.48)	7.86 (3.35)	10.18 (3.67)	7.69 (3.16)	9.92 (3.60)
Global Workload		44.48 (17.04)		37.22 (13.42)		40.13 (15.33)
Mental Demand		51.04 (29.14)		35.55 (27.79)		41.69 (29.22)
Temporal Demand		33.79 (29.59)		25.82 (23.67)		28.98 (26.35)
Physical Demand		11.77 (16.73)		9.62 (13.78)		10.47 (14.99)
Perceived Performance		55.15 (32.00)		50.12 (32.55)		52.12 (32.29)
Effort		43.96 (27.26)		29.18 (25.51)		35.04 (27.10)
Frustration		32.94 (26.79)		30.62 (32.33)		31.54 (30.16)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

Table 22. The table below includes the means and standard deviations for all measures of stress and workload across instruction type (*N* = 121).

	Autonomy-Supportive Instructions (*N* = 59)		Controlled Instructions (*N* = 62)	
	Pre	**Post**	**Pre**	**Post**
Tense Arousal	13.00 (3.40)	15.59 (4.71)	12.94 (3.43)	15.82 (4.77)
Hedonic Tone	26.31 (4.50)	23.03 (4.47)	25.74 (3.91)	22.46 (4.20)
Anger/Frustration	7.61 (3.20)	9.48 (3.22)	7.77 (3.14)	10.33 (3.91)
Global Workload		39.23 (15.46)		40.97 (15.27)
Mental Demand		43.29 (25.65)		40.18 (32.39)
Temporal Demand		27.08 (23.06)		30.79 (29.21)
Physical Demand		11.10 (13.85)		9.87 (16.09)
Perceived Performance		51.95 (31.52)		52.27 (33.27)
Effort		36.56 (25.11)		33.60 (29.00)
Frustration		32.44 (29.82)		30.68 (30.71)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

Table 23. The table below includes the means and standard deviations for all measures of stress and workload across number of displays (N = 121).

	One (N = 55)		Two (N = 33)		Four (N = 33)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Tense Arousal	12.47 (3.10)	15.47 (4.07)	13.18 (3.99)	14.27 (4.77)	13.58 (3.23)	17.59 (5.21)
Hedonic Tone	25.84 (4.33)	22.49 (4.04)	26.42 (3.61)	23.94 (4.18)	25.91 (4.61)	21.94 (4.81)
Anger/ Frustration	8.18 (3.56)	10.39 (3.86)	7.55 (2.99)	9.03 (3.32)	7.03 (2.49)	10.03 (3.35)
Global Workload		37.92 (13.68)		39.23 (16.35)		44.64 (16.31)
Mental Demand		36.24 (26.93)		41.21 (26.14)		51.27 (33.90)
Temporal Demand		23.93 (23.28)		26.97 (21.27)		39.42 (32.81)
Physical Demand		11.91 (18.10)		7.67 (9.78)		10.88 (13.50)
Perceived Performance		50.07 (31.75)		55.27 (34.69)		52.36 (31.43)
Effort		30.78 (24.31)		35.88 (26.52)		41.30 (31.33)
Frustration		27.25 (28.47)		32.76 (33.61)		37.45 (29.07)

Note. Numbers in parentheses represent standard deviations. Raw subscale averages and standard deviations on the NASA-TLX subscales are reported for purposes of completeness.

There was a significant four-way interaction between instruction type, task type, number of displays, and AchM on global workload, $F(2, 97) = 3.67$, $p = .029$, $\eta_p^2 = .071$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on global workload, none of the results approached significance and could be that this interaction is a spurious result. That said, participants in the cognitive condition receiving controlling instructions and monitoring four displays (*M* = 52.01, *SD* = 22.00) reported the highest global workload, closely followed by observers in the cognitive condition monitoring four displays and receiving autonomy-supportive instructions (*M* = 48.15, *SD* = 15.17). Participants in the sensory condition who received autonomy-supportive instructions and monitored only one display (*M* = 34.32, *SD* = 14.52) reported some of the lowest global workload scores, as did participants in the sensory condition receiving controlling instructions and monitoring two displays (*M* = 35.31, *SD* = 13.90).

There was also a significant interaction between number of displays and achievement motivation on pre-task tense arousal, $F(2, 97) = 3.36$, $p = .039$, $\eta_p^2 = .065$, and pre-task anger/frustration, $F(2, 97) = 3.51$, $p = .034$, $\eta_p^2 = .067$. Participants monitoring two and four displays tended to reported higher pre-task tense arousal scores, but reported lower pre-task anger/frustration than observers in the single display condition. There was a significant main effect of number of displays on pre-task tense arousal, $F(2, 97) = 4.05$, $p = .021$, $\eta_p^2 = .077$, as well as pre-task anger/frustration, $F(2, 97) = 3.21$, $p = .045$, $\eta_p^2 = .062$. There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant four-way interaction between instruction type, task type, number of displays, and AuM on pre-task tense arousal, $F(2, 97) = 5.89$, $p = .004$, $\eta_p^2 = .108$. There was a significant interaction between task type and AuM on pre-task tense arousal, $F(1, 97) = 7.42$, $p = .008$, $\eta_p^2 = .071$. There was a significant main effect of task type on pre-task tense arousal, $F(1, 97) = 4.56$, $p = .035$, $\eta_p^2 = .045$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on pre-task tense arousal, several results approached significance. There was a significant effect of the covariate AuM on pre-task tense arousal in the sensory task wherein participants monitored two displays and received controlling instructions, $F(1, 6) = 9.05$, $p = .024$, $\eta_p^2 = .601$, and in the same task where participants monitored four displays and received controlling instructions, $F(1, 9) = 5.63$, $p = .042$, $\eta_p^2 = .385$. Participants in the sensory condition receiving autonomy-supportive instructions and monitoring four displays reported some of the highest pre-task tense arousal (*M* = 14.83, *SD* = 4.49). Similarly, participants in the sensory condition receiving controlling instructions and monitoring two displays (*M* = 14.75, *SD* = 3.81) or four displays (*M* = 14.72, *SD* = 2.57) also reported higher pre-task tense arousal. Participants in the cognitive condition receiving controlling instructions and monitoring only one display reported the lowest pre-task tense arousal (*M* = 11.14, *SD* = 2.19).

There was a significant three-way interaction between instruction type, task type, and number of displays on post-task tense arousal, $F(2, 97) = 5.54$, $p = .005$, $\eta_p^2 = .102$. There was a significant main effect of AuM on post-task tense arousal, $F(1, 97) = 6.35$, $p = .013$, $\eta_p^2 = .062$. In follow-up ANCOVAs exploring the effects of each level of the independent variables on post-task tense arousal, none of the analyses reached significance, therefore these results could be spurious and this interaction should be interpreted with caution. Nonetheless, participants in the cognitive condition monitoring two displays and receiving autonomy-supportive instructions (*M* = 13.14, *SD* = 3.58) and participants in the sensory condition monitoring two displays and receiving controlling instructions (*M* = 12.63, *SD* = 3.16) reported some of the lowest post-task tense arousal scores. Participants in the cognitive condition monitoring four displays and receiving controlling instructions (*M* = 18.56, *SD* = 7.11) reported the highest post-task tense arousal scores.

There was also a significant interaction between instruction type and AuM on global workload, $F(1, 97) = 7.50$, $p = .007$, $\eta_p^2 = .072$. There was a significant interaction between instruction type and task type on global workload, $F(1, 97) = 4.17$, $p = .044$, $\eta_p^2 = .042$. There was a significant main effect of instruction type on global workload, $F(1, 97) = 7.40$, $p = .008$, $\eta_p^2 = .072$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on global workload, only one result approached significance. There was a nearly significant effect of the covariate AuM on global workload in the sensory task where participants monitored two displays and received controlling instructions, $F(1, 6) = 4.97$, $p = .067$, $\eta_p^2 = .453$. Participants in the cognitive condition receiving controlling instructions and monitoring four displays reported the most global workload ($M = 35.31$, $SD = 13.90$), whereas participants in the sensory condition receiving autonomy-supportive instructions reported some of the lowest global workload. Observers in the sensory condition receiving autonomy-supportive instructions and monitoring only one display reported the lowest average global workload score ($M = 34.32$, $SD = 14.52$).

There was a significant main effect of AuM on post-task hedonic tone, $F(1, 97) = 7.40$, $p = .008$, $\eta_p^2 = .072$. There was a significant correlation between AuM and post-task hedonic tone ($r = .286$, $p < .003$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

Performance Measures

Mixed-measures ANCOVAs with task type, type of instructions, and number of displays as the between-subjects factors, period on watch as the within-subjects factor, and AchM or AuM as the covariate were performed on all outcome measures related to performance. Separate

ANCOVAs were performed for each pre-task and post-task measure. The means and standard deviations of the proportion of correct detections are reported in Figures 44-47. The means and standard deviations of the number of false alarms are reported in Figures 48-51. The average response times per each period on watch are included in Figures 52-55. In some instances, Mauchly's Test of Sphericity was violated and a Huynh-Feldt epsilon correction is included in the reported statistics where such a violation was observed.

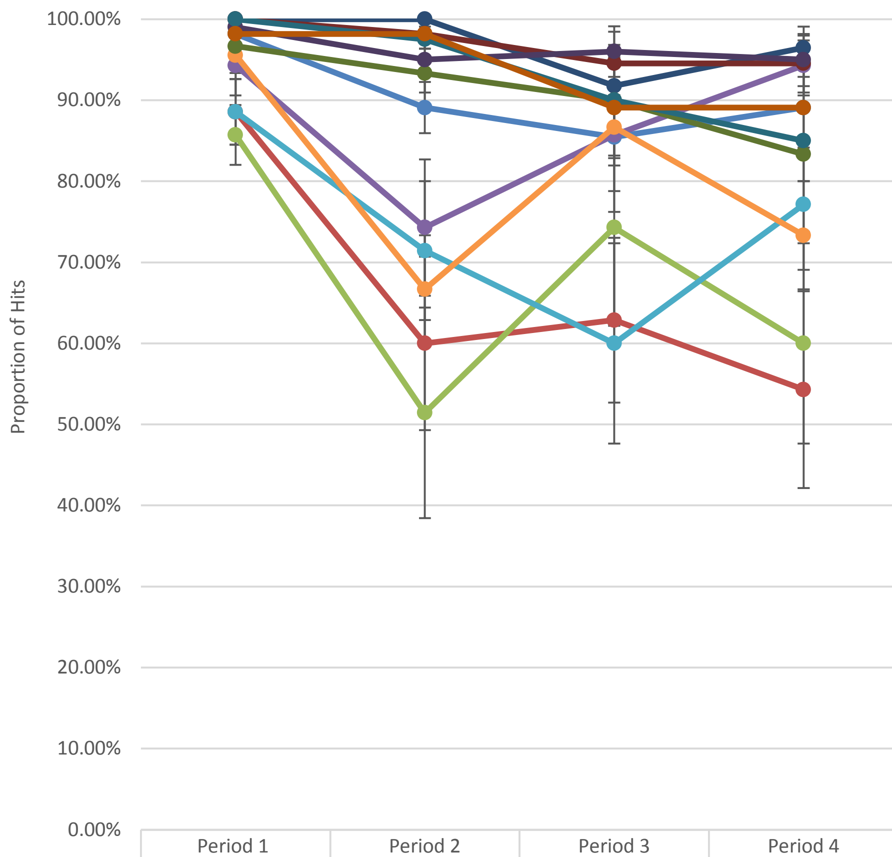
There was a significant interaction between period, task type, number of displays, and AuM on the proportion of correct detections over time, $F(6, 291) = 2.22$, $p = .041$, $\eta_p^2 = .044$, $\varepsilon = 1.00$. There was a significant interaction between period and task type on proportion of correct detections over time, $F(3, 291) = 3.26$, $p = .022$, $\eta_p^2 = .033$, $\varepsilon = 1.00$. There was also a significant interaction between AuM and period on watch on proportion of correct detections, $F(3, 291) = 2.76$, $p = .042$, $\eta_p^2 = .028$, $\varepsilon = 1.00$. The results of a linear regression indicated that as autonomy motivation increased, the proportion of correct detections slightly increased over time (i.e., the slope of the line when plotted against the data were somewhat horizontally oriented, but this was a rather small increase in slope. AuM was not significantly correlated with the proportion of correct detections across any of the periods on watch (r for Period 1 = -.069, r for Period 2 = .109, r for Period 3 = .115, r for Period 4 = .086).

There was also a significant main effect of period on proportion of correction detections indicated over time, $F(3, 291) = 6.25$, $p < .001$, $\eta_p^2 = .061$, $\varepsilon = 1.00$. There was also a significant main effect of task type, $F(1, 97) = 7.14$, $p < .001$, $\eta_p^2 = .061$, as well as autonomous motivation on proportion of correct detections, $F(1, 97) = 4.51$, $p = .036$, $\eta_p^2 = .044$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AuM, three results reached significance. There was a significant main effect of period on the proportion of correct detections for participants assigned to the cognitive condition who monitored two displays and received autonomy-supportive instructions, $F(3, 3) = 5.82$, $p = .008$, $\eta_p^2 = .538$, as well as a significant interaction between AuM and period on watch on proportion of correct detections for participants assigned to this condition, $F(3, 3) = 3.82$, $p = .032$, $\eta_p^2 = .433$. The results of a linear regression indicated that participants high in autonomous motivation showed an increase in correct detections over time. Those low in autonomous motivation achieved fewer correct detections over time. Thus, participants lower in AuM appeared to exhibit a larger decrement in detections. AuM was significantly correlated with the proportion of correct detections reported in Periods 1 ($r = -.879$, $p < .05$) and 2 ($r = .880$, $p < .05$), but not Periods 3 ($r = .183$) or 4 ($r = .491$).

There was also a significant main effect of period on the proportion of correct detections for participants assigned to the cognitive condition who monitored four displays and received controlling instructions, $F(3, 3) = 3.13$, $p = .048$, $\eta_p^2 = .309$. There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant main effect of the covariate AchM ($r = .015$, $p > .003$), but not task type, instruction type, or number of displays on proportion of correction detections indicated over time, $F(1, 97) = 4.52$, $p = .036$, $\eta_p^2 = .045$. There were no additional significant main effects, interactions, or correlations to report for these analyses.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive - One Display	98.18%	89.09%	85.45%	89.09%
Cognitive - Autonomy-Supportive - Two Displays	88.57%	60.00%	62.86%	54.29%
Cognitive - Autonomy-Supportive - Four Displays	85.71%	51.43%	74.29%	60.00%
Cognitive - Controlling - One Display	94.29%	74.29%	85.71%	94.29%
Cognitive - Controlling - Two Displays	88.57%	71.43%	60.00%	77.14%
Cognitive - Controlling - Four Displays	95.56%	66.67%	86.67%	73.33%
Sensory - Autonomy-Supportive - One Display	100.00%	100.00%	91.76%	96.47%
Sensory - Autonomy-Supportive - Two Displays	100.00%	98.18%	94.55%	94.55%
Sensory - Autonomy-Supportive - Four Displays	96.67%	93.33%	90.00%	83.33%
Sensory - Controlling - One Display	99.00%	95.00%	96.00%	95.00%
Sensory - Controlling - Two Displays	100.00%	97.50%	90.00%	85.00%
Sensory - Controlling - Four Displays	98.18%	98.18%	89.09%	89.09%

Figure 44. The average proportion of correct detections with standard errors bars are reported for each of the conditions in Experiment Four.

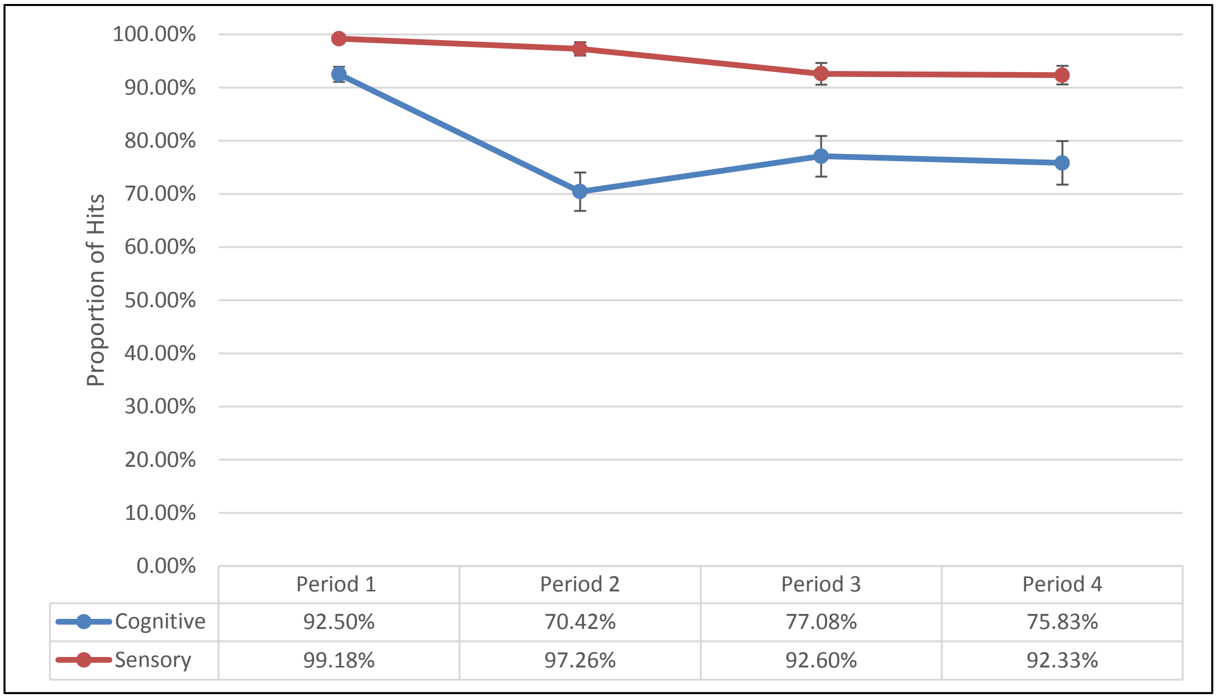


Figure 45. The average proportion of correct detections with standard errors bars are reported across task type for Experiment Four.

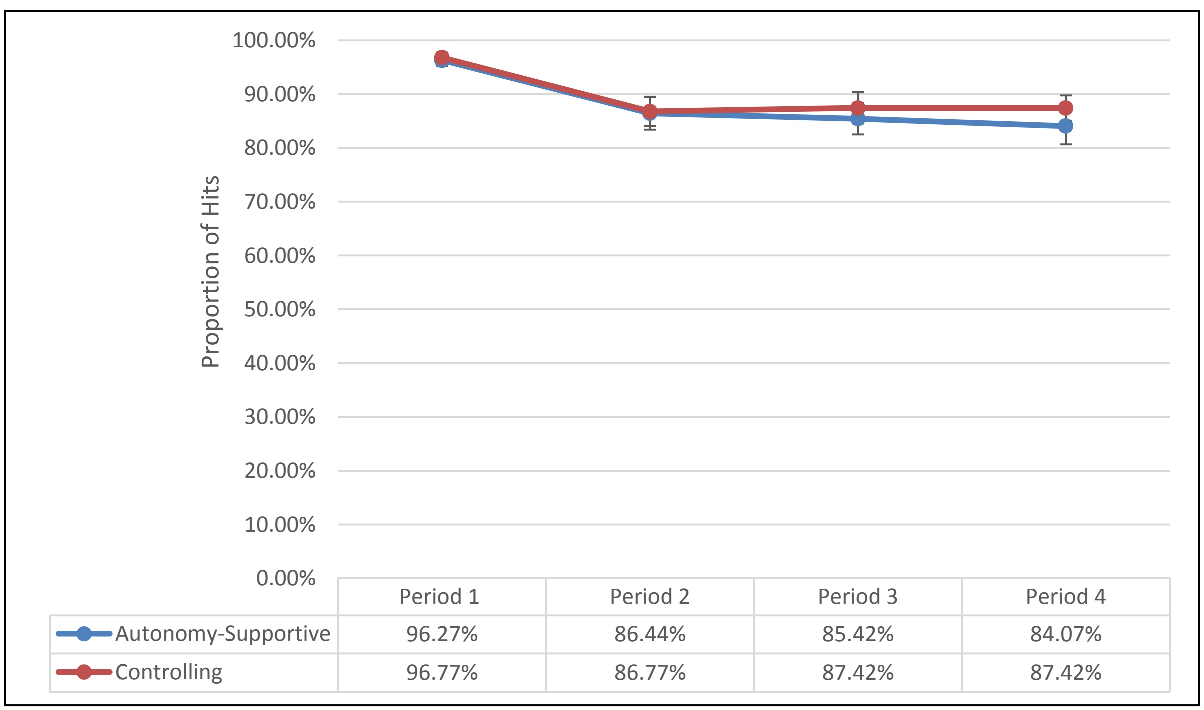
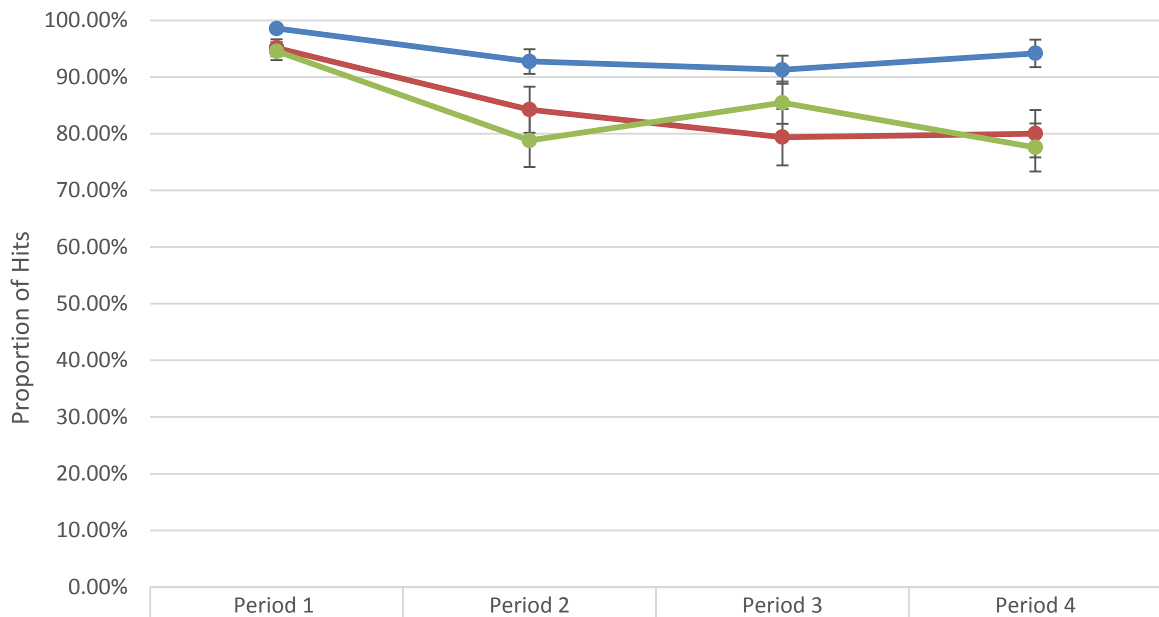


Figure 46. The average proportion of correct detections with standard errors bars are reported across instruction type for Experiment Four.



	Period 1	Period 2	Period 3	Period 4
One	98.55%	92.73%	91.27%	94.18%
Two	95.15%	84.24%	79.39%	80.00%
Four	94.55%	78.79%	85.45%	77.58%

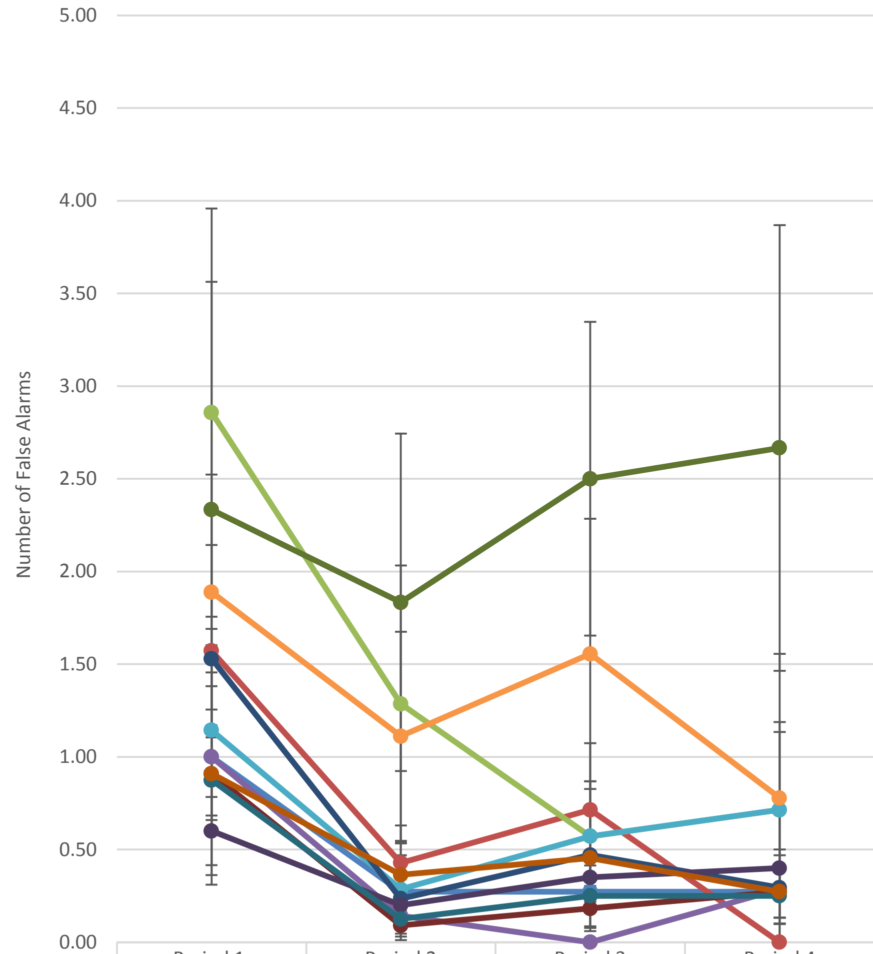
Figure 47. The average proportion of correct detections with standard errors bars are reported across source complexity for Experiment Four.

There was a significant interaction between period on watch, number of displays, and AchM on number of false alarms, $F(5.58, 291) = 2.72$, $p = .016$, $\eta_p^2 = .053$, ε = .930. There was also a significant interaction between period and number of displays on number of false alarms, $F(5.58, 291) = 2.59$, $p = .021$, $\eta_p^2 = .051$, ε = .930.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AchM, only two results reached significance. There was a significant interaction between period on watch and AchM on the number of false alarms reported over time for participants randomly assigned to the cognitive task with four displays and controlling instructions, $F(3, 7) = 3.49$, $p = .029$, $\eta_p^2 = .279$. The results of a linear regression indicated that participants assigned to this specific condition and who had higher achievement motivation scores tended to commit fewer false alarms over time. However, AchM was not significantly correlated with the number of false alarms committed during any of the watch periods (*r* for Period 1 = .579, *r* for Period 2 = .640, *r* for Period 3 = -.158, *r* for Period 4 = -.330).

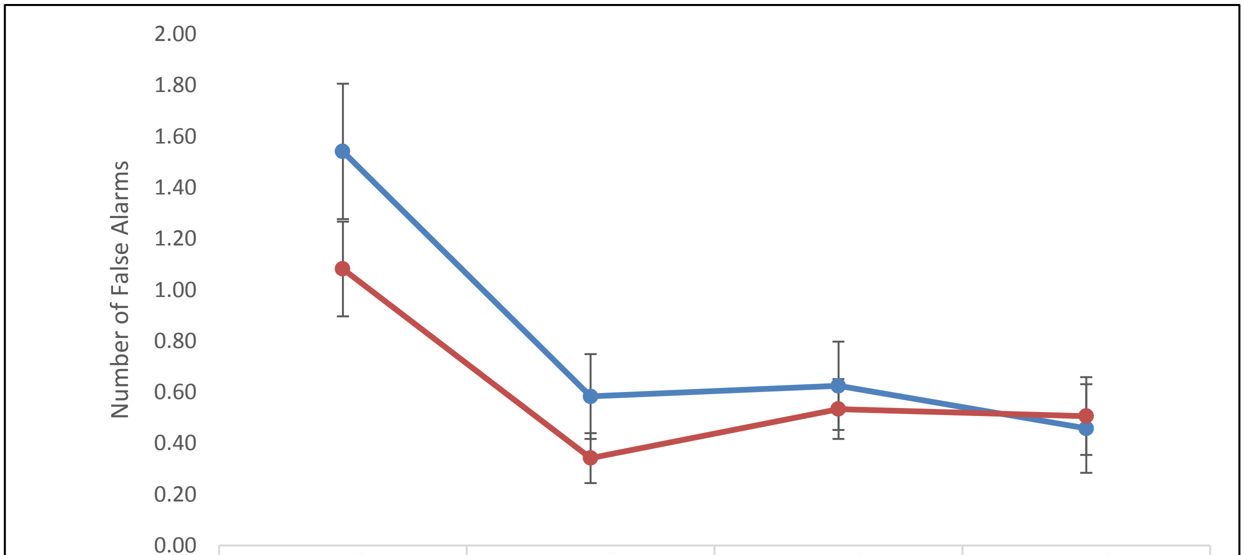
There was also a significant main effect of AchM on the number of false alarms committed for participants randomly assigned to the sensory task who received autonomy-supportive instructions and had two displays to monitor, $F(1, 9) = 8.96$, $p = .015$, $\eta_p^2 = .499$. The results of a linear regression indicated that participants higher in achievement motivation committed slightly more false alarms over time. Interestingly, those lower in achievement motivation made fewer false alarms over periods on watch. AchM was significantly correlated with the number of false alarms committed in Periods 2 ($r = .714$, $p < .05$) and 3 ($r = .771$, $p < .01$), but not Periods 1 ($r = .596$) or 4 ($r = -.012$). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant interaction between number of displays and AuM on number of false alarms, $F(2, 97) = 4.51$, $p = .013$, $\eta_p^2 = .085$. There was a significant main effect of period on number of false alarms, $F(2.95, 291) = 5.31$, $p = .002$, $\eta_p^2 = .052$, $\varepsilon = .984$. There were no additional significant main effects, interactions, or correlations to report for these analyses.



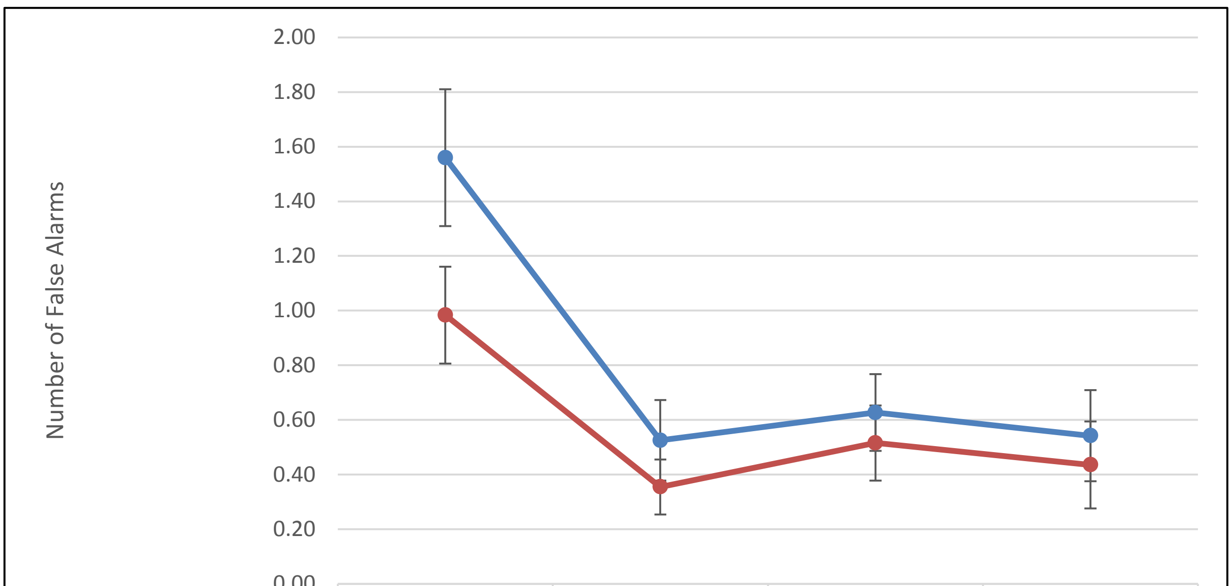
	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive - One Display	1.00	0.27	0.27	0.27
Cognitive - Autonomy-Supportive - Two Displays	1.57	0.43	0.71	0.00
Cognitive - Autonomy-Supportive - Four Displays	2.86	1.29	0.57	0.71
Cognitive - Controlling - One Display	1.00	0.14	0.00	0.29
Cognitive - Controlling - Two Displays	1.14	0.29	0.57	0.71
Cognitive - Controlling - Four Displays	1.89	1.11	1.56	0.78
Sensory - Autonomy-Supportive - One Display	1.53	0.24	0.47	0.29
Sensory - Autonomy-Supportive - Two Displays	0.91	0.09	0.18	0.27
Sensory - Autonomy-Supportive - Four Displays	2.33	1.83	2.50	2.67
Sensory - Controlling - One Display	0.60	0.20	0.35	0.40
Sensory - Controlling - Two Displays	0.88	0.13	0.25	0.25
Sensory - Controlling - Four Displays	0.91	0.36	0.45	0.27

Figure 48. The average number of false alarms with standard errors bars are reported for each of the conditions in Experiment Four.



	Period 1	Period 2	Period 3	Period 4
Cognitive	1.54	0.58	0.63	0.46
Sensory	1.08	0.34	0.53	0.51

Figure 49. The average number of false alarms with standard errors bars are reported across task type in Experiment Four.



	Period 1	Period 2	Period 3	Period 4
Autonomy-Supportive	1.56	0.53	0.63	0.54
Controlling	0.98	0.35	0.52	0.44

Figure 50. The average number of false alarms with standard errors bars are reported across instruction type in Experiment Four.

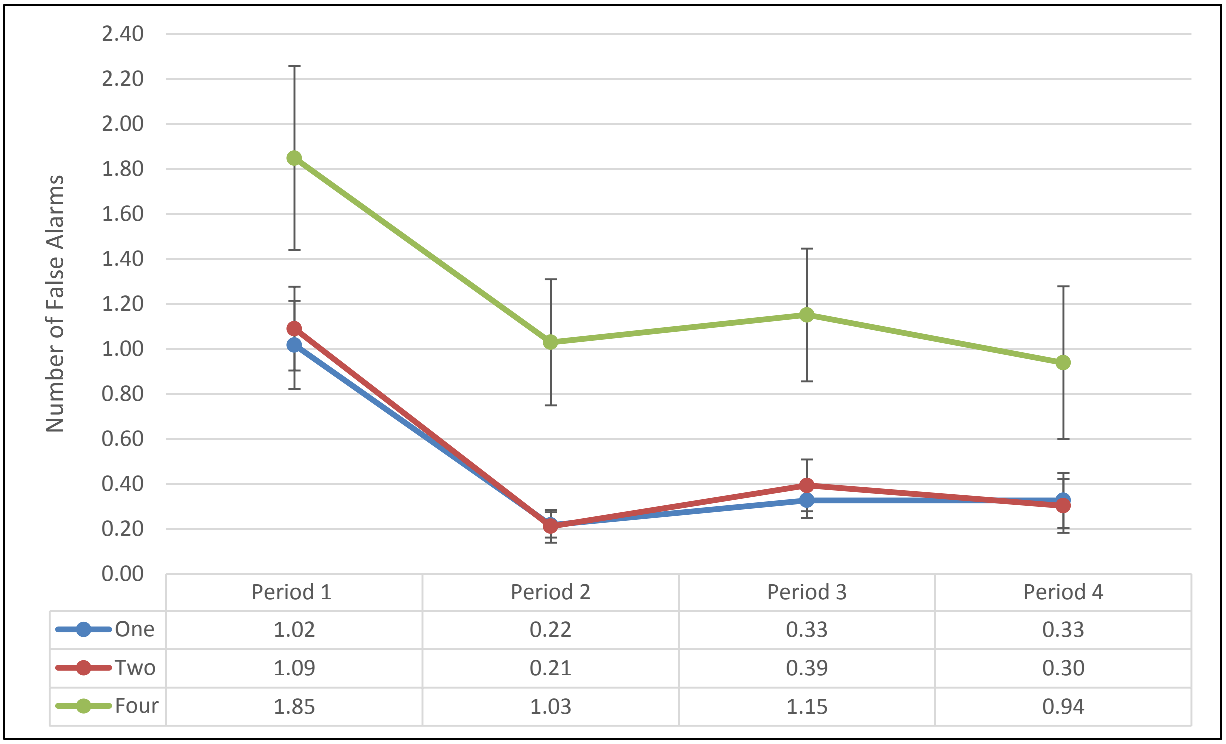


Figure 51. The average number of false alarms with standard errors bars are reported across source complexity in Experiment Four.

There was a significant interaction between period on watch, task type, number of displays, and AchM on mean response time, $F(6, 291) = 2.40$, $p = .028$, $\eta_p^2 = .047$, $\varepsilon = 1.00$. There was a significant interaction between period on watch, instruction type, task type, and AchM on mean response time, $F(3, 291) = 4.71$, $p = .003$, $\eta_p^2 = .046$, $\varepsilon = 1.00$. There was a significant interaction between period, task type, and number of displays on mean response time, $F(6, 291) = 2.14$, $p = .049$, $\eta_p^2 = .042$, $\varepsilon = 1.00$. There was a significant interaction between period on watch, instructions, and task type on mean response time, $F(3, 291) = 4.47$, $p = .004$, $\eta_p^2 = .044$, $\varepsilon = 1.00$.

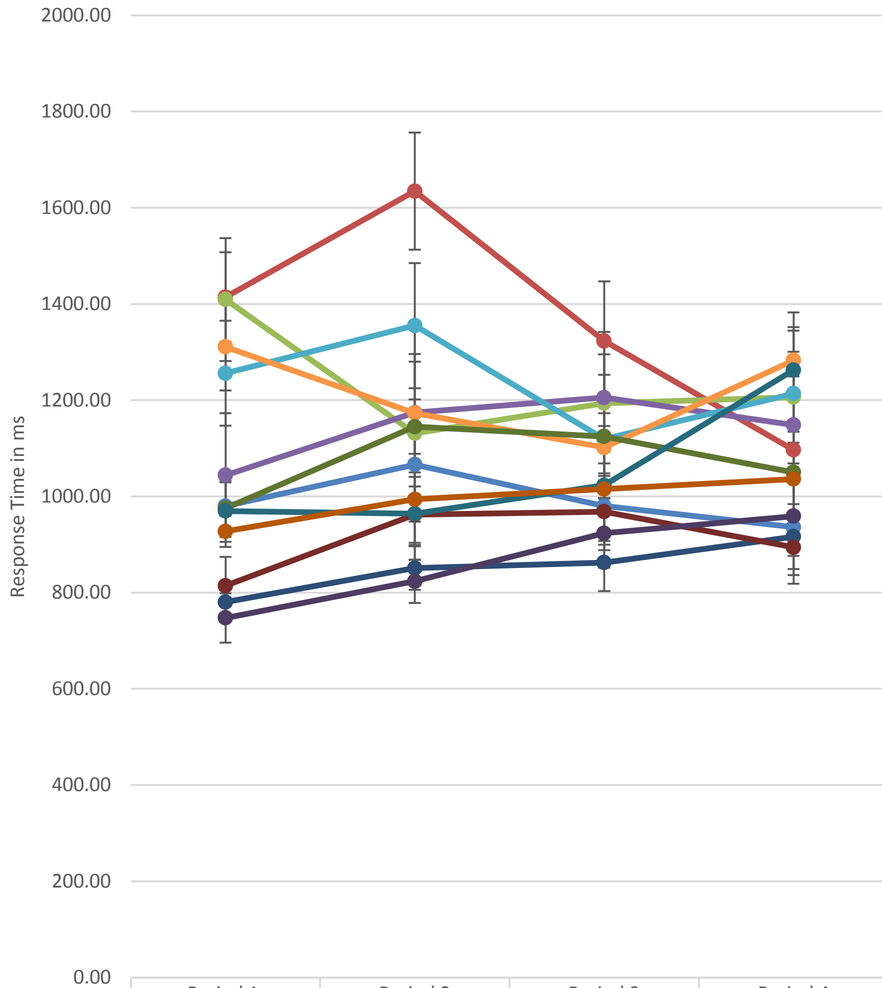
In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AchM, several results reached significance. There was a significant effect of period, but not AchM, on the mean response time for participants in the sensory task with two displays and controlling instructions, $F(3, 7) = 3.44$, $p = .039$, $\eta_p^2 = .365$. There was also an interaction between AchM and period for participants assigned to this condition, $F(3, 7) = 3.08$, $p = .054$, $\eta_p^2 = .339$. The results of a linear regression indicated that participants high in achievement motivation, who were assigned to this specific condition, indicated increased average response times across period on watch. AchM was not significantly correlated with the average response time for any of the watch periods in this specific condition (*r* for Period 1 = -.213, *r* for Period 2 = .697, *r* for Period 3 = .533, *r* for Period 4 = .162).

Similar results were observed for participants randomly assigned to the cognitive task who received controlling instructions and had one display to monitor. There was a nearly significant main effect of period, but not AchM, on mean response time for participants randomly assigned to this condition, $F(3, 3) = 3.53$, $p = .059$, $\eta_p^2 = .414$, $\varepsilon = .764$, as well as a nearly significant interaction between AchM and period on mean response time for participants randomly assigned to this condition, $F(3, 3) = 3.60$, $p = .056$, $\eta_p^2 = .419$, $\varepsilon = .764$. The results of a linear regression indicated that participants high in achievement motivation, who were assigned to this specific condition, indicated longer average response times as a function of period on watch. AchM was not significantly correlated with the average response time for any of the watch periods in this specific condition (*r* for Period 1 = -.197, *r* for Period 2 = .295, *r* for Period 3 = -.363, *r* for Period 4 = .013).There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant interaction between period on watch, task type, number of displays, and AuM on mean response time, $F(6, 291) = 2.25$, $p = .039$, $\eta_p^2 = .044$. There was also a significant interaction between period on watch, instruction type, task type, and AuM on mean response time, $F(3, 291) = 3.52$, $p = .015$, $\eta_p^2 = .035$. There was a significant interaction between period on watch, instruction type, number of displays, and AuM on mean response time, $F(6, 291) = 3.90$, $p = .001$, $\eta_p^2 = .075$. There was a significant interaction between period on watch, instruction type, task type, and number of displays on mean response time, $F(6, 291) = 2.27$, $p = .037$, $\eta_p^2 = .045$. There was a significant interaction between period on watch, instruction type, and AuM on mean response time, $F(3, 291) = 3.07$, $p = .028$, $\eta_p^2 = .031$. There was a significant interaction between period on watch, task type, and number of displays on mean response time, $F(6, 291) = 3.10$, $p = .006$, $\eta_p^2 = .060$. There was a significant interaction between period on watch, instruction type, and number of displays on mean response time, $F(6, 291) = 4.64$, $p < .001$, $\eta_p^2 = .087$. There was a significant interaction between period on watch, instruction type, and task type on mean response time, $F(3, 291) = 3.81$, $p = .011$, $\eta_p^2 = .038$. There was a significant interaction between period on watch and number of displays on mean response time, $F(6, 291) = 2.19$, $p = .044$, $\eta_p^2 = .043$.

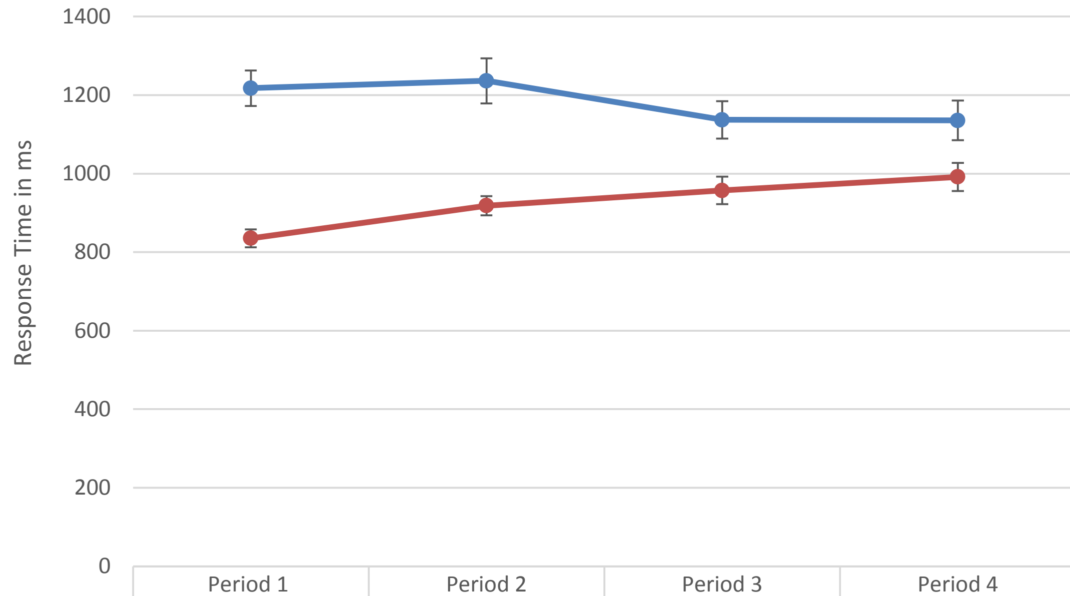
In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AuM, only two results reached significance. There was a significant main effect of period on watch on mean response time for participants randomly assigned to the sensory task who monitored two displays and received controlling instructions, $F(3, 3) = 3.35$, $p = .042$, $\eta_p^2 = .358$.

There was a significant main effect of AuM on mean response time for participants randomly assigned to the sensory task who monitored one display and received controlling instructions, $F(1, 18) = 5.16$, $p = .036$, $\eta_p^2 = .223$. The results of a linear regression indicated that participants high in autonomous motivation, who were assigned to this specific condition, exhibited faster average response times across period on watch. Thus, higher autonomous motivation was associated with improved performance (in terms of response time) over time on watch. AuM was significantly correlated with the average response time only for Period 2 (r = -.702, $p < .01$) and none of the additional periods on watch for this specific condition (r for Period 1 = -.393, r for Period 2 = .640, r for Period 3 = -.443, r for Period 4 = -.312). There were no additional significant main effects, interactions, or correlations to report for these analyses.



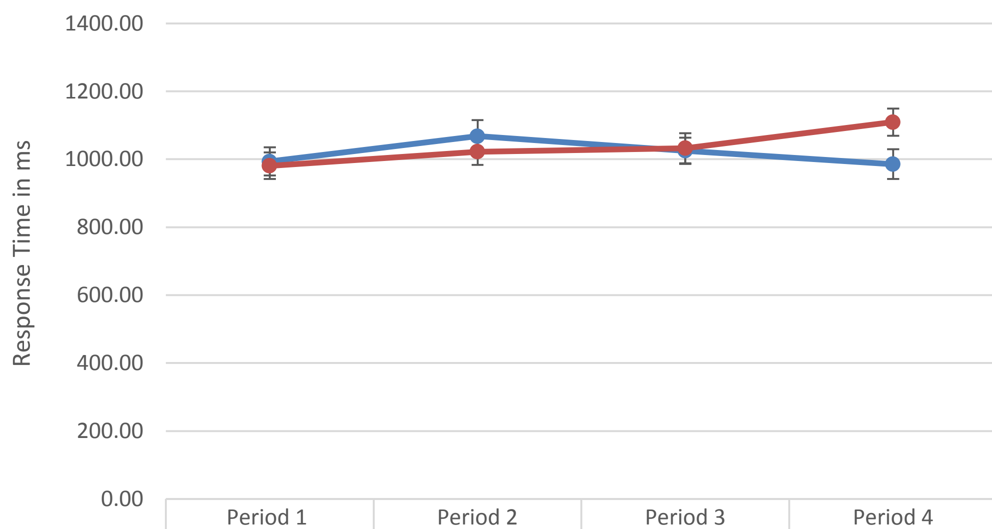
	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive - One Display	979.86	1066.16	979.90	936.12
Cognitive - Autonomy-Supportive - Two Displays	1414.44	1634.42	1323.24	1096.56
Cognitive - Autonomy-Supportive - Four Displays	1409.37	1131.34	1193.79	1206.56
Cognitive - Controlling - One Display	1044.20	1174.10	1205.35	1148.70
Cognitive - Controlling - Two Displays	1256.04	1355.03	1118.99	1213.76
Cognitive - Controlling - Four Displays	1310.70	1173.09	1101.76	1282.83
Sensory - Autonomy-Supportive - One Display	780.54	850.98	862.62	916.32
Sensory - Autonomy-Supportive - Two Displays	814.44	962.27	968.39	894.19
Sensory - Autonomy-Supportive - Four Displays	975.48	1145.03	1124.77	1050.02
Sensory - Controlling - One Display	747.37	823.56	923.41	959.12
Sensory - Controlling - Two Displays	969.58	964.07	1023.20	1262.70
Sensory - Controlling - Four Displays	927.40	993.95	1015.15	1036.19

Figure 52. The average response time with standard errors bars reported for each of the conditions in Experiment Four.



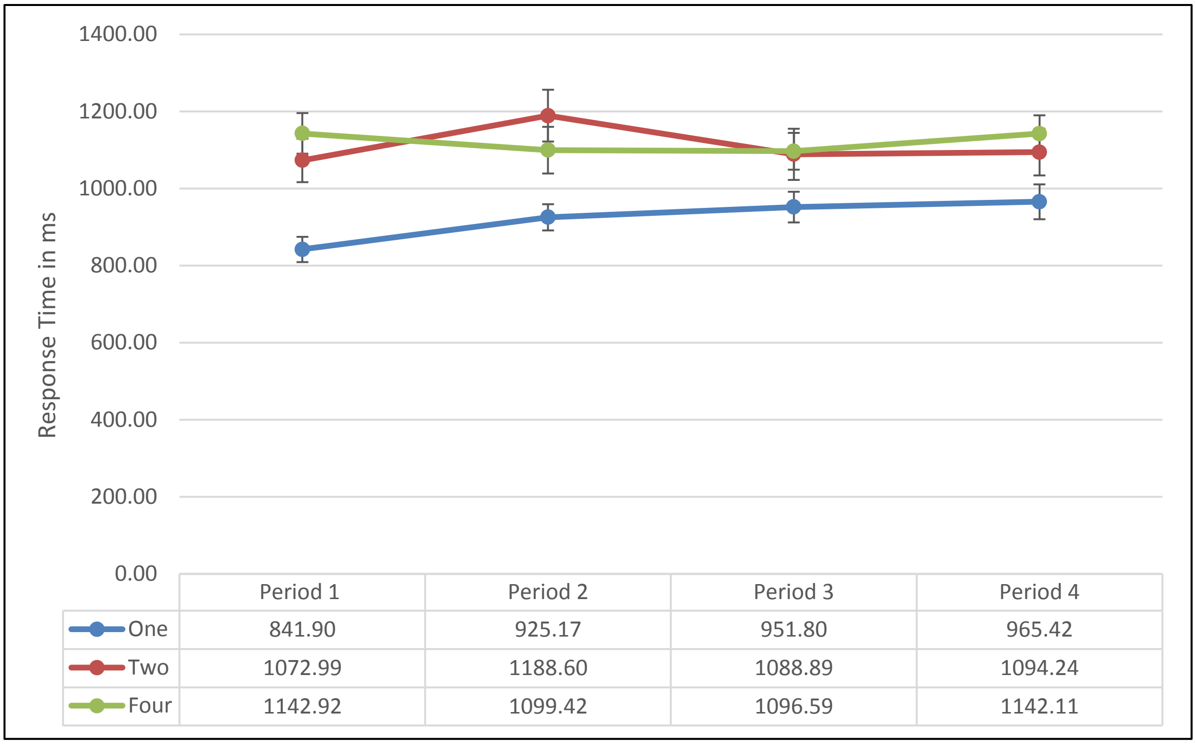
	Period 1	Period 2	Period 3	Period 4
Cognitive	1217.5656	1236.4563	1137.174	1135.4572
Sensory	835.4295	918.3425	957.3402	991.7215

Figure 53. The average response time with standard errors bars reported across task type in Experiment Four.



	Period 1	Period 2	Period 3	Period 4
Autonomy-Supportive	993.66	1067.97	1024.81	985.30
Controlling	980.70	1022.24	1032.36	1109.11

Figure 54. The average response time with standard errors bars reported across instruction type in Experiment Four.



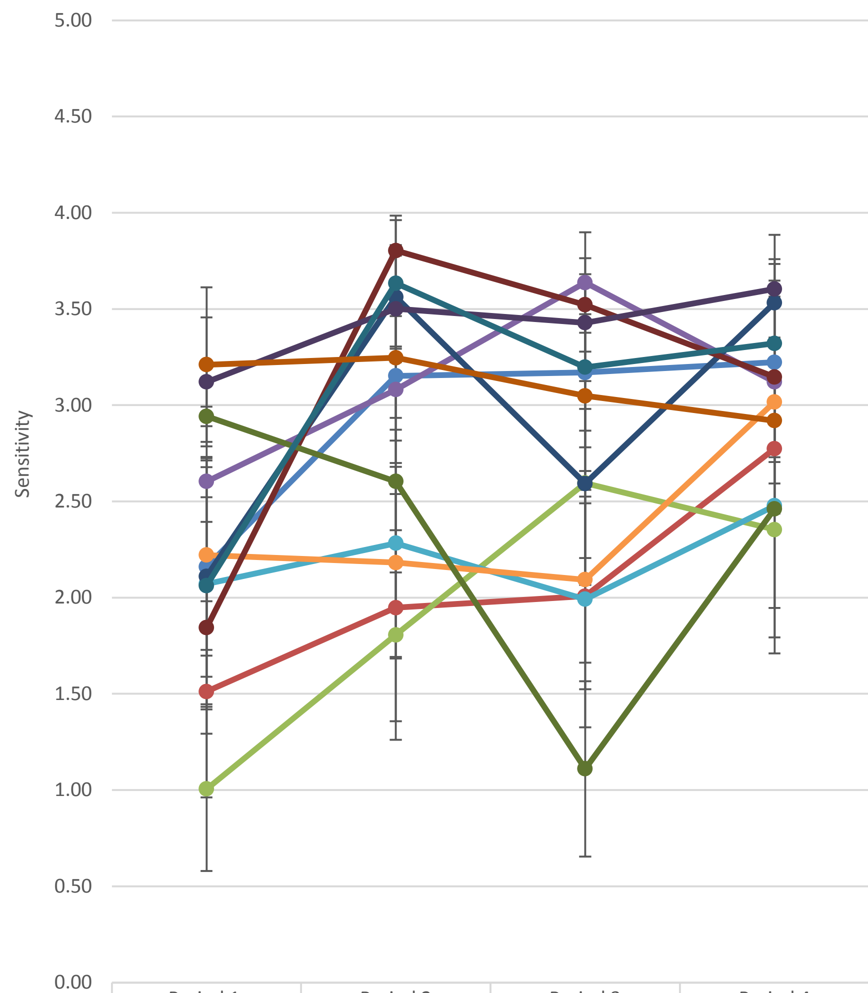
	Period 1	Period 2	Period 3	Period 4
One	841.90	925.17	951.80	965.42
Two	1072.99	1188.60	1088.89	1094.24
Four	1142.92	1099.42	1096.59	1142.11

Figure 55. The average response time with standard errors bars reported across source complexity in Experiment Four.

Sensitivity and Response Bias

The proportion of correct detections and false alarms were used to compute indices of sensitivity (*d'*; reported in Figures 56-59) and response bias (*c*; reported in Figures 60-63; See et al., 1995). Response bias tended to increase over time, which is indicative of an increase in conservative responding, across task type, instruction type, and for two of the source complexity types.

Mixed-measures ANCOVAs with task type, instruction type, and the number of displays as the between-subjects variables, period on watch as the within-subjects variable, and AchM or AuM as the covariate were performed on these indices. Separate ANCOVAs were performed for each of these dependent measures. Correlations between the measures of sensitivity and response bias, and the covariates are included in Appendix H.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive - One Display	2.16	3.15	3.17	3.22
Cognitive - Autonomy-Supportive - Two Displays	1.51	1.95	2.01	2.77
Cognitive - Autonomy-Supportive - Four Displays	1.01	1.81	2.60	2.35
Cognitive - Controlling - One Display	2.60	3.08	3.64	3.12
Cognitive - Controlling - Two Displays	2.07	2.28	1.99	2.48
Cognitive - Controlling - Four Displays	2.22	2.18	2.09	3.02
Sensory - Autonomy-Supportive - One Display	2.11	3.56	2.59	3.53
Sensory - Autonomy-Supportive - Two Displays	1.84	3.80	3.52	3.15
Sensory - Autonomy-Supportive - Four Displays	2.94	2.60	1.11	2.46
Sensory - Controlling - One Display	3.12	3.50	3.43	3.60
Sensory - Controlling - Two Displays	2.06	3.63	3.20	3.32
Sensory - Controlling - Four Displays	3.21	3.25	3.05	2.92

Figure 56. Sensitivity with standard errors bars is reported for each of the conditions in Experiment Four.

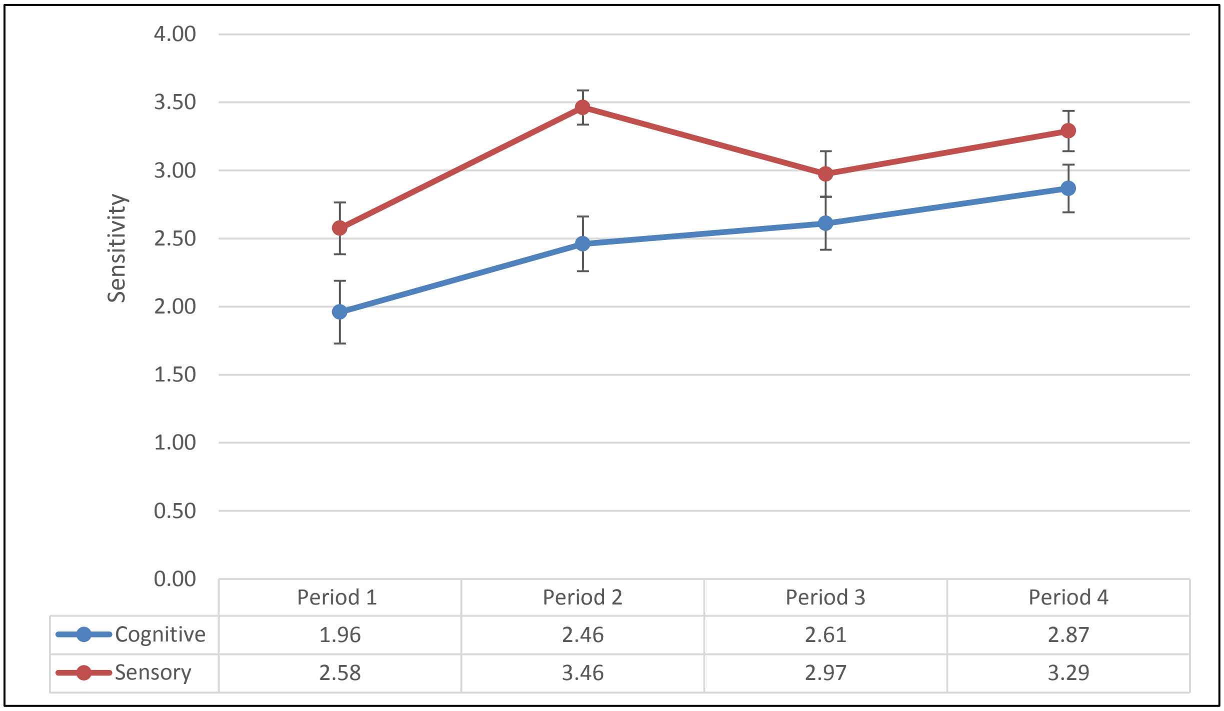


Figure 57. Sensitivity with standard errors bars is reported across task type in Experiment Four.

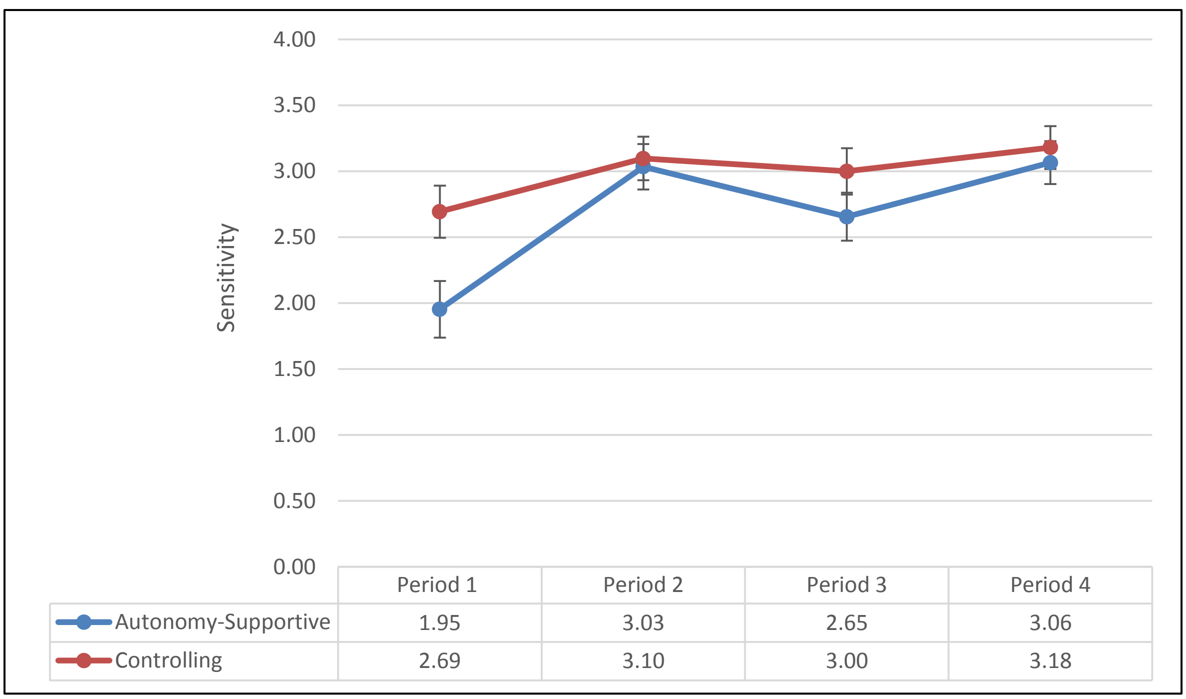
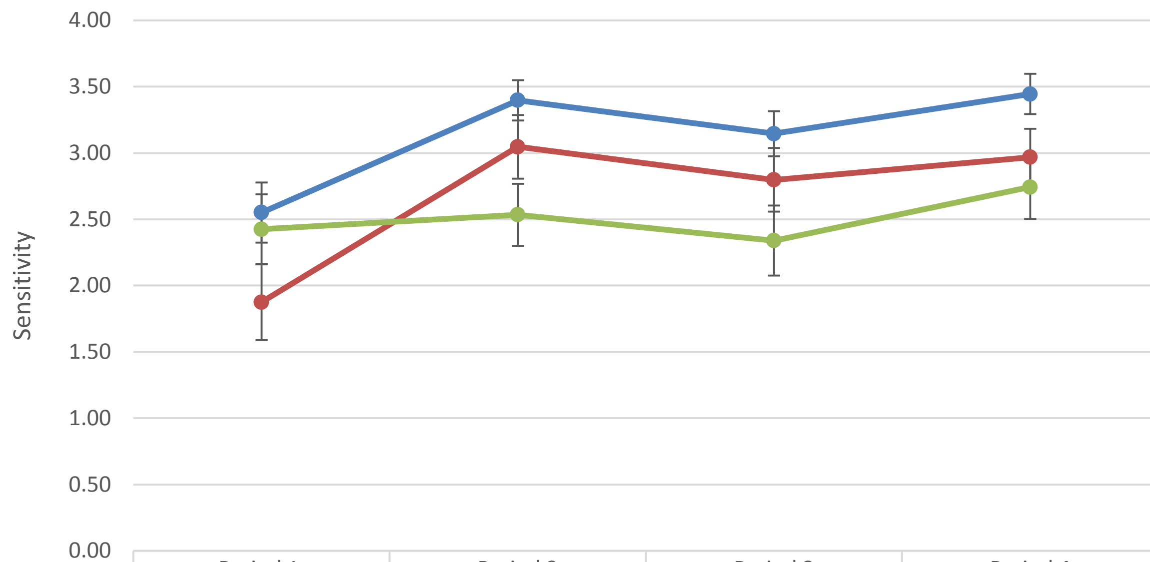


Figure 58. Sensitivity with standard errors bars is reported across instruction type in Experiment Four.



	Period 1	Period 2	Period 3	Period 4
One	2.55	3.40	3.15	3.44
Two	1.87	3.05	2.80	2.97
Four	2.42	2.53	2.34	2.74

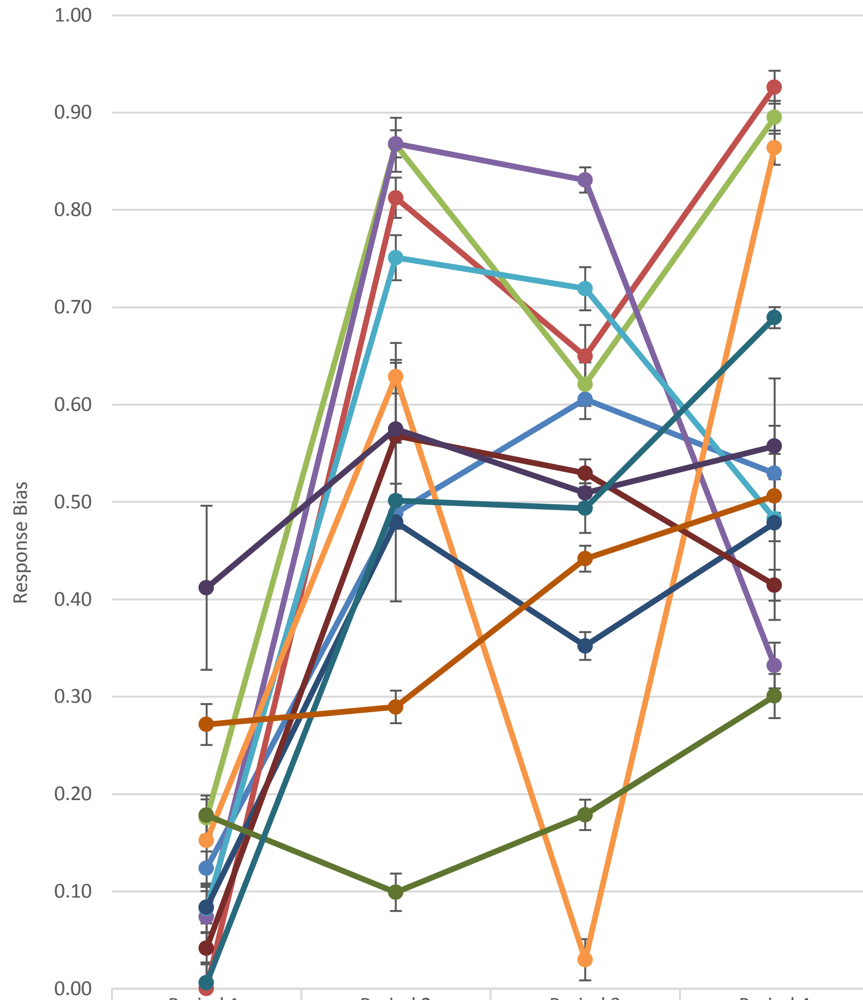
Figure 59. Sensitivity with standard errors bars is reported across source complexity in Experiment Four.

There was a significant five-way interaction between period on watch, instruction type, task type, number of displays, and AchM on sensitivity, $F(6, 291) = 2.20$, $p = .043$, $\eta_p^2 = .043$, $\varepsilon = 1.00$. There was a significant interaction between instruction type, task type, number of displays, and AchM on sensitivity, $F(2, 97) = 4.17$, $p = .018$, $\eta_p^2 = .079$. There was also a significant four-way interaction between period on watch, instruction type, task type, and number of displays on sensitivity, $F(6, 291) = 2.45$, $p = .025$, $\eta_p^2 = .048$, $\varepsilon = 1.00$. There was a significant three-way interaction between instruction type, task type, and number of displays on sensitivity, $F(2, 97) = 4.39$, $p = .015$, $\eta_p^2 = .083$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AchM, only one result reached significance. There was a significant main effect of

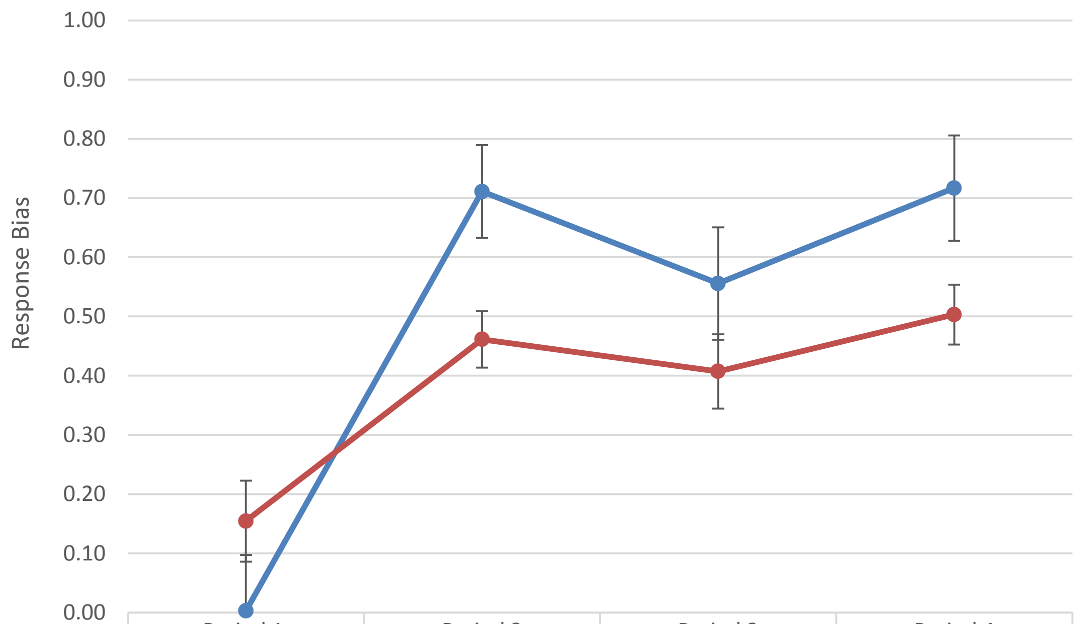
AchM for participants randomly assigned to the sensory task with four displays and autonomy-supportive instructions on sensitivity, $F(1, 4) = 8.21$, $p = .046$, $\eta_p^2 = .672$. The results of a linear regression indicated that participants high in achievement motivation, who were assigned to this specific condition, demonstrated a decline in sensitivity over time. AchM was not significantly correlated with sensitivity across any of the watch periods in this specific condition (r for Period 1 = -.550, r for Period 2 = -.746, r for Period 3 = .205, r for Period 4 = -.633). Higher AchM was associated with a steeper sensitivity decrement. There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant interaction between period on watch and AuM on sensitivity, $F(3, 97) = 2.71$, $p = .046$, $\eta_p^2 = .027$. The results of a linear regression indicated virtually no steepness (i.e., a nearly horizontal line or slope of 0), which indicated that those high or low in autonomous motivation were not significantly different in their change in sensitivity as a function of time on watch. Thus, it is possible that this significant interaction is potentially spurious and should therefore be interpreted with caution. AuM was significantly correlated with sensitivity in Period 3 ($r = -.180$, $p < .01$), but none of the other periods on watch (r for Period 1 = .164, r for Period 2 = -.015, r for Period 4 = -.017). There was a significant main effect of period on watch on sensitivity, $F(3, 97) = 4.18$, $p = .006$, $\eta_p^2 = .041$. There were no additional significant main effects, interactions, or correlations to report for these analyses.



	Period 1	Period 2	Period 3	Period 4
Cognitive - Autonomy-Supportive - One Display	0.12	0.49	0.61	0.53
Cognitive - Autonomy-Supportive - Two Displays	0.00	0.81	0.65	0.93
Cognitive - Autonomy-Supportive - Four Displays	0.18	0.87	0.62	0.90
Cognitive - Controlling - One Display	0.07	0.87	0.83	0.33
Cognitive - Controlling - Two Displays	0.08	0.75	0.72	0.48
Cognitive - Controlling - Four Displays	0.15	0.63	0.03	0.86
Sensory - Autonomy-Supportive - One Display	0.08	0.48	0.35	0.48
Sensory - Autonomy-Supportive - Two Displays	0.04	0.57	0.53	0.41
Sensory - Autonomy-Supportive - Four Displays	0.18	0.10	0.18	0.30
Sensory - Controlling - One Display	0.41	0.57	0.51	0.56
Sensory - Controlling - Two Displays	0.01	0.50	0.49	0.69
Sensory - Controlling - Four Displays	0.27	0.29	0.44	0.51

Figure 60. Response bias with standard errors bars is reported for each of the conditions in Experiment Four.



	Period 1	Period 2	Period 3	Period 4
Cognitive	0.00	0.71	0.56	0.72
Sensory	0.15	0.46	0.41	0.50

Figure 61. Response bias with standard errors bars is reported across task type in Experiment Four.

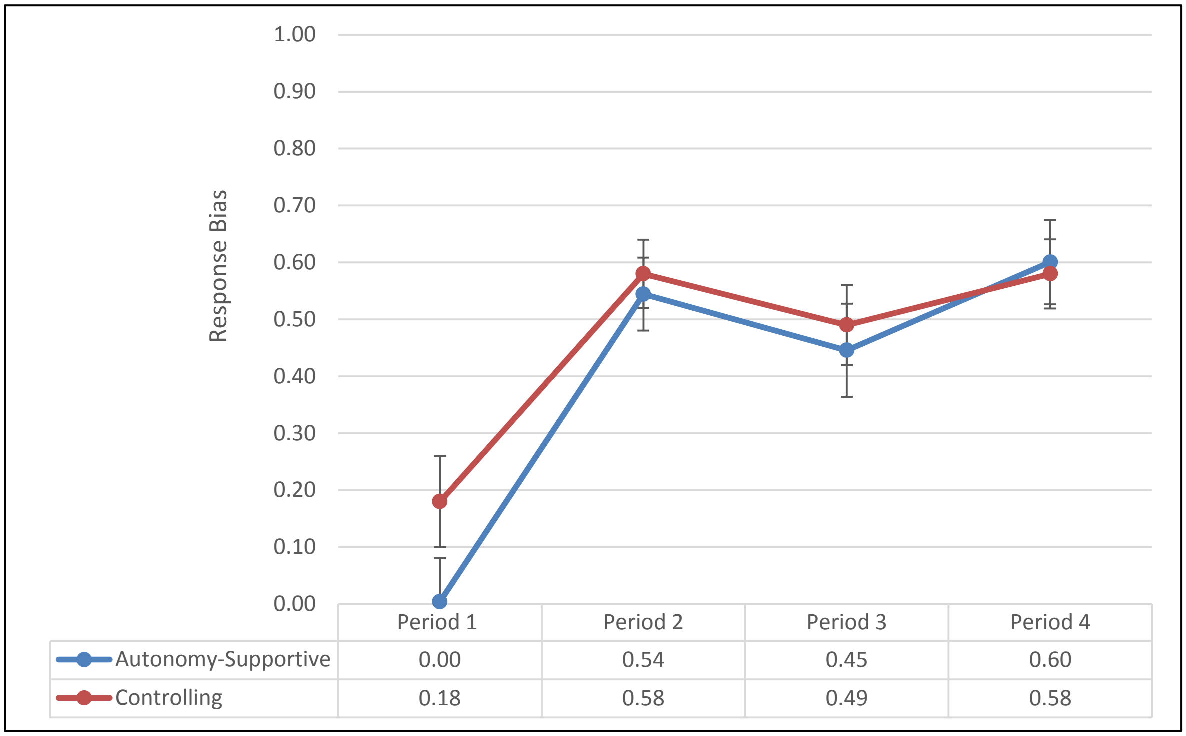


Figure 62. Response bias with standard errors bars is reported across instruction type in Experiment Four.

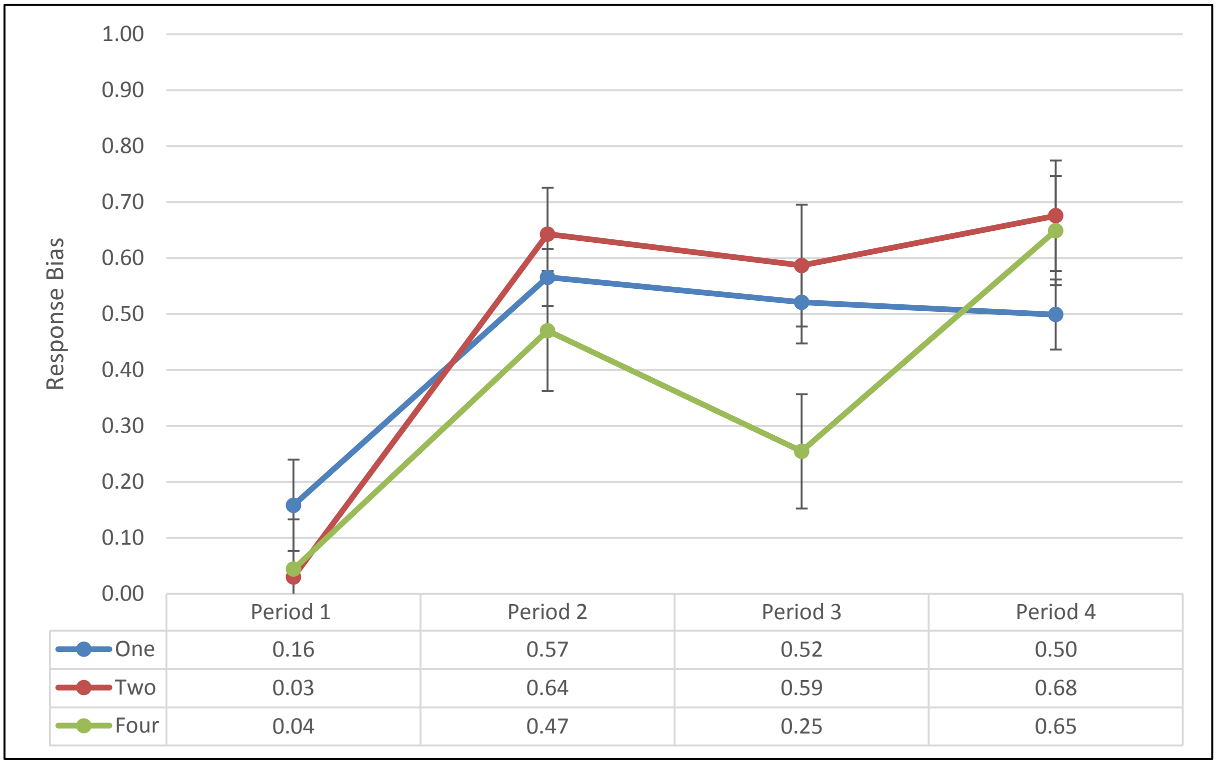


Figure 63. Response bias with standard errors bars is reported across instruction type in Experiment Four.

There was a significant interaction between instruction type, task type, number of displays, and AchM on response bias, $F(2, 97) = 5.12$, $p = .008$, $\eta_p^2 = .095$. There was a significant four-way interaction between period on watch, instruction type, task type, and number of displays, but not AchM, on response bias, $F(6, 291) = 2.14$, $p = .049$, $\eta_p^2 = .042$, $\varepsilon = 1.00$. There was a significant interaction between instruction type, task type, and number of displays, $F(2, 97) = 4.85$, $p = .010$, $\eta_p^2 = .091$.

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AchM, only one result reached significance. There was a significant interaction of period and AchM on response bias for participants randomly assigned to the cognitive task with four displays and autonomy-supportive instructions, $F(3, 3) = 5.00$, $p = .013$, $\eta_p^2 = .500$. There also a main effect of period, which was approaching significance, for participants assigned to this same condition, $F(3, 3) = 3.26$, $p = .051$, $\eta_p^2 = .395$. The results of a linear regression indicated a slope close to zero (i.e., there was no significant difference in the change in response bias over periods between participants high or low in achievement motivation) for participants assigned to this specific condition. AchM was significantly correlated with the response bias only in Period 4 ($r = .851$, $p < .05$), but not for any of the other watch periods (r for Period 1 = -.666, r for Period 2 = .344, r for Period 3 = -.368). There were no additional significant main effects, interactions, or correlations to report for these analyses.

There was a significant three-way interaction between period on watch, task type, and AuM on response bias, $F(3, 291) = 5.88$, $p = .001$, $\eta_p^2 = .057$. There was a significant interaction between period on watch and AuM on response bias, $F(3, 291) = 5.02$, $p = .002$, $\eta_p^2 = .049$. There was a significant interaction between task type and period on watch on response bias, $F(3, 291) = 7.86$, $p < .001$, $\eta_p^2 = .075$. There was a significant main effect of period on watch on response bias, $F(3, 291) = 10.74$, $p < .001$, $\eta_p^2 = .010$. There was a significant correlation between response bias in Period 3 and AuM ($r = -.254$, $p < .005$).

In follow-up ANCOVAs exploring the effects of each level of the independent variables on period and AuM, several results reached significance. There was a significant main effect of period on response bias for participants assigned to the sensory condition monitoring two displays and receiving controlling instructions, $F(3, 3) = 7.94$, $p = .001$, $\eta_p^2 = .569$, participants assigned to the sensory condition monitoring four displays and receiving autonomy-supportive instructions, $F(3, 3) = 5.74$, $p = .011$, $\eta_p^2 = .589$, participants assigned to the cognitive condition monitoring one display and receiving autonomy-supportive instructions, $F(3, 3) = 3.15$, $p = .041$, $\eta_p^2 = .259$, participants assigned to the cognitive condition monitoring two displays and receiving controlling instructions, $F(3, 3) = 4.03$, $p = .028$, $\eta_p^2 = .446$, and participants assigned to the cognitive condition monitoring four displays and receiving controlling instructions, $F(3, 3) = 3.82$, $p = .025$, $\eta_p^2 = .353$.

There was a significant interaction between period and AuM on response bias for participants assigned to the sensory condition monitoring two displays and receiving controlling instructions, $F(3, 3) = 7.48$, $p = .002$, $\eta_p^2 = .555$. The results of a linear regression indicated that participants high in autonomous motivation, who were assigned to this specific condition, showed a decline in response bias (increased leniency) over time. AuM was significantly correlated only with Period 3 ($r = -.839$, $p < .01$), but none of the other periods on watch (r for Period 1 = -.073, r for Period 2 = .373, r for Period 4 = -.227).

There was a significant interaction between period and AuM on response bias for participants assigned to the sensory condition monitoring four displays and receiving autonomy-supportive instructions, $F(3, 3) = 4.02$, $p = .034$, $\eta_p^2 = .501$. The results of a linear regression indicated that participants high in autonomous motivation, who were assigned to this specific condition, exhibited a decline response bias (increased leniency) over time. AuM was not significantly correlated any of the periods on watch (r for Period 1 = -.345, r for Period 2 = .113, r for Period 3 = .662, r for Period 4 = -.662). There were no additional significant main effects, interactions, or correlations to report for these analyses.

Discussion

Engagement and Motivation

Achievement motivation, in addition to task type, instruction type, and source complexity, was significantly related to pre-task intrinsic motivation, post-task concentration, and post-task task-unrelated thoughts. Participants monitoring four displays tended to have significantly higher intrinsic motivation at pre-task. It is possible that this latter result is due to data cleaning procedures. In order to remain in the sample for analyses, participants had to meet the inclusion criteria, which required them to detect no less than 70% of the signals presented in the first period on watch and commit no more than ten false alarms during any period on watch. Many participants were removed in Experiment Four due to low correct detection rates and high false alarm rates (predominantly from the cognitive conditions).

It is probable that a trait like achievement motivation assisted participants in learning about task parameters and understanding signal-to-noise discrimination, which also resulted in some of the groups reporting higher intrinsic motivation at pre-task, as well as more concentration and fewer task-unrelated thoughts at post-task. These results suggest that concentration may be linked to task-related and task-unrelated thoughts, which does not support mind-wandering or mindlessness theory, rather these results support the initial conceptualization of “worry,” which is defined by the DSSQ as an increase in concentration, TRTs, and a decrease in TUTs. Based on the operationalization of each of these information processing theories, there should be more mind-wandering or cognitive disengagement from the task, not more concentration toward the task.

The results indicated that participants in the cognitive condition monitoring either two or four displays demonstrated the most concentration at post-task, which indicates that source complexity can influence individual cognitive engagement with the task. Furthermore, observers receiving autonomy-supportive instructions tended to report more task-unrelated thoughts at post-task, which would indicate that these instructions might afford more or less mind-wandering or mindlessness associated with the task. Observers randomly assigned to receive controlling instructions reported more task-related and fewer task-unrelated thoughts at post-task, which indicates that the type of task instructions play a role in attentional resources retained upon the conclusion of the vigil.

Autonomous motivation, in addition to task type, and instruction type, was significantly related to pre-task and post-task intrinsic motivation. This result suggests that participants higher in autonomous motivation may have slightly more intrinsic motivation to perform the vigilance task at post-task. Instruction type also significantly influenced post-task intrinsic motivation. Participants receiving controlling instructions reported the most post-task intrinsic motivation compared to participants receiving autonomy-supportive instructions (on average). Participants receiving controlling instructions also reported slightly higher post-task success motivation (on average). These results indicate that instruction manipulations can influence motivation and that autonomy-supportive instruction, while it implies choice, may actually result in less motivation upon conclusion of the task.

Stress and Workload

Achievement motivation had little effect on a majority of the stress-related measures, with the exception of pre-task tense arousal and anger/frustration. Participants monitoring two and four displays tended to report higher pre-task tense arousal, but lower pre-task anger/frustration than observers in the single display condition. However, achievement motivation seemed to have the greatest impact on perceived global workload. Participants monitoring one or two displays in either sensory condition reported some of the lowest global workload. Observers in the cognitive condition monitoring four displays reported some of the highest global workload. Manipulations to motivational instructions did not appear to affect global workload.

Autonomous motivation affected pre-task tense arousal and post-task hedonic tone. Interestingly, participants randomly assigned to the sensory task reported higher tense arousal, whereas participants in the cognitive condition lower on this measure prior to completing the vigil. Participants in the cognitive condition monitoring only one display had some of the lowest tense arousal scores. In addition to effecting tense arousal, autonomous motivation was also related to perceived global workload. Participants in the cognitive condition receiving controlling instructions and monitoring four displays reported the most global workload; however, participants in the sensory condition receiving autonomy-supportive instructions and monitoring only one display reported the lowest global workload. Autonomy-supportive instructions seemed to reduce workload in most cases, except when participants were randomly assigned to monitor four displays, which require significantly more information processing, which apparently offset the benefits of the autonomy-supportive instructions.

Performance

Autonomous motivation and achievement motivation influenced vigilance performance over time, but did so in dramatically different ways. For example, achievement motivation played a role in the proportion of correct detections over time, but autonomous motivation significantly interacted with task type, instruction type, source complexity, and period on watch, to affect the proportion of correct detections observed over time. In nearly every sensory condition, the traditional vigilance decrement tended to manifest over time, with the exception of participants in the sensory condition who received autonomy-supportive instructions and monitored only one display.

Performance in the cognitive condition tended to be more variable and potentially indicative of the vigilance increment, which is an increase in performance over time (Loeb et al., 1988; Sprague, 1981). Participants in the cognitive condition who received controlling instructions and monitored either one or two displays demonstrated a decrease in performance early on in the vigil, but subsequently indicated an improvement in performance in the last periods on watch. It could be the case that autonomous motivation results in observers become more aware of their performance over time, which would explain some of the variable increases in performance (i.e., motivation drives compensation for poorer performance). For example, participants high in autonomous motivation in the cognitive condition may realize their performance is declining, thus these individuals direct more resources toward performing the task well and improve from each period on watch. In sensory conditions, individuals may be less aware of performance declines over time due to the limited number of information processing requirements associated with this task.

In terms of false alarms, achievement motivation and autonomous motivation, in addition to the number of displays, influenced the number of false alarms during the vigil. Several interesting findings were observed in relation to the false alarm data that were not hypothesized. First, it is worth noting that in two cognitive conditions participants committed zero false alarms.

Secondly, participants in the sensory condition who received autonomy-supportive instructions and monitored four displays demonstrated an increase in false alarms over time. This group also demonstrated some of the greatest standard errors surrounding the number of false alarms over time. The number of false alarms committed by participants in the sensory conditions tended to be variable with a trend toward a slight increase in the number of false alarms over time. In most instances, participants in the cognitive conditions demonstrated a numerical decline in the number of false alarms committed throughout the vigil.

Achievement motivation and autonomous motivation did not appear to have a robust effect on mean response time except in Experiment Four. In this experiment, there were significant interactions between achievement motivation and autonomous motivation based on task type, instruction type, and source complexity. Response time varied across conditions, however in two conditions there was a significant decrease in mean response time over the course of the vigil: participants in the cognitive condition who received autonomy-supportive instructions and monitored two displays and participants in the sensory condition with autonomy-supportive instructions who monitored four displays. In many conditions, response time tended to increase. There was a trend toward an increase in response time in nearly all of the sensory conditions, whereas response time was variable (i.e., fluctuating between increases and decreases or vice versa) in the cognitive conditions.

Achievement motivation and autonomous motivation demonstrated the greatest impact on sensitivity and response bias in Experiment Four. Achievement motivation and autonomous motivation influenced sensitivity toward critical signals based on task type, instruction type, and number of displays. In most of the cognitive conditions, sensitivity tended to increase over time, which indicates that individuals were better able to discern critical signals from non-signals.

However, in the sensory conditions, sensitivity tended to decline variably (with the exception of participants in the sensory condition receiving controlling instructions and monitoring two displays where sensitivity actually increased over time). For example, observers in the sensory condition receiving controlling instructions and monitoring four displays became steadily less sensitive to differences between signals and non-signals over time.

In terms of response bias, there were extremely inconsistent findings between task type, instruction type, and number of displays; however, response bias trended toward the same pattern over time. This indicates that response criteria shifted dramatically from liberal and conservative responding throughout the course of the vigil. This could be due in part to individual differences in motivation or potentially due to a third variable which was not measured in the present dissertation.

CHAPTER NINE: GENERAL DISCUSSION

An overarching goal for this dissertation was test the assumption that the vigilance decrement is a manifestation of task design and individual differences (Hancock, 2013, 2016). Thinking in this same vein, it could then be argued that the antithesis is also true: the vigilance decrement is a phenomenon that can be offset by thoughtful task design, which could include designing for motivational affordances (Szalma, 2014) or individual differences in trait or state motivation. It was established in this dissertation that in order to cognitively engage participants in the vigilance task, several features were required: 1) a true cognitive aspect, such as symbolic processing and manipulation (i.e., processing beyond that required of sensory vigilance tasks), 2) an optimal degree of complexity and information processing demands, and 3) a consideration of individual differences in autonomous motivation. Given this, future research could serve to integrate these features into the operationalization of cognitive vigilance tasks, especially since there is little cohesion in the literature for the definition of cognitive vigilance tasks.

Furthermore, the four studies performed in this dissertation extended the research on motivation and vigilance. In each study, it was demonstrated that achievement motivation and autonomous motivation may play a role in vigilance performance and signal detection. Importantly, it was found that achievement motivation and autonomous motivation act distinctly in vigilance performance, as well as in perceived stress and workload, and motivation and engagement post-task. Moreover, these four studies provided partial support for the resource-depletion account of vigilance and did not indicate a great degree of support for mindlessness theory or mind-wandering theory, which are two information processing theories currently utilized in the literature to explain the performance decrement. For example, the pattern of response across measures of motivation, stress, and performance tended to support the resource account of the vigilance decrement.

This dissertation also demonstrated that achievement motivation and autonomous motivation are individual differences that should be considered in tasks that require vigilance. Both types of motivation appear to be involved in the cognitive engagement associated with the task, especially in post-task engagement. For example, both autonomous motivation and achievement motivation were significantly related to more task-related thoughts at post-task, more concentration at pre-task and post-task, and fewer task-unrelated thoughts, which is indicative of less mind-wandering and more cognitive engagement with the task upon conclusion of the vigil.

Finally, there were several significant findings that supported the examination of achievement motivation and autonomous motivation in each of the experiments. Each significant result for task motivation and task engagement, workload and stress, performance, and sensitivity and response bias across achievement motivation and autonomous motivation are reiterated below in Tables 24-27 for purposes of clarity.

Table 24. The table below includes the significant results for measures of engagement and motivation across each experiment (*N* = 398).

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
Achievement Motivation	1) Main effect of AchM on pre-task energetic arousal 2) Main effect of task type on post-task energetic arousal	1) Interaction between task type and number of displays on post-task task-unrelated thoughts	1) Interaction between AchM and task type on post-task intrinsic motivation 2) Interaction between AchM and task type on pre-task concentration 3) Interaction between instruction type and task type on pre-task concentration 4) Interaction between instruction type and task type on pre-task task-unrelated thoughts 5) Main effect of AchM on pre-task energetic arousal 6) Main effect of AchM on post-task energetic arousal	1) Interaction between AchM, instruction type, task type, and number of displays on pre-task intrinsic motivation 2) Interaction between AchM, instruction type, task type, and number of displays on post-task concentration 3) Interaction between AchM, instruction type, task type, and number of displays on post-task task-unrelated thoughts 4) Interaction between AchM, task type, and number of displays on post-task concentration 5) Interaction between AchM and instruction type on pre-task intrinsic motivation 6) Interaction between instruction type, task type, and number of displays on post-task concentration 7) Interaction between instruction type, task type, and number of displays on post-task task-unrelated thoughts 8) Interaction between task type and number of displays on post-task concentration

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
				9) Interaction between AchM and number of displays on post-task task-unrelated thoughts 10) Main effect of AchM on post-task success motivation 11) Main effect of AchM on pre-task energetic arousal 12) Main effect of AchM on post-task task-unrelated thoughts 13) Main effect of number of displays on post-task task-unrelated thoughts 14) Main effect of instruction type on pre-task intrinsic motivation
Autonomous Motivation	1) Main effect of AuM on post-task energetic arousal 2) Main effect of AuM on pre-task intrinsic motivation 3) Main effect of condition on post-task intrinsic motivation 4) Main effect of AuM on post-task task-unrelated	1) Interaction between task type, AuM, and number of displays on post-task energetic arousal 2) Main effect of number of displays on post-task energetic arousal 3) Main effect of task type on post-task concentration	1) Interaction between task type, AuM, and instruction type on pre-task concentration 2) Interaction between instruction type and AuM on pre-task concentration 3) Interaction between AuM and instruction type on post-task task-unrelated thoughts 4) Main effect of AuM on pre-task energetic arousal	1) Interaction between instruction type, task type, and AuM on post-task intrinsic motivation 2) Interaction between number of displays and AuM on post-task intrinsic motivation 3) Interaction between instruction type and task type on post-task intrinsic motivation 4) Interaction between instruction type and AuM on pre-task success motivation 5) Interaction between task type, number of

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
	thoughts		5) Main effect of AuM on post-task energetic arousal 6) Main effect of AuM on post-task success motivation 7) Main effect of AuM on pre-task intrinsic motivation 8) Main effect of AuM on pre-task concentration 9) Main effect of AuM on post-task concentration 10) Main effect of AuM on pre-task task-unrelated thoughts 11) Main effect of AuM on post-task task-unrelated thoughts 12) Main effect of instruction type on pre-task concentration 13) Main effect of instruction type on post-task concentration	displays, and AuM on post-task energetic arousal 6) Interaction between task type and number of displays on post-task energetic arousal 7) Main effect of AuM on post-task success motivation 8) Main effect of AuM on pre-task intrinsic motivation 9) Main effect of instruction type on pre-task success motivation 10) Main effect of instruction type on pre-task energetic arousal 11) Main effect of number of displays on post-task intrinsic motivation

Table 25. The table below includes the significant results for measures of stress and workload across each experiment (*N* = 398).

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
Achievement Motivation		1) Main effect of task type on post-task tense arousal	1) Interaction between instruction type, task type, and AchM on global workload 2) Interaction between instruction type and task type on global workload 3) Interaction between instruction type and AchM on global workload 4) Main effect of AchM on pre-task hedonic tone 5) Main effect of AchM on post-task hedonic tone	1) Interaction between instruction type, task type, number of displays, and AchM on global workload 2) Interaction between number of displays and AchM on pre-task tense arousal 3) Interaction between number of displays and AchM on pre-task anger/frustration 4) Main effect of number of displays on pre-task tense arousal 5) Main effect of number of displays on pre-task anger/frustration
Autonomous Motivation	1) Main effect of AuM on post-task tense arousal 2) Main effect of AuM on post-task hedonic tone 3) Main effect of AuM on pre-task anger/frustration	1) Main effect of AuM on post-task hedonic tone	1) Main effect of AuM on post-task tense arousal 2) Main effect of AuM on pre-task hedonic tone 3) Main effect of AuM on post-task hedonic tone	1) Interaction between instruction type, task type, number of displays, and AuM on pre-task tense arousal 2) Interaction between instruction type, task type, and number of displays on pre-task tense arousal 3) Interaction between task type and AuM on pre-task tense arousal 4) Interaction between AuM and instruction type on global workload 5) Interaction between

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
	4) Main effect of AuM on post-task anger/frustration			instruction type and task type on global workload 6) Main effect of AuM on post-task tense arousal 7) Main effect of AuM on post-task hedonic tone 8) Main effect of task type on pre-task tense arousal 9) Main effect of instruction type on global workload

Table 26. The table below includes the significant results for measures of performance across each experiment (*N* = 398).

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
Achievement Motivation		1) Main effect of period on number of false alarms	1) Main effect of period on number of false alarms	1) Interaction between period, number of displays, and AchM on false alarms 2) Interaction between period and number of displays on false alarms 3) Interaction between period, AchM, task type, and number of displays on response time 4) Interaction between period, instruction type, task type, and AchM on response time 5) Interaction between period, task type, and number of displays on response time 6) Interaction between period, instruction type, and task type on response time 7) Main effect of AchM on proportion of correct detections
Autonomous Motivation	1) Main effect of period on number of false alarms	1) Interaction between period, number of displays, and AuM on response time 2) Interaction between period and task type on response time 3) Interaction between period and number of	1) Interaction between instruction type, task type, and AuM on proportion of correct detections 2) Interaction between instruction type and task type on proportion of correct detections 3) Interaction	1) Interaction between period, task type, number of displays, and AuM on proportion of correct detections 2) Interaction between period and task type on proportion of correct detections 3) Interaction between AuM and period on proportion of correct

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
		displays on response time 4) Main effect of period on proportion of correct detections	between instruction type and AuM on proportion of correct detections 4) Main effect of instruction type on proportion of correct detections 5) Main effect of period on proportion of correct detections	detections 4) Interaction between number of displays and AuM on false alarms 5) Interaction between period, task type, number of displays, and AuM on response time 6) Interaction between period, instruction type, task type, and AuM on response time 7) Interaction between period, instruction type, number of displays, and AuM on response time 8) Interaction between period, instruction type, task type, and number of displays on response time 9) Interaction between period, instruction type, and AuM on response time 10) Interaction between period, task type, and number of displays on response time 11) Interaction between period, instruction type and number of displays on response time 12) Interaction between period, instruction type, and task type on response time 13) Interaction between period and number displays on response time 14) Main effect of period

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
				on proportion of correct detections 15) Main effect of task type on proportion of correct detections 16) Main effect of AuM on proportion of correct detections 17) Main effect of period on false alarms

Table 27. The table below includes the significant results for measures of sensitivity and response bias across each experiment (*N* = 398).

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
Achievement Motivation	1) Main effect of period on sensitivity	1) Main effect of task type on sensitivity		1) Interaction between period, instruction type, task type, number of displays, and AchM on sensitivity 2) Interaction between AchM, instruction type, task type, and number of displays on sensitivity 3) Interaction between period, instruction type, task type, and number of displays on sensitivity 4) Interaction between instruction type, task type, and number of displays on sensitivity 5) Interaction between instruction type, task type, number of displays, and AchM on response bias 6) Interaction between period, instruction type, task type, and number of displays on response bias 7) Interaction between instruction type, task type, and number of displays on response bias
Autonomous Motivation		1) Interaction between period and AuM on response bias		1) Interaction between period and AuM on sensitivity 2) Interaction between period, task type, and AuM on response bias 3) Interaction between period and AuM on response bias

Covariate	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
				4) Interaction between task type and period on response bias 5) Main effect of period on sensitivity 6) Main effect of period on response bias

Implications for Motivation and Engagement in Vigilance

There have been few published studies in the extant literature on vigilance focused on the effect of manipulations to motivation on performance. The present dissertation investigated motivation and engagement through three distinct, but interrelated, lenses: 1) motivation as both a state and trait individual difference (i.e., autonomous motivation and achievement motivation), 2) motivation through task design (i.e., manipulations to the type of task and source complexity), and 3) motivation through instructional design (i.e., autonomy-supportive vs. controlling instructions).

The results of the four studies included in this dissertation demonstrated that achievement motivation, which is motivation to experience success, and autonomous motivation, which is motivation to experience choice, significantly influence cognitive state, specifically energetic arousal, success motivation, intrinsic motivation, concentration, task-related, and task-unrelated thoughts. However, achievement motivation and autonomous motivation act differently on measures of engagement depending on the type of task, type of instructions administered, and the degree of source complexity. For example, in Experiment Four post-task concentration and post-task task-unrelated thoughts were significantly dependent upon achievement motivation, task type, source complexity, and instruction type. There was also a main effect of achievement motivation on post-task success motivation, pre-task energetic arousal, and post-task task-unrelated thoughts. These results support previous findings from Experiments Two and Three, which demonstrated that achievement motivation is implicated in the perception of engagement in the task and motivation to perform the task at pre- and post-task. Juxtaposing this, Experiment Four indicated that autonomous motivation was significantly related to post-task energetic arousal, post-task intrinsic motivation, and post-task task-unrelated thoughts through main effects and in combination with task type, instruction type, and source complexity.

Across each of the four experiments it was demonstrated that both achievement motivation and autonomous motivation influenced post-task task-unrelated thoughts. However, achievement motivation was linked to concentration more frequently than autonomous motivation, which tended to interact more frequently with energetic arousal and intrinsic motivation. This is not necessarily surprising given that autonomous motivation is a subfactor of the Intrinsic Motivation Inventory, which is rooted in self-determination theory. But, this is of particular interest given that vigilance tasks do not exert a great deal of motivational affordances or even necessarily intrinsically motivating to perform by nature. Achievement motivation may have more to do with task focus (i.e., task concentration) than task engagement or task motivation.

In addition to state and trait motivation, the results of this doctoral work indicated that the type of task and complexity associated with the task also influence task engagement and self-reported motivation to perform the vigilance task. This research also suggests that the vigilance decrement is iatrogenically created, as well as implies that motivation and engagement are too induced by the design of the task. Thus, motivational design, which is afforded in this case by task type and source complexity, not only influenced the performance decrement, but also affected subjective reports of motivation and engagement at pre- and post-task. For example, task type (i.e., cognitive or sensory) and source complexity (i.e., number of displays) significantly influenced the degree of post-task task-unrelated thoughts, post-task concentration, post-task intrinsic motivation, and post-task energetic arousal, across each of the four studies in this dissertation (and when autonomous motivation or achievement motivation was accounted for as a covariate).

The results of this dissertation, particularly Experiments Three and Four, indicated that the type of instructions could also impact the task engagement and task motivation associated with vigilance. Interestingly, autonomy-supportive instructions, while these instructions imply choice, may actually result in less motivation toward the task upon conclusion of the vigil, at least when task type and the degree of source complexity are taken into account. In many autonomy-supportive instruction conditions, performance was actually poorer than anticipated. It is also possible that the autonomy-supportive manipulation to instructions (as opposed to potentially stronger manipulations, which may include the choice over rest breaks or the choice to leave the study early) was too weak to elicit an effect.

For example, in Experiment Four participants in the autonomy-supportive group tended to succumb to the vigilance decrement (particularly participants in the sensory four-display condition) and demonstrated some of the most liberal response bias and decreased sensitivity over time. Furthermore, participants in the controlling motivation condition demonstrated some of the best performance (i.e., many correct detections, few if any false alarms). It is possible that motivational instruction manipulations may prime participants to respond in a particular, which influences both motivation and engagement to perform the vigilance task, as well as performance in the task itself. However, the latter is a proposition that will require further empirical testing in the future.

Implications for Theories of Vigilance and Information Processing

Another purpose of this dissertation was to examine the degree to which the results supported resource theory, mindlessness theory, or mind-wandering theory, which are three theories of information processing that attempt to explain the vigilance decrement. To recapitulate, resource theory suggests that the vigilance decrement occurs due to a depletion of mental resources, which enable individuals to process information and respond to critical signals, as well as avoid false alarms. Resource theory implies a greater performance decrement will be observed in more demanding tasks due to the increase in the utilization of more information processing resources, which are being depleted due to the demand and time on task.

Conversely, mind-wandering theory suggests that the decrement occurs, not necessarily because of resource depletion, but because attention is directed away from the task primarily by task-unrelated thoughts. Mind-wandering theory posits that this cognitive 'drifting away' from the task can be either intentional (i.e., the individual purposefully allows their mind to wander) or unintentional (i.e., attention slips away from the task), which may manifest behaviorally as fewer physical responses to critical signals (i.e., button presses for correct detections; Thomson et al., 2015). Mind-wandering theory also implies that greater cognitive engagement can be established when the task is designed to be more behaviorally engaging (see Thomson et al., 2015; Pop et al., 2012). Like resource theory, mind-wandering somewhat suggests (albeit, it is not directly stated, but rather implied) that the task can be designed to afford more or less engagement, but suggests behavioral engagement equates to cognitive engagement, which is most akin to a misnomer.

Furthermore, the third information processing theory that seeks to explain the vigilance decrement is mindlessness theory. Like mind-wandering theory, mindlessness theory suggests that the decrement is a result of under-stimulation of the mind during vigilance, ultimately resulting in the performance decrement. Supporters in favor of this theory suggest that the mind becomes “thoughtless” after a period of time, which occurs due to the monotony of vigilance performance (Manley et al., 1999; Robertson et al., 1997). This results in a pattern of automatic responding over time. However, one major distinction between mind-wandering theory and mindlessness theory is what happens to attentional processes during the vigil. Mindlessness does not describe what happens to attention rather this theory merely suggests that the mind becomes blank, which implies that there are no inward or outward thoughts. Moreover, mindlessness theory does not discuss the mechanism of recovery of attention, nor does this theory discuss where the mind goes during vigilance.

The evidence in supporting of each of these theories is included in Table 28. An overwhelming proportion of the significant results supported resource theory, which also argues that vigilance tasks are accompanied by high workload and stress. The results from Experiments Two, Three, and Four indicated that global workload increased in conditions that were more complex and required symbolic processing (i.e., the cognitive task). Similarly, measures of stress (i.e., tense arousal and anger/frustration) tended to increase between pre-task and post-task, which are results that were consistently demonstrated across all four experiments. These results favor the resource-depletion account of the vigilance decrement.

Moreover, measures of task engagement (i.e., task-related thoughts, task-unrelated thoughts, concentration, and energetic arousal) also indicated support for resource theory. For example, task-related thoughts and energetic arousal increased pre-post vigil across each of the experiments. This indicates that these tasks are at least somewhat engaging to perform and that participants were interested in their performance on the task at post-task, which is implied by the increase in task-related thoughts and decrease in task-unrelated thoughts over time (albeit, in most of the conditions).

In many instances, correct detection performance initially declined in the cognitive condition and then increased over time, which could be considered a vigilance increment. This claim is supported by several significant interactions between measures of performance, such as proportion of correct detections, number of false alarms, and response time with autonomous motivation or achievement motivation. There were also significant, positive correlations between these individual differences and measures of performance, which indicated that higher motivation scores were associated with improved performance in specific periods on watch. Again, this evidence tends to favor the resource theory of vigilance performance.

In order to demonstrate support for mind-wandering theory or mindlessness theory, there should not be an increase in energetic arousal or task-related thoughts between pre-task and post-task. Instead, the opposite should be observed: an increase in task-unrelated thoughts and decreases in task-related thoughts, concentration, and energetic arousal. There was only partial evidence from Experiments Two, Three, and Four to support either of these theories.

Furthermore, there should be no difference across task types or variations in source complexity in terms of measures of stress and workload according to mind-wandering theory and mindlessness theory. These theories of information processing do not distinguish between task type effects. In sum, mind-wandering theory and mindlessness theory posit that vigilance is vigilance and will be accompanied by a decline in performance over time regardless of source complexity or task type because a vigilance task is ultimately perceived as monotonous and boring.

In that vein, is important to note that the traditional vigilance decrement was only observed in specific instances across each of the experiments. In Experiment Two, the vigilance decrement was observed in only the sensory four-display condition. In Experiment Three, the vigilance decrement was observed in both the autonomy-supportive and controlling instruction sensory conditions, but not in any of the cognitive conditions. In Experiment Four, the vigilance decrement was observed in sensory condition where participants received the autonomy-supportive instructions and monitored two displays, the sensory condition where participants received the controlling instructions and monitored two displays, the sensory condition where participants received controlling instructions and monitored four displays, and, the cognitive condition where participants received autonomy-supportive instructions and monitored two displays. In Experiment One, a vigilance decrement was not observed for either task type.

Table 28. The table below includes the results of each experiment supporting evidence for each of the above information processing theories (N = 398).

Theory	EXP. ONE (N = 79)	EXP. TWO (N = 105)	EXP. THREE (N = 93)	EXP. FOUR (N = 121)
Resource Theory	1) Energetic arousal increased between pre- and post-task across task type 2) TRTs increased between pre- and post-task across task type 3) TUTs decreased between pre- and post-task across task type 4) Tense arousal increased between pre- and post-task across task type 5) Anger/frustration increased between pre- and post-task across task type	1) Energetic arousal increased between pre- and post-task across task type and source complexity 2) TRTs increased between pre- and post-task across task type and source complexity 3) Tense arousal increased between pre- and post-task across task type and source complexity 4) Anger/frustration increased between pre- and post-task across task type and source complexity 5) High global workload was reported for participants in the cognitive task 6) High global workload was reported for participants monitoring one or four displays	1) Energetic arousal increased between pre- and post-task across task type and instruction type 2) TRTs increased between pre- and post-task across task type and instruction type 3) TUTs decreased between pre- and post-task in the cognitive task 4) TUTs decreased between pre- and post-task across instruction type 5) Tense arousal increased between pre- and post-task across task type and instruction type 6) Anger/frustration increased between pre- and post-task across task type and instruction type 7) High global workload was reported for participants in the cognitive task	1) Energetic arousal increased between pre- and post-task across task type, instruction type, and source complexity 2) TRTs increased between pre- and post-task across task type, instruction type, and source complexity 3) TUTs decreased between pre- and post-task across task type and instruction type 4) TUTs decreased between pre- and post-task for participants monitoring one or four displays 5) Tense arousal increased between pre- and post-task across task type, instruction type, and source complexity 6) Anger/frustration increased between pre- and post-task across task type, instruction type, and source complexity 7) High global workload was reported for participants in the

Theory	EXP. ONE (*N* = 79)	EXP. TWO (*N* = 105)	EXP. THREE (*N* = 93)	EXP. FOUR (*N* = 121)
				cognitive task 8) Global workload increased as source complexity increased
Mindlessness Theory	1) Concentration decreased between pre- and post-task across task type 2) Low global workload was reported across task type	1) Concentration decreased between pre- and post-task across task type and source complexity 2) Lower global workload was reported for participants in the sensory task 3) Lower global workload was reported for participants monitoring two displays	1) Concentration decreased between pre- and post-task across task type and instruction type 2) Lower global workload was reported across instruction type	1) Concentration decreased between pre- and post-task across task type, instruction type, and source complexity
Mind-wandering Theory	1) Low global workload was reported across task type	1) TUTs increased between pre- and post-task across task type and source complexity 2) Lower global workload was reported for participants in the sensory task 3) Lower global workload was reported for participants monitoring two displays	1) TUTs increased in the sensory task 2) Lower global workload was reported across instruction type	1) TUTs increased in the two-display conditions only 2) Low global workload was reported across instruction type 3) Lower global workload was reported for participants in the sensory task

Note. TRTs = task-related thoughts. TUTs = task-unrelated thoughts.

Limitations to this Work and Future Directions

This dissertation is not without its limitations. For example, there was a great deal of attrition in the cognitive conditions in nearly all of the experiments, especially in instances where participants were required to monitor four displays (i.e., Experiments Two and Four). Anecdotally, many participants (who tended to be removed from the study during data cleaning) randomly assigned to the cognitive condition noted that monitoring the four displays for critical signals was extremely difficult. In other conditions, participants tended to report that monitoring one display (despite the task being either cognitive or sensory) was very boring and monotonous. They reported similar suggestions central to the idea of making the task more engaging. While this is anecdotal evidence, it does align with previous findings, which suggests that vigilance need not be vigilance, if the individual can achieve a sort of "flow state" or the difficulty of the task is "titrated" to match the capacity of the individual. Again, this dissertation did demonstrate that the vigilance decrement is likely a manifestation of task design.

In addition to task type, future vigilance research could examine the effect of different instructional sets. For example, in the present dissertation, the effect of autonomy-supportive instructions on vigilance performance was not as hypothesized, especially in terms of response bias and criterion shifting. Autonomy-supportive instructions tended to result in participants responding more liberally to false alarms. In some conditions, instruction type actually lowered post-task motivation to perform the vigilance task and altered engagement in the vigil at pre-task. Furthermore, participants in the controlling instruction condition tended to demonstrate better performance most likely because they performed exactly as directed.

It is not the goal of this dissertation to argue that one form of instructions are more important over another, rather the purpose of testing different instructional sets was to empirically demonstrate that task framing can influence task perception and performance. In that vein, combinations of instruction types were not studied in the present dissertation (i.e., initially autonomy-supportive instructions seguing into controlling instructions) and it is likely the case that a combination of instruction types will be necessary to maximize the potential for optimal performance. In terms of future research, it could also be useful to revisit the early work in vigilance, which framed the task as a "challenge," considering there has been little work in this area since these original studies. Future research could also explore other successful manipulations to task instructions involving motivation (i.e., rationale, acknowledgement, choice/autonomy) and examine the effect of these instructions on vigilance performance (see Deci et al., 1994).

Finally, another limitation to this dissertation was the lack of consistency in the results from experiment to experiment. For example, trait or state motivation would correlate to response time in one experiment, but not in another. In some conditions a decrement was observed, but not across subsequent experiments. In some conditions there was fluctuation in performance from period to period (e.g., sensitivity and response bias in Experiment Four), and in some instances there was an increment in performance between pre- and post-task (albeit after an initial decline). While the results are not necessarily clean, there are several implications based on these findings: 1) replication of this work is required within the laboratory and outside of the laboratory to provide support for the effect of motivation, or potential lack of effect of motivation, in vigilance, and 2), future research should extend the length of the vigil to observe the long-term effects of achievement motivation and autonomous motivation on vigilance performance.

To conclude, this dissertation resulted in several theoretical and practical implications, which could be used to guide future research involving vigilance performance. First, it was demonstrated across several studies that autonomous motivation and achievement motivation were two covariates related to task engagement, perceived stress, perceived workload, and vigilance performance. Each of type of motivation affects these measures differently. For example, autonomous motivation covaried more often with pre- and post-task measures of task engagement, pre- and post-task measures of perceived stress, and interacted with measures of vigilance performance, whereas achievement motivation covaried more often with workload and response time measures. These results indicated that it is important to consider individual differences in motivation in various types of vigilance tasks (i.e., complex, simple, sensory, cognitive). Motivational manipulations to task instructions also influence task engagement, perceived stress, perceived workload, and vigilance performance. In sum, the results of this dissertation indicated that motivation is an important construct to consider in the measurement of sustained attention and design of tasks requiring vigilance. In terms of practical application, motivation could also be used a selection tool to screen for individuals high or low in either of achievement motivation or autonomous motivation, which could result in better performance on real-world vigilance tasks.

Additionally, the patterns of the task engagement, perceived stress, and vigilance performance data tended to support the resource-depletion account of the vigilance decrement across the four experiments presented in this dissertation. For example, task-related thoughts increased (in most cases) at post-task and task-unrelated thoughts tended to decrease post-vigil, which is not in line with mind-wandering theory or mindlessness theory. The results from the stress measures also align with a resource interpretation, or overload account, of the data.

Participants indicated worry and concern with their performance at post-task and tended to report higher perceived stress and workload post-vigil, which is indicative of capacity limitations and that energy is being drained over time. There was extremely limited support for mindlessness theory (i.e., vigilance decrement results from automaticity) or mind-wandering theory (i.e., intentional or unintentional perceptual withdrawal). This theoretical extension will aid in better understanding the relationship between motivation and attention in practical settings that require vigilance, such as baggage screening, improvised explosive device (IED) detection, and thwarting cyber-attacks.

APPENDIX A
IRB OUTCOME LETTER

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

Approval of Human Research

From: **UCF Institutional Review Board #1 FWA00000351, IRB00001138**

To: **Alexis R. Dewar** and Co-PI: **James L. Szalma**

Date: **September 08, 2015**

Dear Researcher:

On 09/08/2015, the IRB approved the following human participant research until 09/07/2016 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	Task Perceptions and Sustained Attention
Investigator:	Alexis R. Dewar
IRB Number:	SBE-15-11589
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 09/07/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the

Investigator Manual. On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB

Chair, this letter is signed by:

Signature applied by Joanne Muratori on 09/08/2015 04:06:15

PM EDT

IRB manager

APPENDIX B
IRB OUTCOME LETTER FOR CONTINUING REVIEW

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

Approval of Human Research

From: **UCF Institutional Review Board #1 FWA00000351, IRB00001138**

To: **Alexis R. Neigel**

Date: **October 10, 2016**

Dear Researcher:

On 10/10/2016 the IRB approved the following human participant research until 10/09/2017 inclusive:

Type of Review:	IRB Continuing Review Application Form Expedited Review
Project Title:	Task Perceptions and Sustained Attention
Investigator:	Alexis R. Neigel, M.S.
IRB Number:	SBE-15-11589
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 10/09/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the

Investigator Manual. On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB

Chair, this letter is signed by:

Signature applied by Kamille Chaparro on 10/10/2016 03:10:48

PM EDT IRB Coordinator

APPENDIX C
CORRELATIONS WITH MEASURES OF ENGAGEMENT AND MOTIVATION ACROSS ALL STUDIES

	EXP. ONE		EXP. TWO		EXP. THREE		EXP. FOUR	
	AchM	AuM	AchM	AuM	AchM	AuM	AchM	AuM
AchM	-	-.049	-	-.051	-		-	
AuM	-.049	-	-.051	-	-.145	-	-.137	-
Pre-Success Motivation	-.105	.099	.136	.147	-.156	.106	-.110	.024
Post-Success Motivation	-.124	.163	-.109	.227	-.295**	.330**	-.327**	.256*
Pre-Intrinsic Motivation	.082	.261	.041	.344**	-.033	.247	-.067	.250*
Post-Intrinsic Motivation	-.095	.426**	-.032	.355**	-.009	.048	-.076	-.001
Pre-Concentration	.027	.272	-.144	.217	.039	.497**	-.225	.141
Post-Concentration	-.015	.297*	-.016	.054	-.022	.347**	-.190	.172
Pre-Energetic Arousal	-.265	.036	-.286**	.161	-.385**	.270*	-.248*	.112
Post-Energetic Arousal	-.269	.270	-.160	.165	-.326**	.347**	-.226	.206
Pre-TRTs	-.152	-.150	.116	-.152	-.215	-.203	-.035	-.105
Post-TRTs	-.105	-.018	-.052	.113	-.159	-.074	-.183	-.094
Pre-TUTs	-.191	-.176	.084	-.183	-.070	-.321**	.003	-.198
Post-TUTs	-.044	-.268	-.032	-.143	-.023	-.396**	-.002	-.115

Note. * = $p < .01$. ** = Bonferroni correction of $p < .004$.

APPENDIX D
MEANS AND STANDARD DEVIATIONS FOR FULL DSSQ ACROSS ALL STUDIES

	EXP. ONE		EXP. TWO		EXP. THREE		EXP. FOUR	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Energetic Arousal	16.57 (4.10)	17.28 (4.18)	16.56 (3.90)	17.17 (4.18)	16.99 (4.12)	17.57 (5.05)	17.78 (3.78)	18.33 (4.43)
Tense Arousal	12.96 (4.08)	16.13 (5.42)	12.65 (3.40)	15.29 (5.03)	12.81 (3.35)	14.76 (4.04)	12.97 (3.40)	15.71 (4.72)
Hedonic Tone	25.63 (3.94)	22.16 (4.27)	25.46 (4.06)	22.22 (3.95)	25.38 (4.60)	22.52 (4.21)	26.02 (4.20)	22.74 (4.33)
Anger/ Frustration	7.77 (3.41)	11.29 (4.55)	8.00 (3.38)	10.83 (4.25)	7.89 (3.53)	10.42 (4.28)	7.69 (3.16)	9.92 (3.60)
Success Motivation	20.91 (6.09)	19.80 (7.25)	13.91 (8.03)	18.79 (6.73)	20.02 (7.74)	19.39 (7.01)	20.24 (6.71)	20.00 (6.83)
Intrinsic Motivation	24.87 (5.05)	15.34 (4.92)	21.32 (4.88)	11.63 (4.97)	18.05 (4.50)	12.26 (4.34)	17.50 (4.71)	12.50 (4.75)
Overall Motivation	3.39 (1.13)	2.76 (1.26)	2.25 (1.45)	2.75 (1.18)	3.14 (1.38)	2.82 (1.28)	3.11 (1.20)	2.92 (1.25)
Self-Focused Attention	22.41 (6.61)	18.66 (8.45)	13.21 (9.59)	16.66 (7.09)	17.41 (8.19)	16.02 (7.38)	19.59 (7.76)	17.58 (7.80)
Self-Esteem	11.28 (7.66)	15.86 (6.17)	17.59 (8.42)	16.41 (5.22)	13.83 (7.21)	17.42 (4.79)	12.51 (7.23)	15.60 (6.34)
Concentration	15.53 (6.08)	6.99 (6.95)	21.78 (6.00)	7.71 (6.65)	17.39 (6.46)	8.76 (7.02)	15.81 (6.45)	7.33 (6.95)
Control/ Confidence	21.80 (4.78)	25.62 (7.31)	14.91 (8.21)	25.38 (7.57)	20.25 (7.12)	26.57 (7.39)	20.74 (5.42)	25.22 (7.51)
Task-Related Thoughts	19.89 (7.94)	23.62 (7.20)	11.25 (8.38)	20.94 (6.16)	15.67 (7.81)	19.20 (6.13)	17.74 (8.34)	20.58 (7.04)
Task-Unrelated Thoughts	17.66 (14.89)	14.89 (7.17)	9.93 (8.72)	15.25 (6.88)	13.83 (7.91)	14.31 (6.83)	16.96 (9.23)	16.21 (7.72)

Note. Numbers reported in parentheses are standard deviations.

APPENDIX E
MEANS AND STANDARD DEVIATIONS FOR FULL NASA-TLX ACROSS ALL STUDIES

	EXP. ONE	EXP. TWO	EXP. THREE	EXP. FOUR
Global Workload	38.55 (13.27)	39.35 (12.84)	38.53 (13.96)	40.13 (15.33)
Mental Demand	36.58 (27.93)	36.61 (26.71)	35.10 (28.20)	41.69 (29.22)
Temporal Demand	35.44 (26.91)	28.26 (25.57)	25.68 (23.98)	28.98 (26.35)
Physical Demand	9.34 (9.11)	9.96 (12.07)	12.56 (17.96)	10.47 (14.99)
Perceived Performance	41.98 (31.50)	53.75 (32.93)	46.59 (33.52)	52.11 (32.29)
Effort	30.87 (25.06)	29.91 (25.47)	32.06 (26.66)	35.04 (27.09)
Frustration	34.84 (33.10)	32.81 (30.55)	31.52 (31.12)	31.54 (30.16)

Note. Numbers reported in parentheses are standard deviations.

APPENDIX F
CORRELATIONS WITH MEASURES OF STRESS AND WORKLOAD ACROSS ALL STUDIES

	EXP. ONE		EXP. TWO		EXP. THREE		EXP. FOUR	
	AchM	AuM	AchM	AuM	AchM	AuM	AchM	AuM
Pre-Tense Arousal	-.097	.006	.104	-.105	.152	-.219	.071	-.080
Post-Tense Arousal	-.044	-.240	.062	-.212	.082	-.295*	-.080	-.134
Pre-Hedonic Tone	-.042	.114	-.044	.268*	-.320**	.314**	-.153	.099
Post-Hedonic Tone	-.126	.460**	-.084	.402**	-.300*	.427**	-.187	.286**
Pre-Anger/ Frustration	-.007	-.300*	.114	-.277**	.132	-.274*	.159	-.148
Post-Anger/Frustration	.038	-.485**	.166	-.257	.097	-.343**	.132	-.173
Global Workload	.079	-.123	.130	.025	-.170	.028	-.166	-.032
Mental Demand	-.095	-.057	.021	.136	-.240	.216	-.116	.162
Temporal Demand	-.100	-.105	.111	.034	.080	-.090	.001	.005
Physical Demand	-.080	.002	.108	-.008	-.102	.012	.145	-.104
Perceived Performance	-.096	.010	-.007	.030	.102	.159	.058	-.048
Effort	.070	-.020	.111	.098	-.095	.121	-.068	.106
Frustration	-.074	-.327**	.081	-.128	.175	-.326**	-.016	-.136

Note. * = p < .01. ** = Bonferroni correction p < .003.

APPENDIX G
CORRELATIONS WITH MEASURES OF PERFORMANCE ACROSS ALL STUDIES

	EXP. ONE		EXP. TWO		EXP. THREE		EXP. FOUR	
	AchM	AuM	AchM	AuM	AchM	AuM	AchM	AuM
Period 1 Hits	.152	.118	-.012	.145	-.010	-.001	-.028	-.069
Period 2 Hits	-.098	.123	.038	.131	-.015	.035	.041	.109
Period 3 Hits	.014	.115	-.036	.306**	.064	.174	.030	.115
Period 4 Hits	-.102	-.202	-.023	.048	-.122	.000	-.022	.086
Overall Hits	-.013	.144	-.008	.208	-.034	.076	.015	.108
Period 1 FAs	-.110	-.141	-.119	.039	-.007	-.128	.155	-.002
Period 2 FAs	-.172	-.048	.027	.167	-.021	-.024	.116	.190
Period 3 FAs	-.021	-.199	.084	.032	.046	-.233	.114	.190
Period 4 FAs	-.075	.073	.070	-.133	.214	-.063	.034	.131
Overall FAs	-.095	-.175	-.019	.045	.038	-.167	.139	.142
Period 1 RT	-.029	-.186	-.062	-.137	-.038	.124	-.039	-.051
Period 2 RT	-.023	-.289	.016	-.176	.039	.023	-.086	-.154
Period 3 RT	-.165	-.249	.017	-.122	.004	-.069	-.086	-.140
Period 4 RT	-.025	-.278	.050	-.155	-.130	.109	.011	-.170
Overall RT	-.097	-.287	.059	-.175	.053	-.185	-.063	.109

Note. * = $p < .01$. ** = Bonferroni correction $p < .003$. Hits = proportion of correct detections. FAs = number of false alarms. RT = mean response time.

APPENDIX H
CORRELATIONS WITH MEASURES OF SENSITIVITY AND RESPONSE BIAS ACROSS ALL STUDIES

	EXP. ONE		EXP. TWO		EXP. THREE		EXP. FOUR	
	AchM	AuM	AchM	AuM	AchM	AuM	AchM	AuM
Sensitivity								
Period 1	.194	.148	.093	.063	.036	-.029	.018	.164
Period 2	-.037	.116	.037	.014	-.015	.100	-.050	-.015
Period 3	0.21	.176	.014	.127	.048	.165	.018	-.180
Period 4	-.022	.174	-.055	.099	-.205	.037	-.001	-.017
Response Bias								
Period 1	-.037	-.029	.111	.027	-.062	.022	-.026	.070
Period 2	.231	-.073	-.014	-.201	-.087	.042	-.127	-.149
Period 3	.002	.000	.029	-.222	-.094	-.023	-.083	-.254**
Period 4	.147	.076	-.022	.052	-.081	.026	.041	-.115

Note. * = $p < .01$. ** Bonferroni correction = $p < .005$.

APPENDIX I
RELIABILITY OF THE ACHIEVEMENT MOTIVATION AND AUTONOMOUS MOTIVATION MEASURES ACROSS ALL STUDIES

	Sample			
	EXP. ONE	**EXP. TWO**	**EXP. THREE**	**EXP. FOUR**
Cronbach's alpha (α) for Achievement Motivation	.506	.523	.562	.538
Cronbach's alpha (α) for Autonomous Motivation	.879	.795	.821	.805
N	79	105	93	121

Note. The Ray Achievement Motivation Scale (Ray, 1979) consisted of 14 items and the Autonomy subscale of the Intrinsic Motivation Inventory (Deci et al., 1994; Ryan, 1982) consisted of seven items.

APPENDIX J
ENGAGEMENT, MOTIVATION, STRESS, AND WORKLOAD DATA FOR EXCLUDED PARTICIPANTS ACROSS ALL STUDIES

	EXP. ONE (N = 13)	EXP. TWO (N = 19)	EXP. THREE (N = 11)	EXP. FOUR (N = 27)
Motivation Measures				
Achievement Motivation	20.69 (2.87)	21.32 (2.75)	27.64* (9.82)	23.96 (4.92)
Autonomous Motivation	30.92 (7.58)	34.53 (10.07)	34.45 (10.08)	45.44** [a] (2.53)
Pre-Energetic Arousal	15.62 (3.31)	16.00 (3.23)	18.18 (3.79)	17.89 (3.83)
Post-Energetic Arousal	18.54 (3.99)	17.37 (3.64)	18.09 (6.24)	18.19 (3.87)
Pre-Intrinsic Motivation	25.69 (4.79)	18.68 (4.62)	25.82** (3.06)	22.74** (5.52)
Post-Intrinsic Motivation	15.31 (4.13)	9.16 (3.86)	17.27** (6.25)	16.59* [a] (6.57)
Pre-Success Motivation	25.77* (4.17)	9.05 (6.00)	20.82 (8.76)	22.81 (6.49)
Post-Success Motivation	19.69 (7.95)	19.58 (6.79)	25.82 (3.06)	20.26 (7.50)
Engagement Measures				
Pre-Concentration	11.00* (4.38)	25.74** [a] (3.31)	16.00 (6.36)	13.59 (6.72)
Post-Concentration	7.00 (7.07)	10.89 (6.67)	7.82 (7.11)	8.19 (6.83)
Pre-TRTs	20.46 (8.55)	8.37 (5.10)	16.27 (10.15)	20.78 (7.75)
Post-TRTs	23.46 (7.33)	19.95 (6.60)	19.09 (6.39)	21.74 (7.82)
Pre-TUTs	14.69 (7.80)	8.63 (8.07)	12.91 (7.87)	19.78 (7.24)
Post-TUTs	12.69 (4.53)	15.42 (8.20)	13.45 (8.93)	14.67 (6.25)
Stress Measures				
Pre-Tense Arousal	13.54 (3.97)	13.37 (3.89)	13.91 (3.11)	12.63 (3.80)
Post-Tense Arousal	21.31** (5.44)	16.05 (4.10)	14.36 (2.77)	15.11 (4.53)

	EXP. ONE (N = 13)	EXP. TWO (N = 19)	EXP. THREE (N = 11)	EXP. FOUR (N = 27)
Pre-Hedonic Tone	25.46 (3.60)	25.05 (4.72)	24.27 (2.87)	25.48 (4.38)
Post-Hedonic Tone	18.31* (4.11)	21.11 (3.83)	23.64 (3.07)	21.63 (5.32)
Pre-Anger/Frustration	8.54 (4.48)	8.21 (3.05)	9.45 (3.14)	8.85 (3.58)
Post-Anger/Frustration	13.08 (4.82)	10.37 (4.02)	9.45 (2.62)	11.08 (4.05)
Workload Measures				
Global Workload	48.38 (16.08)	38.98 (13.85)	40.36 (15.58)	43.01 (16.87)

Note. Standard deviations are reported in parentheses. N = number of participants excluded for performance deviations. TRTs = task-related thoughts. TUTs = task-unrelated thoughts. * = $p < .01$. ** Bonferroni correction = $p < .002$. Significant results indicate a significant difference between participants included in the experiment and participants excluded from the experiment. [a] = equal variances not assumed.

APPENDIX K
EFFECT SIZES FOR ENGAGEMENT, MOTIVATION, STRESS, AND WORKLOAD DATA ACROSS EXCLUDED PARTICIPANTS FOR ALL EXPERIMENTS

	Cohen's *d*			
	EXP. ONE (*N* = 13)	**EXP. TWO (*N* = 19)**	**EXP. THREE (*N* = 11)**	**EXP. FOUR (*N* = 27)**
Motivation Measures				
Achievement Motivation	0.49	0.19	0.79	0.47
Autonomous Motivation	0.46	0.10	0.05	1.66
Pre-Energetic Arousal	0.25	0.16	0.30	0.03
Post-Energetic Arousal	0.31	0.05	0.09	0.03
Pre-Intrinsic Motivation	0.17	0.34	2.02	1.02
Post-Intrinsic Motivation	0.01	0.56	0.93	0.71
Pre-Success Motivation	0.93	0.69	0.10	0.39
Post-Success Motivation	0.01	0.12	1.19	0.04
Engagement Measures				
Pre-Concentration	0.85	0.82	0.22	0.34
Post-Concentration	0.001	0.48	0.13	0.12
Pre-TRTs	0.07	0.42	0.07	0.38
Post-TRTs	0.02	0.15	0.02	0.16
Pre-TUTs	0.37	0.15	0.17	0.34
Post-TUTs	0.37	0.02	0.11	0.22
Stress Measures				
Pre-Tense Arousal	0.14	0.20	0.34	0.09
Post-Tense Arousal	0.95	0.17	0.12	0.13
Pre-Hedonic Tone	0.05	0.09	0.29	0.13
Post-Hedonic Tone	0.92	0.29	0.30	0.23
Pre-Anger/Frustration	0.19	0.07	0.50	0.34
Post-Anger/Frustration	0.38	0.11	0.27	0.30
Workload Measures				
Global Workload	0.67	0.02	0.12	0.18

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