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A STUDY OF SEMANTIC PROCESSING PERFORMANCE

by

DARYN A. DEVER

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
in the College of Sciences
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

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Thesis Chair: Dr. James Szalma

ABSTRACT

Examining the role of individual differences, especially variations in human motivation, in vigilance tasks will result in a better understanding of sustained semantic attention and processing, which has, to date, received limited study in the literature (see Fraulini, Hancock, Neigel, Claypoole, & Szalma, 2017; Epling, Russell, & Helton, 2016; Thomson et al., 2016). This present study seeks to understand how individual differences in intrinsic motivation affect performance in a short semantic vigilance task. Performance across two conditions (lure vs. standard condition) were compared in the present study of 79 undergraduate students at the University of Central Florida. The results indicated significant main effects of intrinsic motivation on pre- and post-task stress factors, workload, and performance measures, which included correct detections, false alarms, and response time. Sensitivity and response bias, which are indices of signal detection theory, were also examined in the present study. Intrinsic motivation influenced sensitivity, but not response bias, which was affected by period on watch. The theoretical and practical implications of this research are also discussed.

ACKNOWLEDGEMENTS

I would like to thank Dr. James Szalma for agreeing to work with me as my committee chair and assisting me with the development of this thesis. I also extend an immeasurable amount of gratitude to Dr. Alexis Neigel for serving on my committee and guiding me through this process by dedicating her time and attention to this thesis. I would also like to thank all of the Performance Research Laboratory (PeRL), especially Victoria Claypoole in lending their support and assistance, and time to this thesis.

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Introduction

Vigilance, or sustained attention, is the ability to attend to information for a prolonged period of time (Davies & Parasuraman, 1982; Jerison, 1970; Warm, 1977) and requires observers to detect critical signals, or distinguish important information from non-signals (e.g., neutral events; Matthews & Davies, 1998). In vigilance tasks, performance tends to decrease over a long period of time on watch, which leads to a decline in correctly identified critical signals, and is typically associated with longer response times to this information. This phenomenon is known as the vigilance decrement in the literature, and is defined as a "decline in performance efficiency over time on a task" (Helton, Kern, & Walker, 2009, pg. 600).

Theories Related to Information Processing and the Vigilance Decrement

Broadly speaking, several theories have been proposed to explain vigilance performance and the subsequent decrement. Two current perspectives include mind-wandering theory (Smallwood & Schooler, 2006; Thomson, Besner, & Smilek, 2016) and cognitive resource theory (Davies & Parasuraman, 1982; Navon & Gopher, 1979; Wickens, 1984, 2002). The mind-wandering theory argues that when presented with a vigilance task that is repetitive for a long amount of time, there is a decrease in the efficiency of the supervisory attention system, which may reduce the observers' awareness of the vigilance task (Dillard et al., 2014) and the observer becomes 'thoughtless' for a period of time (Manly et al., 1999). It is also possible that daydreams, or other forms of inattention related to mind-wandering, are the cause of the vigilance decrement (Manly et al., 1999). Mind-wandering theory also assumes that individuals disengage from the vigilance task by intentionally or unintentionally mind-wandering, which implies that people can engage or disengage attention from the task either unknowingly or at will

(Smallwood & Schooler, 2006; Thomson, Besner, & Smilek, 2016). In sum, mind-wandering theory suggests that the mind becomes less focused on the vigilance task over time, and this leads to the performance decrement.

On the other hand, the resource model of information processing suggests that the presence of missed critical signals occurs when observers' information processing assets, or resources, are depleted as a result of the continuous discriminations the observers must make between critical signals and neutral events (Dillard et al., 2014). The resource model views attention as limited and more specifically suggests that individuals are limited in their capacity to maintain attention due to the number of available resources (Caggiano & Parasuraman, 2004; Moray, 1967; Hirst & Kalmar, 1987). The resource model assumes that, as time progresses, the amount of available resources decrease, resulting in the vigilance decrement (Head & Helton, 2012). Because a great deal of this model supports vigilance research, and because this model accounts for performance disparities based on individual differences, it is used as a guiding framework for the present study.

Other Possible Causes of the Vigilance Decrement Related to Task Design

Additional variables that are associated with vigilance performance include task difficulty (Dillard et al., 2014) or the monotony associated with the task (Scerbo, 2001). Task monotony, which has been previously determined in other studies using the present vigilance task (Thomson, Besner, & Smilek, 2016; Thomson & Hasher, 2017), suggests that attentional resources are diminished due to the uniform nature of the task stimuli (Scerbo, 2001). The uniform nature of task stimuli increases the perceived monotony associated with performing the vigilance task. In the present study, monotony may be induced because the target stimuli are

mixed within a number of inanimate objects and the temporal demand of the task is held

consistent. However, monotony will be examined with measures of distress and workload.

In some studies, task monotony can also be physically determined. For example, if there

are periods between critical signals that require no physical activity (i.e., a button push, writing

something down), then "task disengagement is most likely to occur" (Donald & Donald, 2015,

pg. 122). The present study does not require a great deal of physical demand, so when there is a

break in between critical stimuli, disengagement may occur. In another study, Pop, Stearman,

Kazi, and Durso (2012) had observers 'engage' by using a computer mouse to click on incoming

airplane in a flight collision vigilance task. Observers who had to use a computer mouse to click

on an incoming aircraft outperformed observers who had to simply monitor planes for possible

collisions (Pop et al., 2012). This task may have facilitated a more autonomous experience of the

task. It is possible that this physical task engagement supports the idea of Hancock (2013), which

suggests that task engagement is determined by human design (Hancock, 2017; Hancock &

Szalma, 2003; Hancock, Volante, & Szalma, 2016).

Furthermore, task difficulty can be determined by the type of task stimuli or by the

cognitive engagement, required to complete the task (Neigel, 2017). For example, Deaton and

Parasuraman (1988) observed that cognitive vigilance tasks were less susceptible to a decrement

over time. In a meta-analysis, See et al. (1995) determined that greater vigilance decrements tend

to occur in sensory vigilance tasks than cognitive vigilance tasks, but this is also dependent upon

event rate, as well as the type of discrimination required. For example, tasks with a high event

rate result in a rapid vigilance decrement and are typically associated with higher cognitive

demand.

Based on this research, the present semantic vigilance task, which is associated with moderate cognitive demand, may hold the attention of the observer, but it is also possible that the temporal demand associated with the Thomson et al. (2016) semantic vigilance task may lead to a decrement in performance over the course of the vigil.

Individual Differences and the Vigilance Decrement

Previous studies have indicated that motivation, intrinsic or extrinsic, can influence task performance (Bonnefond, Doignon-Camus, Hoeft, & Dufour, 2011; Neigel, 2017; Upadhyay & Singh, 2013). In one study, Bonnefond et al. (2011) investigated the effect of motivation on cognitive control throughout the duration of a monotonous task. In a task where intrinsic motivation is manipulated, performance is found to remain stable throughout a relatively simple task when observers are perceived as motivated (Bonnefond et al., 2011). Similarly, Upadhyay and Singh (2013) argue that given a reason to perform well, observers will detect targets with reduced response times. In Neigel (2017), autonomous motivation, a factor of intrinsic motivation, significantly increased observer correct detection performance in both a sensory and cognitive vigilance task. In a similar vein, Hancock (2017) argues that in the evaluation vigilance tasks, the meaning of the task for the individual, in terms of motivation to perform the task, is often omitted. In many instances, the purpose of the vigilance experiment is not always clear to observers and the importance of the task is not made salient. This echoes previous arguments that suggest the vigilance decrement may stem "from merging the scores of conscientious subjects with individuals who lack the commitment and dedication to maintain attention to the task" (Dember, Galinsky, & Warm, 1992, pg. 201; Hancock, 2017). Without considering motivation, it is difficult to understand who commits the vigilance decrement and under which task conditions. To summarize, very few studies have connected intrinsic motivation to the performance of vigilance tasks, and many fail to consider the meaning of the task to the observer.

One theory that may be important and useful in examining individual differences in intrinsic motivation, and the subsequent effect of these differences on performance, is self-

determination theory (SD-T). Self-determination theory proposes that "people are inherently motivated to internalize the regulation of uninteresting, but important activities", which is an aspect of many vigilance tasks (Deci, Eghrari, Patrick, & Leone, 1994, pg. 119; Ryan & Deci, 2008). Individuals higher in intrinsic motivation tend to demonstrate higher quality performance on monotonous tasks (Ryan & Deci, 2008). It is possible that higher levels of intrinsic motivation may influence vigilance task performance, but this is a claim that remains relatively untested (but see Neigel, 2017). Furthermore, implicit theories of willpower indicate a positive interaction between motivational and cognitive processes that sustain attention over a period of time (Miller, Walton, Dweck, Job, Trzesniewski, & McClure, 2012).

In the present study, observers in this experimental research are recruited from an undergraduate sample, and they may only be performing the task for partial course credit or extra credit (i.e., extrinsic motivation). Without studying individual differences in motivation, it is difficult to understand how a combination of extrinsic and intrinsic factors, especially varying levels of intrinsic motivation, affects vigilance performance.

The Present Study

The purpose of the present study is to understand how individual differences in intrinsic motivation affect performance on a semantic vigilance task, which is moderate in its difficulty and cognitive in nature. The present task utilizes the stimuli of Thomson et al. (2016), which is a semantic vigilance task requiring observers to detect differences between four-legged animals, non-four-legged animals, and common objects. Semantic processing is the encoding of information regarding words and carefully selecting and processing information related to their meaning (Hancock, 2017). The act of "processing written words engages not only orthographic but also phonological and semantic processes" (Pattamadilok, Chanoine, Pallier, Anton, Naxarian, Belin, & Ziegler, 2017, pg. 244). As such, semantic tasks require observers to manipulate and interpret the meaning of words, or symbols.

It is important to note that semantic tasks have received limited study in the domain of vigilance (see Fraulini, Hancock, Neigel, Claypoole, & Szalma, 2017; Epling, Russell, & Helton, 2016; Thomson et al., 2016), thus the effects of individual differences (i.e., cognitive abilities, motivation, etc.) in performing these tasks remains relatively unknown. The present study examines the control condition (i.e., standard information processing) and an experimental condition containing "lures" (i.e., added information processing), which are stimuli that are perceptually similar, but distinct from the critical signal stimuli. The presence of lures requires observers to crucially think about the meaning of a word, which requires processing the word for semantic meaning (not present within control condition).

Therefore, it is hypothesized that poorer performance (i.e., fewer correct detections, more false alarms, and slower response times) will be exhibited by the experimental group, or the lure

condition. However, this performance may be offset by individual differences in intrinsic motivation. Individuals in intrinsic motivation may not demonstrate a vigilance decrement and may not indicate any poor performance. The results will be interpreted from a resource theory perspective.

Methodology

Participants

Seventy-six observers (47 female; 29 male) were recruited from the University of Central Florida's psychology research participation system (SONA). The average age of observers was 18.76 years (*Median* = 18.00 years, *SD* = 2.24 years). The oldest observer was 30-years-old and the youngest observer was 18 years of age. In this sample, 80.2% of observers were college freshman, 10.5% were sophomores, 3.9% were juniors, 3.9% were seniors, and 1.3% were transfer students. All observers reported normal or corrected-to-normal vision. Observers indicated that they did not to consume caffeine 24 hours prior to this study.

Measures

Dundee Stress State Questionnaire. One of the measures used in the present study was the Dundee Stress State Questionnaire (DSSQ; Matthews et al., 2002). This was used to measure the stress levels of observers before and after the vigilance task in the form of pre- and post-task questions. This questionnaire assesses distress, worry, and task engagement in relation to stress-induced tasks.

NASA-Task Load Index. The NASA-TLX (Hart & Staveland, 1988) is used to measure perceived workload associated with performing and task. The NASA-TLX is a post-task measure that assesses mental demand, physical demand, temporal demand, performance, frustration, and effort. This scale is measured from 0 – 100, 0 reflecting a lower level of workload and 100 reflecting a high level of workload.

Intrinsic Motivation Inventory. The Intrinsic Motivation Inventory (IMI; Deci et al., 1994; Ryan & Deci, 2008) measures individual intrinsic motivation toward the task. The IMI

includes several subscales, which measure perceived interest/enjoyment, value/usefulness, and choice/autonomy over the duration of the vigilance task. The IMI is used a covariate in the present study.

Demographics. A post-task demographics questionnaire investigated an observer's age, gender, ethnicity, grade point average (GPA), and academic standing.

Procedure

Observers were randomly assigned to either the lure condition or the control (i.e., standard) condition. Observers were then instructed to remove any watches in direct sight and silence their cell phones and put them away where they could not be seen to reduce distractions and time effects. Upon completion of the informed consent, observers completed pre-test questionnaires including the pre-task version of the DSSQ (Matthews et al., 2002). Observers then completed a computer-based semantic vigilance task in a private, quiet laboratory space. After the completion of the vigilance task, observers filled out post-task measures including the post-DSSQ, the NASA-Task Load Index, the Intrinsic Motivation Inventory (IMI; Deci et al., 1994), which were randomized to control for order effects. Then observers completed the demographics survey (NASA-TLX; Hart, 2006; Hart & Staveland, 1988). A researcher was not present in the room for the vigil and waited outside in a nearby laboratory for the observers to complete the vigil. All surveys were administered electronically using Qualtrics survey software.

Vigilance Task and Stimuli

The semantic vigilance task contains different stimulus sets for the lure condition and the standard condition. The standard condition contains ten critical signals and 90 neutral events, which are referred to as "distracters". Critical signals consist of four-legged animals such as

"Donkey" and "Bear," while neutral events are inanimate objects such as "Ball" and "Cabinet". The lure condition contains ten critical signals, ten lure stimuli (i.e., non-four-legged animals such as "Chicken" and "Walrus"), and eighty neutral events.

Before starting the task, observers were instructed to press the spacebar when there is the presence of a critical signal. Observers are instructed to withhold any response to non-four-legged creature stimuli. Words are presented in white lettering in 24-point Times New Roman font on a black screen for 200 milliseconds and an interstimulus interval (ISI) of 1100 milliseconds. This allows for the observer to respond to a stimulus for a total of 1300 milliseconds. A cross ("+") served as the ISI and was presented between trials. The cross was also presented in white, in the center of the screen, on a black background. The vigil was held for 12 minutes with five periods with each period averaging approximately 2.4 minutes.

Data Cleaning and Outlier Removal

Seventy-nine observers were recruited from the SONA study pool in total. One observer was removed from the present analyses for being an outlier on overall IMI score (i.e., over 70 points below the average; well over +/- 3 standard deviations). One observer was removed as an outlier from the lure condition for excessive distracter false alarms (i.e., 57 distracter false alarms in total; well over +/- 3 standard deviations). One observer was removed from the standard condition as an outlier based on the number of correct detections indicated in Period One (i.e., only three hits were made by this observer). Thus, the following analyses are performed on a sample of 76 undergraduate students from the University of Central Florida. Of these 76 students, 37 observers were randomly assigned to the standard condition and 39 were randomly assigned to the lure condition.

Results

Stress and workload scores (note that NASA-TLX subscales were analyzed using a *t*-test) were analyzed using a factorial Analysis of Covariance (ANCOVA) with condition (standard vs. lure) as a between factor and IMI score as the covariate. Performance data was analyzed using a mixed factorial ANCOVA with condition as the between factor, overall IMI score as the covariate, and period on watch as the within factor.

Intrinsic Motivation

An independent samples *t*-test indicated no significant difference in the overall IMI scores between the lure and standard conditions, $t(74) = 1.524$, $p = .132$, *Cohen's d* = .354. However, it is worth noting that the standard condition ($M = 162.41$, $SD = 30.95$) was associated with an average score that was approximately ten points higher than the lure condition ($M = 152.64$, $SD = 24.71$). Intrinsic motivation scores are illustrated in Figure 1.
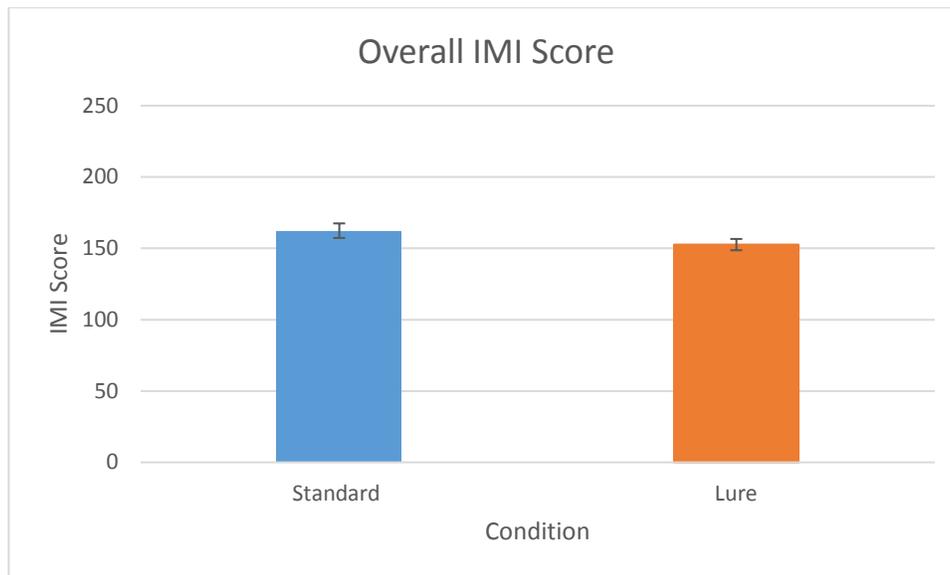
Figure 1. Intrinsic motivation scores between the conditions (note that error bars represent standard error around the mean).

Stress Analyses

Task Engagement. Pre- and post-task engagement scores as a function of the experimental condition are shown in Figure 2. A factorial ANCOVA indicated a significant main effect of the covariate, overall IMI on pre-task engagement, $F(1, 72) = 12.449$, $p = .001$, $\eta_p^2 = .011$. Although, the Bonferroni-adjusted pairwise comparisons between the estimated marginal means for pre-task engagement between the lure ($M = 19.22$, $SE = .567$) and standard condition ($M = 19.98$, $SE = .579$) were not significantly different.

A separate factorial ANCOVA indicated a significant main effect of the covariate, overall IMI, on post-task engagement, $F(1, 72) = 40.90$, $p < .001$, $\eta_p^2 = .362$. However, the Bonferroni-adjusted pairwise comparisons between the estimated marginal means for post-task engagement between the lure ($M = 17.46$, $SE = .679$) and standard ($M = 17.32$, $SE = .694$) condition were not

significantly different. There were no additional significant main effects or interactions to report for these analyses.
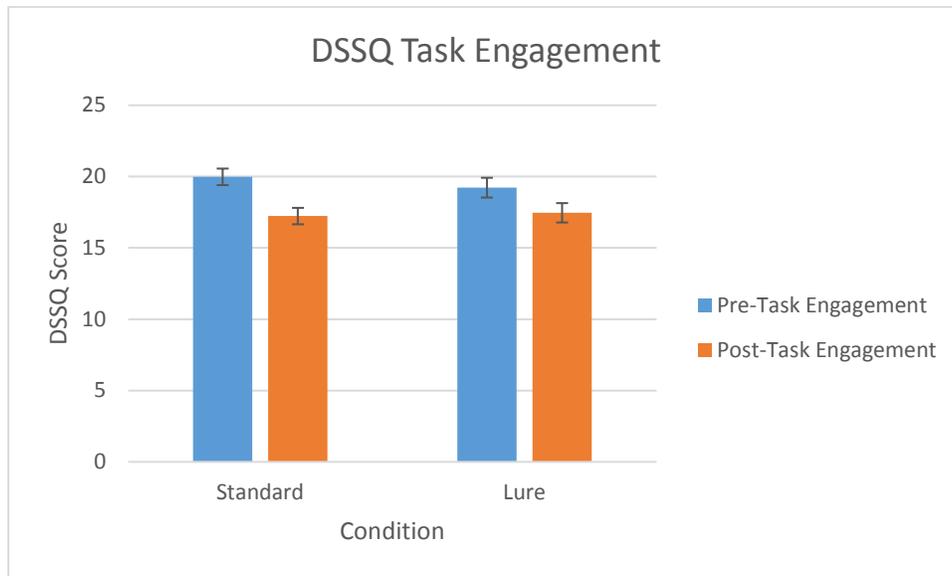

Figure 2. Task engagement scores after controlling for the covariate at pre- and post-task (note that error bars represent standard error around the mean).

Distress. Pre- and post-task distress scores as a function of the experimental condition are shown in Figure 3 below. A factorial ANCOVA indicated a significant interaction between the covariate and condition on pre-task distress, $F(1, 72) = 4.44$, $p = .039$, $\eta_p^2 = .058$. There was also a significant main effect of condition, $F(1, 72) = 5.62$, $p = .020$, $\eta_p^2 = .072$, and a main effect of overall IMI on pre-task distress, $F(1, 72) = 12.67$, $p = .001$, $\eta_p^2 = .150$. Bonferroni-corrected pairwise comparisons did not indicate a significant difference between pre-task distress scores between the standard ($M = 5.42$, $SE = .649$) and lure conditions ($M = 6.91$, $SE = .636$).

A factorial ANCOVA of post-task distress indicated a significant main effect of condition, $F(1, 72) = 5.62$, $p = .025$, $\eta_p^2 = .068$, and a main effect of motivation, $F(1, 72) = 6.12$,

$p = .016$, $\eta_p^2 = .078$. Post-task distress scores for the standard condition ($M = 6.75$, $SE = .824$) were significantly lower than the lure condition ($M = 10.29$, $SE = .807$). There was no significant interaction between intrinsic motivation and condition for post-task distress.

Figure 3. Distress scores after controlling for the covariate at pre- and post-task (note that error bars represent standard error around the mean).

Worry. Pre- and post-task worry scores as a function of the experimental condition are shown in Figure 4. Separate factorial ANCOVAs examining pre-task and post-task worry scores did not yield any significant main effects or interactions.
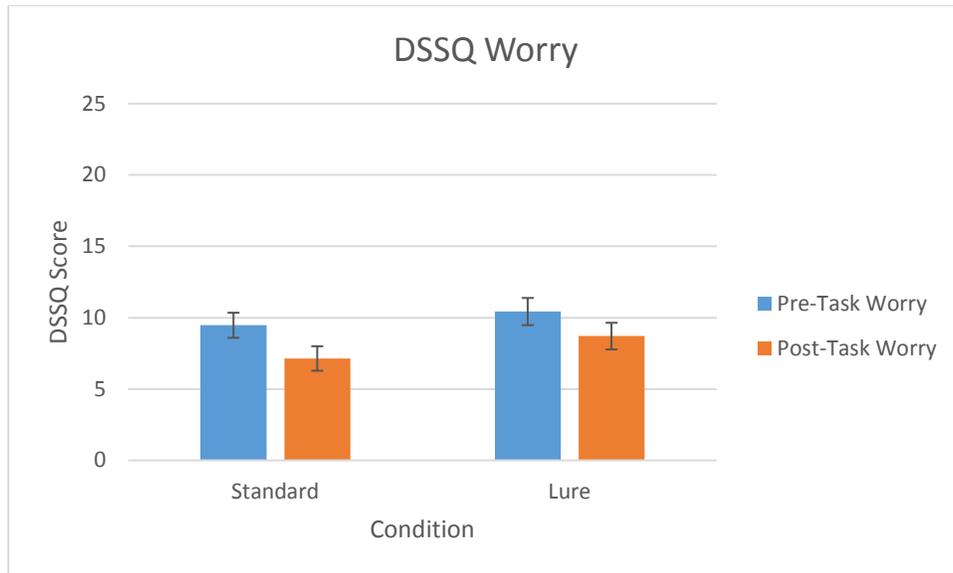
Figure 4. Worry scores after controlling for the covariate at pre- and post-task (note that error bars represent standard error around the mean).

Perceived Workload Analyses

Subscale scores across experimental conditions for the NASA-TLX are illustrated in Figure 5. Because the effects of condition and motivation on global workload scores are of the greatest interest, these results are analyzed with a factorial ANCOVA. Differences between conditions on the subscales on the NASA-TLX are of less interest in this thesis and are analyzed using multiple independent samples *t*-tests with a Bonferroni-correction for consecutive comparisons.

Global Workload. A factorial ANCOVA with condition as the between-measures factor and intrinsic motivation as the covariate on global workload did not yield any significant main effects or interactions.

Mental Demand. There was no significant difference between the mental demand scores reported in the standard ($M = 54.35$, $SD = 29.95$) and lure condition ($M = 59.49$, $SD = 22.93$), $t(74) = -.836$, $p = .406$.

Physical Demand. There was no significant difference between the physical demand scores reported in the standard ($M = 11.11$, $SD = 9.26$) and lure condition ($M = 11.08$, $SD = 11.93$), $t(74) = .013$, $p = .990$.

Temporal Demand. There was no significant difference between the temporal demand scores reported in the standard ($M = 54.08$, $SD = 29.48$) and lure condition ($M = 56.54$, $SD = 29.66$), $t(74) = -.362$, $p = .718$.

Performance. There was no significant difference between the performance scores reported in the standard ($M = 42.35$, $SD = 33.60$) and lure condition ($M = 50.36$, $SD = 25.09$), $t(74) = -1.17$, $p = .245$.

Effort. There was no significant difference between the effort scores reported in the standard ($M = 51.03$, $SD = 30.09$) and lure condition ($M = 52.21$, $SD = 22.31$), $t(74) = -.193$, $p = .848$.

Frustration. There was a significant difference between the frustration scores reported in the standard ($M = 18.54$, $SD = 20.92$) and lure condition ($M = 36.79$, $SD = 28.36$), $t(74) = -3.21$, $p = .002$ (Bonferroni-corrected significance for multiple *t*-tests).
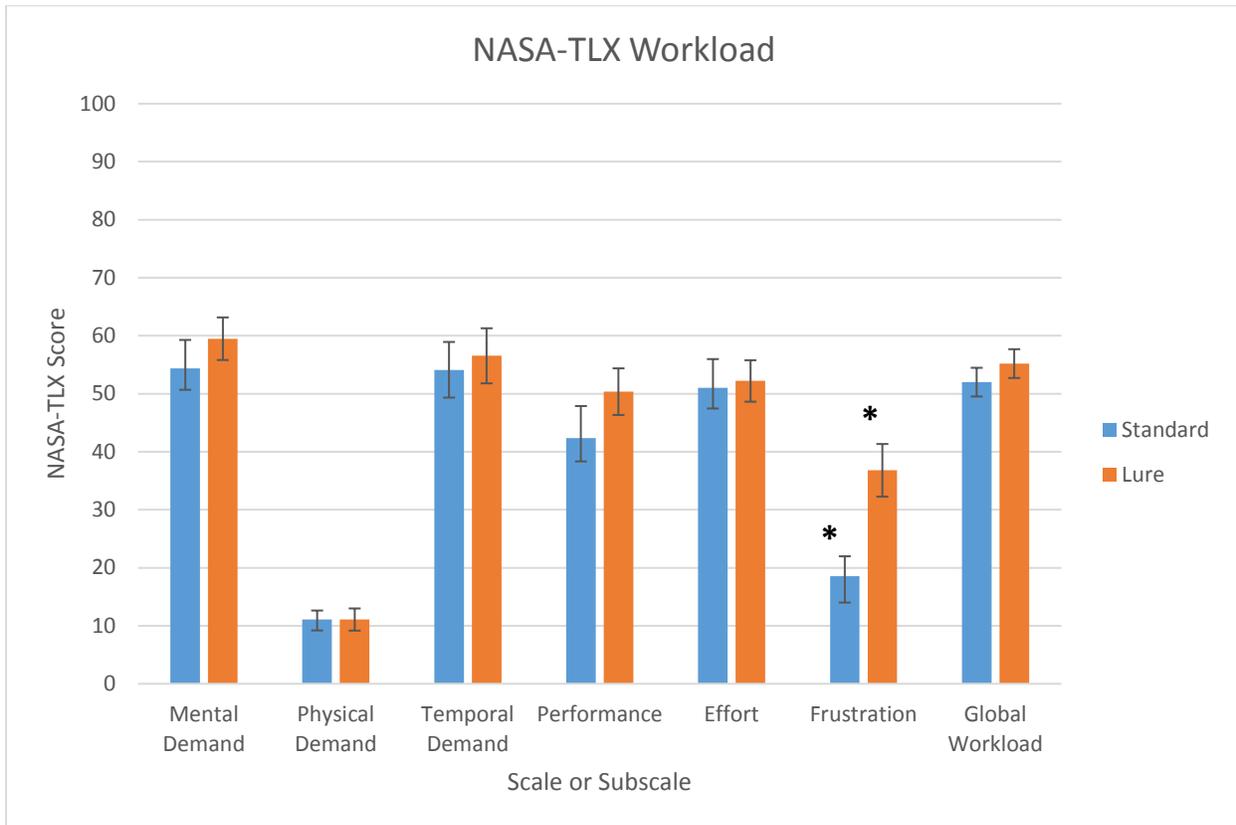
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Figure 5. Workload scores across conditions (note that error bars represent standard error around the mean). Global workload scores depicted here control for the covariate. * indicates a significant difference at the $p = .001$ level.

Correct Detection Performance

Correct detection performance is plotted as a function of period on watch and experimental condition in Figure 6. Following a mixed-measures factorial ANCOVA, there was a trending significant main effect of motivation on proportion of correct detections, $F(1, 72) = 2.21$, $p = .078$, $\eta_p^2 = .030$. There was a significant positive bivariate correlation between the average proportion of correct detections and motivation ($r = .281$, $p = .014$), which indicated that as motivation increased, the total proportion of hits increased. There was also a trending main effect of period on watch on proportion of correct detections, $F(4,288) = 2.21$, $p = .078$, $\eta_p^2 = $

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.030, Huynh-Feldt Ɛ = .867. There were no additional significant main effects or interactions to report for this analysis.
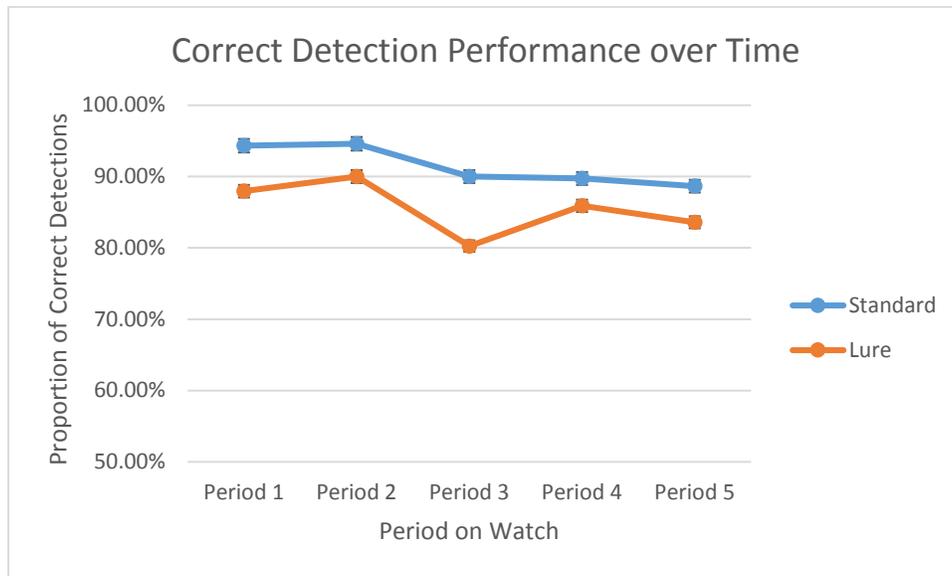

Figure 6. Correct detection performance over time by condition (note that error bars represent standard error around the mean).

Distracter False Alarm Performance

Distracter false alarm performance is plotted as a function of period on watch and experimental condition in Figure 7. Following a mixed-measures factorial ANCOVA, there was a trending main effect of condition on the number of distracter false alarms committed, $F(1, 72) = 3.14$, $p = .080$, $\eta_p^2 = .042$. There were no additional significant main effects or interactions to report for this analysis.
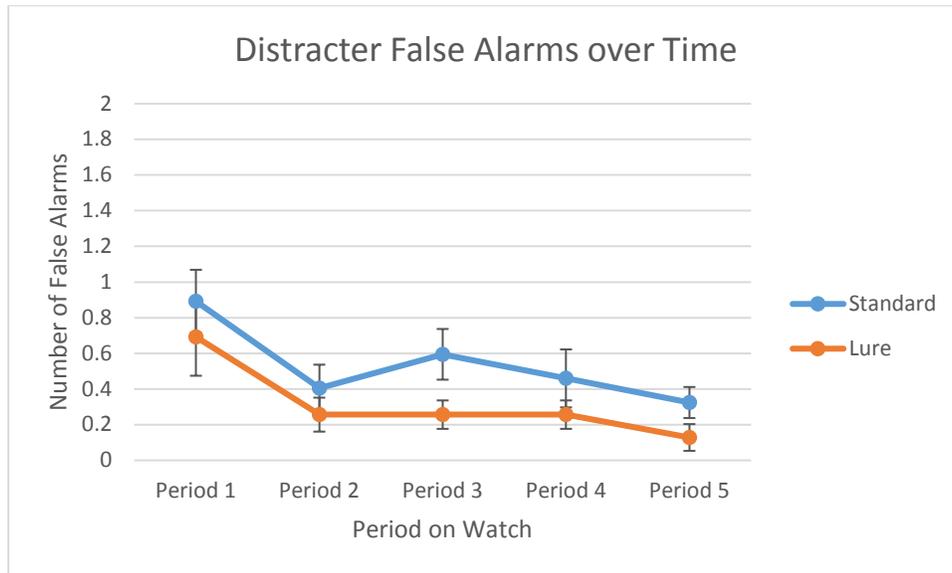
Figure 7. Distracter false alarm performance over time by condition (note that error bars represent standard error around the mean).

Lure False Alarm Performance

Lure false alarm performance is included in Figure 8. Following a mixed-measures factorial ANCOVA, there was a significant main effect of period on watch on the number of lure false alarms committed, $F(4, 288) = 4.39$, $p = .040$, $\eta_p^2 = .057$, Huynh-Feldt $\varepsilon = .800$. There was also a significant main effect of motivation on the number of lure false alarms committed, $F(1, 72) = 5.41$, $p = .023$, $\eta_p^2 = .070$. A significant negative bivariate correlation indicated that as motivation increased, the number of lures tended to decrease ($r = -.269$, $p = .019$). There were no additional significant main effects or interactions to report for this analysis.
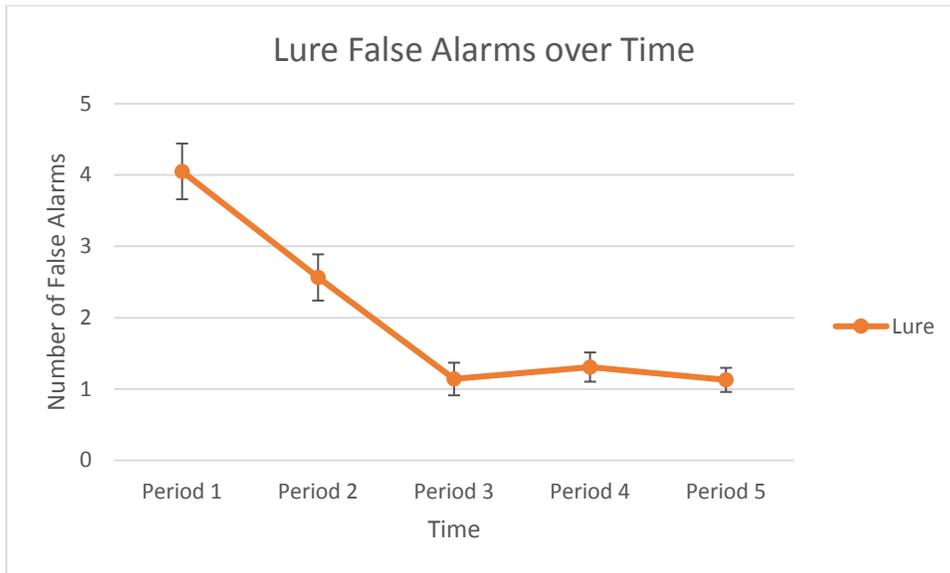
Figure 8. Lure false alarm performance over time by condition (note that error bars represent standard error around the mean).

The lure data were analyzed further to determine if specific lures were responded to more frequently than others. As depicted in Figures 9 and 10, this seems to be the case. For example, nearly half (i.e., 51.28%) of the observers in the lure condition responded to "ant" as a lure false alarm, 76.92% responded to "chicken" as a lure false alarm, 61.54% responded to "duck" as a lure false alarm, 51.28% responded to "flamingo" as a lure false alarm, and 35.90% responded to "turkey" as a lure false alarm. Compared to previous studies (Neigel, Claypoole, Hancock, Fraulini, & Szalma, forthcoming), observers continued to have problems withholding response to commonly known bird stimuli.
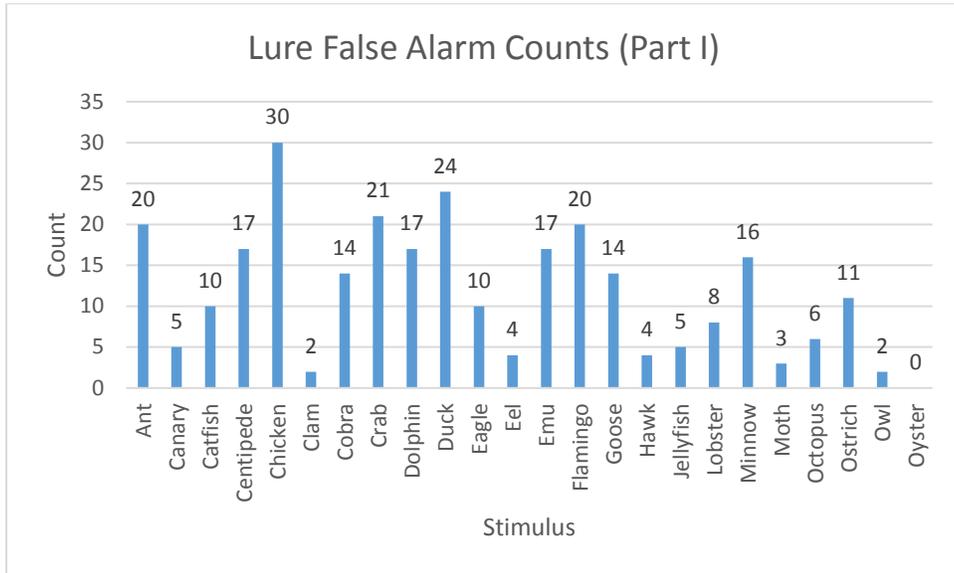
Figure 9. Number of lure false alarms to specific stimuli for the first half of lures (listed alphabetically).
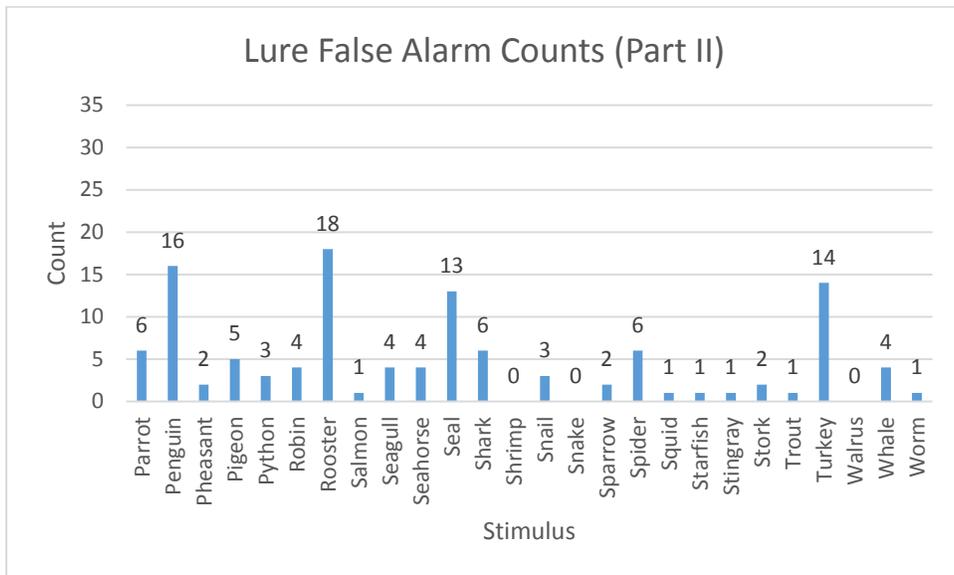

Figure 10. Number of lure false alarms to specific stimuli for the second half of lures (listed alphabetically).

Response Time

Response time is plotted as a function of period on watch and the experimental condition in Figure 11. Following a mixed-measures factorial ANCOVA, there were no significant main effects of interactions to report for this analysis.
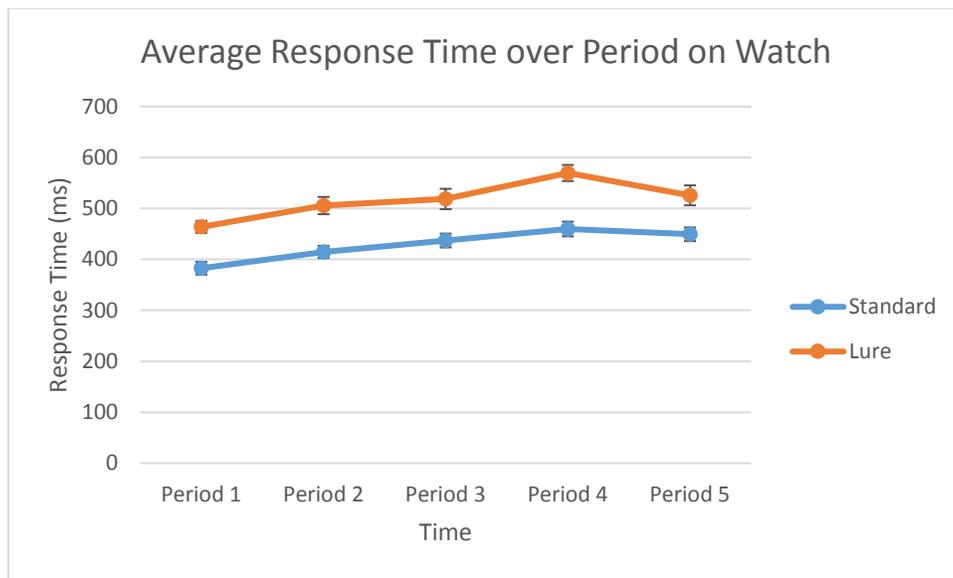
Figure 11. Average response time over time by condition (note that error bars represent standard error around the mean).

Sensitivity

Both *A'* and *d'* (which is calculated using parametric test assumptions; Macmillan & Creelman; Green & Swets, 1966) were used to calculate sensitivity. Separate mixed-measures factorial ANCOVAs, were conducted for *A'* and *d'*.

Following a mixed-measures ANCOVA performed for *d'*, the results indicated a significant main effect of condition, $F(1, 72) = 6.26$, $p = .015$, $\eta_p^2 = .080$. Pairwise comparisons indicated that overall sensitivity for the standard condition ($M = 3.82$, $SE = .078$) was

significantly higher ($p < .001$) than overall sensitivity for the lure condition ($M = 3.25$, $SE = .077$).

There was also a significant main effect of IMI on sensitivity, $F(1, 72) = 13.02$, $p = .001$, $\eta_p^2 = .153$. Motivation was significantly correlated with sensitivity using d' in Period One ($r = .336$, $p = .003$), Period Two ($r = .284$, $p = .013$), Period Three ($r = .332$, $p = .003$), and Period Four ($r = .408$, $p < .001$), but not Period Five ($r = .209$, $p = .070$). These results indicate that as motivation increased, sensitivity increased.

There were no additional significant main effects or interactions to report for these analyses. Sensitivity over time using d' as a function of period on watch and the experimental condition is shown in Figure 12.
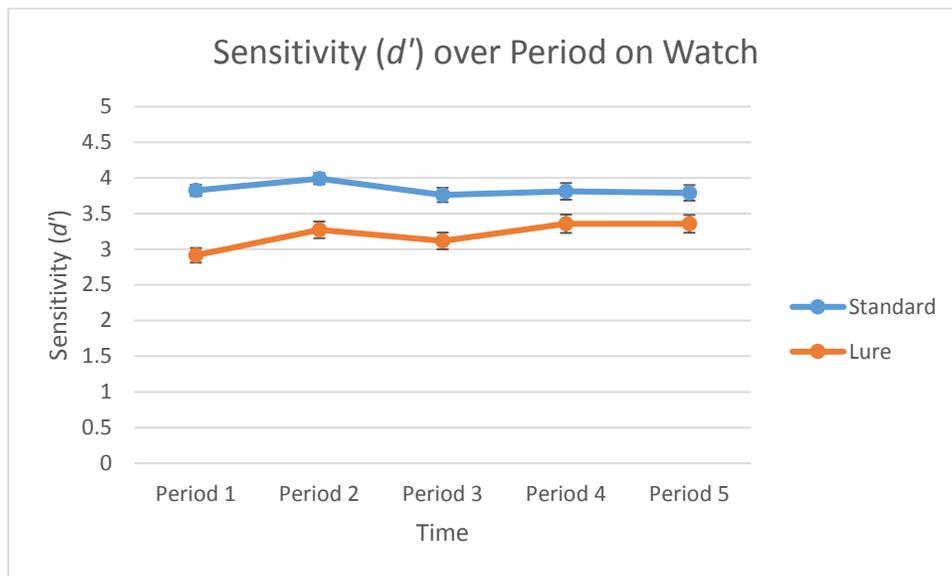

Figure 12. Sensitivity using d' over time by condition and controlling for motivation (note that error bars represent standard error around the mean).

Following a mixed-measures ANCOVA performed for *A'*, the results indicated a significant main effect of IMI on sensitivity, $F(1, 72) = 5.99$, $p = .017$, $\eta_p^2 = .077$. Motivation was significantly correlated with sensitivity using *A'* in Period One ($r = .301$, $p = .008$), Period Three ($r = .253$, $p = .028$), and Period Four ($r = .329$, $p = .004$), but not Period Two ($r = .175$, $p = .130$) or Period Five ($r = .149$, $p = .200$). These results indicate that as motivation increased, sensitivity increased.

There was also a trending main effect of condition, $F(1, 72) = 3.01$, $p = .087$, $\eta_p^2 = .040$. Pairwise comparisons indicated that overall sensitivity for the standard condition (*M* = .969, *SE* = .006) was significantly higher (*p* = .032) than overall sensitivity for the lure condition (*M* = .952, *SE* = .005).

There were no additional significant main effects or interactions to report for these analyses. Sensitivity over time using *A'* as a function of period on watch and the experimental condition is shown in Figure 13.
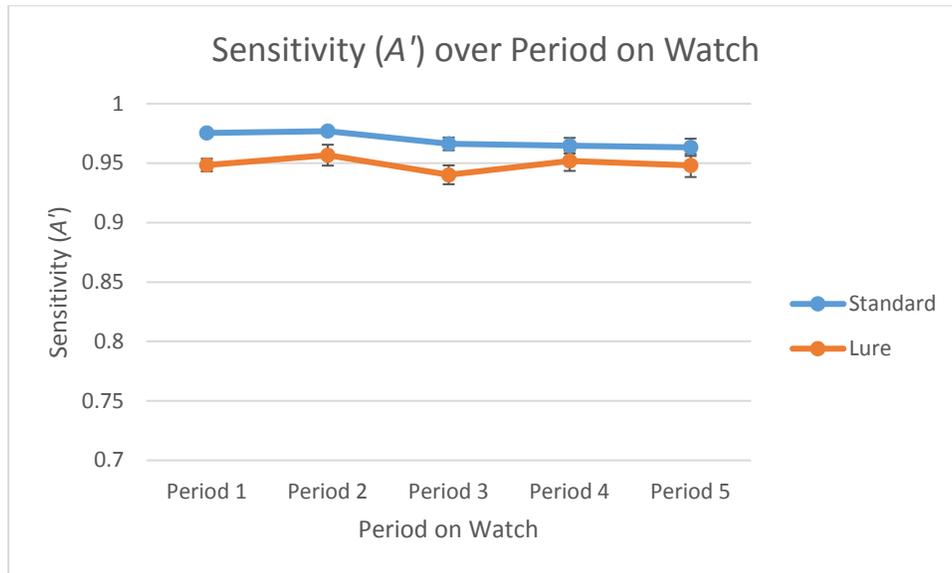
Figure 13. Sensitivity using *A'* over time by condition (note that error bars represent standard error around the mean).

Response Bias

Both B_D'' and *c* (which is calculated using parametric test assumptions; Macmillan & Creelman; Green & Swets, 1966) were used to calculate response bias. Separate mixed factorial ANCOVAs, were conducted for B_D'' and *c*.

A mixed ANCOVA performed for *c*, indicated a significant main effect of time on response bias, $F(1, 72) = 2.88$, $p = .027$, $\eta_p^2 = .027$, Huynh-Feldt $\varepsilon = .921$. Bonferroni-corrected pairwise comparisons indicated that response bias was significantly different between Period One compared to Periods Two – Five ($p < .001$), Period Two compared to Periods Three – Five ($p < .001$), and Period Three compared to Periods One and Two ($p < .001$).

There were no additional significant main effects or interactions to report for these analyses. Response bias over time (using *c*) is plotted as a function of period on watch and the experimental condition in Figure 14.

Figure 14. Response bias using *c* over time by condition (note that error bars represent standard error around the mean).

Following a mixed-measures ANCOVA performed for B_D", there were no significant main effects of interactions to report for this analysis. Response bias over time using B_D" is included in Figure 15.

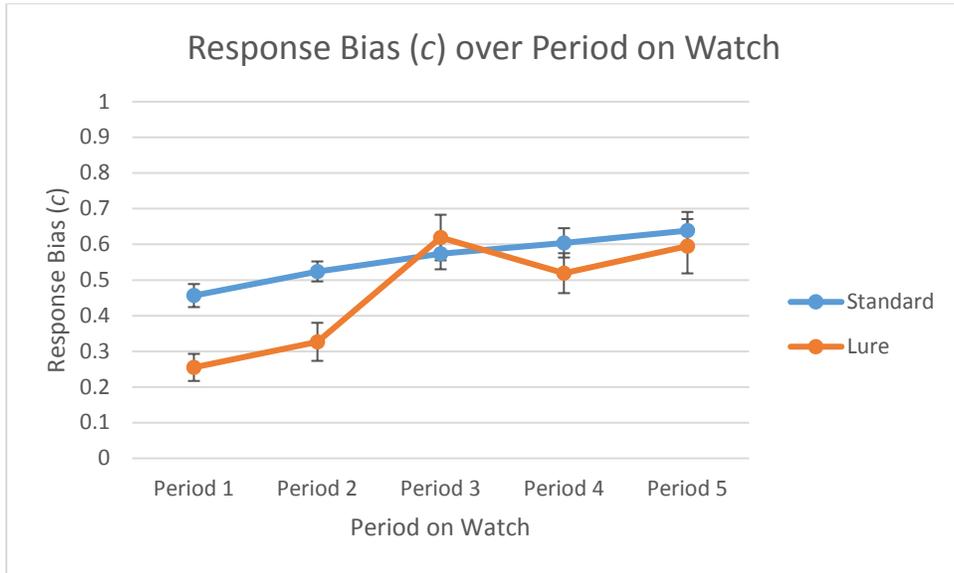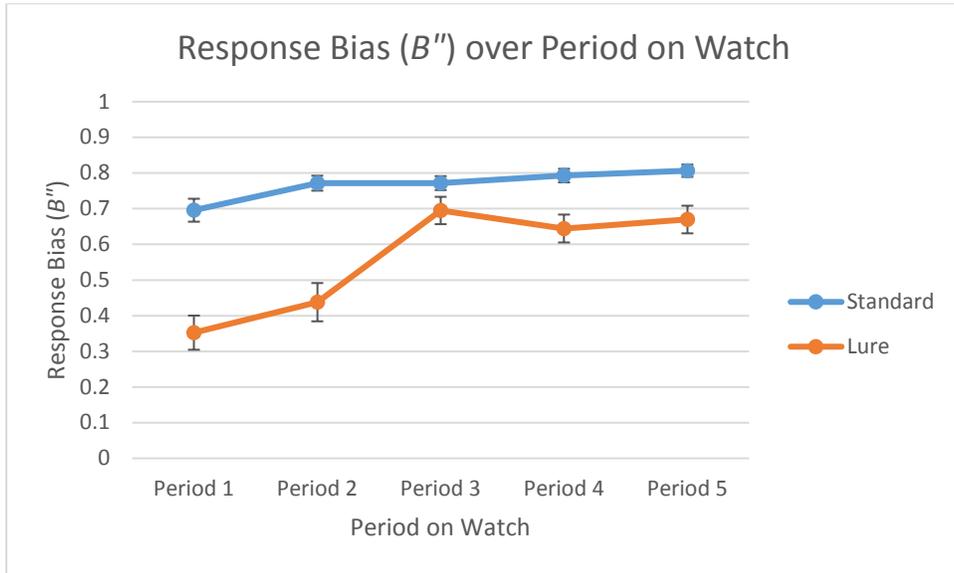*Figure 15.* Response bias using B_D'' over time by condition (note that error bars represent standard error around the mean).

Discussion

Stress and Workload Analyses

Intrinsic motivation had a significant positive relationship on both pre- and post-task engagement. This is expected because task engagement should be related to intrinsic motivation, or how intrinsically motivated an observer is to perform the vigilance task, which involves engagement. This finding is important because this indicates that intrinsic motivation influenced task engagement for observers, but was not systematically different between conditions.

Intrinsic motivation also affected pre- and post-task distress. In the lure condition, observers are significantly more distressed after the task than observers assigned to the standard task. This is likely due to the presence of lures, which could be taxing on cognitive resources for information processing. Interestingly, intrinsic motivation did not have an effect on worry scores. However, changes in worry are not typically observed in vigilance tasks (Matthews et al., 2013).

Motivation and task condition did not affect global workload. The only difference that emerged between tasks was on the frustration subscale of the NASA-TLX. Consistent with the post-task distress results, observers in the lure condition indicated significantly more frustration than observers in the standard task. Again, it is likely the lure stimuli contributing to this difference. This task is likely perceived as more frustrating because observers must make fine-grained distinctions between non-four-legged animals and four-legged animals, which requires more information processing and introduces multiple decision-making criteria.

Vigilance Performance Analyses

There was a trending main effect of intrinsic motivation on the proportions of correct detections, which indicated that as motivation increased, the total proportion of hits increased.

But, both the standard and lure tasks also demonstrated a performance decrement over time. There was also a trending main effect of period on watch on proportion of correct detections, which indicated that correct detections decreased over time for both conditions. But, it is possible that with a different statistical technique, such as regression, clearer performance trends over time may emerge. It is also possible that the length of time spent performing the vigil could influence these results. For example, vigilance tasks tend to be longer in length (i.e., over 30 minutes) compared to the present vigil (12 minutes total in length), and clearer differences due to intrinsic motivation may emerge in longer vigilance tasks.

Interestingly, intrinsic motivation had an effect on lure false alarms, but not distracter false alarms. Distracter false alarms were impacted by condition, with observers in the standard condition committing more of these false alarm types than those in the lure condition. A significant negative bivariate correlation indicated that as intrinsic motivation increased, the number of lures tended to decrease. Similarly, fewer lure false alarms were committed in the lure false alarm group over time. This may reflect a learning effect and it is possible that intrinsic motivation is important in learning to inhibit response to the lure stimuli over time; or it could be that intrinsic motivation is important in allocating mere effect to processing lure stimuli and subsequently results in improved response inhibition.

Motivation, period on watch, and condition did not affect the average response times of observers. However, observers in the lure condition demonstrated slower response times than observers in the standard condition. The trends in response time mirror the findings related to the number of false alarms committed. For example, response time increased after Period One for both groups, indicating that observers took slightly longer to process words before responding,

which also mirrors the shift in more conservative responding. Clearly, the presence of lure stimuli also requires more information processing and results in slower response times. However, it is interesting that this difference is not significant.

Sensitivity and Response Bias Analyses

The standard condition demonstrated greater perceptual sensitivity to the stimuli than the lure condition. Importantly, sensitivity, but not response bias, was affected by intrinsic motivation. As intrinsic motivation increased over period on watch, sensitivity increased. Both indices of sensitivity demonstrated an increase in perceptual sensitivity to the stimuli over time.

Both indices of response bias and both conditions demonstrated a conservative shift in responding over time. The lure group was slower in its shift toward conservatism. Interestingly, conservative or liberal responding was not affected by intrinsic motivation.

Limitations and Future Directions

In this study, a small student sample size was used. Student samples have been previously criticized for being homogenous and not necessarily reflective of the larger population. This small sample size may also be the reason for finding trending main effects and interactions.

Additionally, observers in this study did receive an external motivator, which included course credit or extra credit. This is a limitation because extrinsic motivators can have an undermining effect on intrinsic motivation and it makes it difficult to disentangle how this type of motivator influences individual differences in intrinsic motivation in the present task.

Another limitation is the length of the vigil (i.e., 12 minutes). Many vigilance tasks are longer than this and time could significantly interact with intrinsic motivation to perform the task. But, previous studies have demonstrated a vigilance decrement using a task that was similar in length. It will be important for future studies to examine the effects of motivation in long duration vigilance tasks.

Theoretical Implications

First, this thesis demonstrates how motivation may influence vigilance performance. This has implications for current theories of vigilance. This research demonstrates how motivation could potentially offset the decrement (although there was an overall decrease in performance, motivation was positively correlated with increased correct detection performance over time). For example, this research indicates that intrinsic motivation to perform the vigilance task may influence resource expenditure (i.e., self-regulation toward lure stimuli). Self-regulation would imply that the observer acknowledges control over their actions and the resulting consequences, or that individuals are inherently motivated to regulate activities that are important, but not interesting (Deci, Eghrari, Patrick, & Leone, 1994). The previously described results provide support for the SD-T interpretation of intrinsic motivation and its involvement in performing boring, but important, tasks.

Second, this research demonstrated for support for resource theory, but not mind-wandering theory, which is another theory of information processing that seeks to explain the vigilance decrement. Mind-wandering theory cannot appropriately account for the increase in frustration and distress associated with this task. If observers are mind-wandering during the task, then such high workload and stress scores should not be reported. However, it is possible that the workload and stress associated with this task is related to the increased self-regulation in the lure condition.

Practical Implications

The results of the present study indicate that individual differences play a role in vigilance performance. This research could be extended into considering human factors design implications that augment intrinsic motivation, especially in workplaces that are plagued by monotony. While practitioners may omit the consideration of motivational design factors, important individual differences in intrinsic motivation are also omitted as well (Hancock, 2017; Szalma, 2014). Therefore, it is suggested that not only design considerations be discussed in workplace or task redesign, but individual differences that may increase the effectiveness of motivational design.

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