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Examining Energetic and Structural Components of Knowledge of Result Using a Vigilance Paradigm

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EXAMINING ENERGETIC AND STRUCTURAL COMPONENTS OF KNOWLEDGE OF RESULT USING A VIGILANCE PARADIGM

by

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ABSTRACT

Vigilance, or the ability to maintain attention to stimuli over a prolonged period of time (Davies & Parasuraman, 1982; Warm & Jerison, 1984), has been a troublesome research topic since World War II. Scientists have sought to counteract performance declines in vigilance tasks by training observers on these tasks. Though an extensive literature has been developed to examine the effectiveness of these techniques, the mechanisms by which many forms of vigilance training help performance are largely unknown. The present dissertation seeks to further the understanding of how two forms of training for vigilance, practice and knowledge of result, function to improve observers' ability to remain vigilant as time on task increases. In addition to understanding these forms of training, this dissertation seeks to develop a training protocol that would train observers for vigilance without adversely affecting their cognitive resources. Finally, this dissertation utilizes this new training protocol to examine the potential for transfer of training, which has been a question for vigilance researchers for decades. Results relating to these three research questions are presented, as well as a discussion of how these results may inform or influence vigilance research in the future.

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CHAPTER ONE: INTRODUCTION

Vigilance refers to the ability of an observer to maintain attention and remain alert to stimuli over a sustained period of time (Davies & Parasuraman, 1982; Warm & Jerison, 1984). Vigilance research stretches as far back as World War II, when the British Royal Air Force utilized early methods of radar detection to protect convoy ships from incoming enemy U-boats (Warm, 1984; Warm & Dember, 1998). Mackworth (1948) began the systematic study of vigilance using his famous Clock Test. Mackworth found a distinct decline in performance as time progressed, a discovery that would be shown repeatedly in the decades to follow. This decline in performance over time, later called the *vigilance decrement*, would become the focus of vigilance researchers in the years to come. Vigilance research has been carried out in a variety of contexts, ranging from basic laboratory tasks to studies in operational environments. Importantly, research conducted in applied settings represents a link to real-world issues concerning vigilance, including air traffic control, baggage screening, and automation (Drury, 2015; Hancock & Hart, 2002; Hitchcock, Dember, Warm, Moroney, & See, 1999, Hitchcock et al., 2003; Molloy & Parasuraman, 1996; Parasuraman, Molloy, & Singh, 1993).

Mental Workload and Stress

The vigilance decrement has not only been used to describe a decline in measures of performance over time. Furthermore, researchers are concerned with how vigilance tasks induce effects on observers' mental workload and stress as time on task increases. Performance on vigilance tasks tends to decline as subjective levels of mental workload and stress rise (Dember, Warm, Nelson, Simons, Hancock, & Gluckman, 1993; Szalma et al., 2004; Warm, Parasuraman,

& Matthews, 2008). Mitigating mental workload and stress is a common concern for researchers in many performance contexts, vigilance research included. An issue with examining these concepts empirically, though, is their ambiguity. Mental workload is not necessarily directly observable; although we can infer its rise and fall based on performance measures, these linkages are not directly tapping subjective and physiological states (Matthews, Reinerman-Jones, Barber, & Abich, 2015). Definitions of mental workload used by vigilance researchers generally focus on the expenditure of information processing during task performance (O'Donnell & Eggemeier, 1986; Warm et al., 2008). The predominant method of measuring subjective mental workload in human factors research has been via the NASA – Task Load Index (NASA-TLX; Hart and Staveland, 1988; Warm, Dember, & Hancock, 1996). The NASA-TLX is comprised of six scales: Mental Demand; Physical Demand; Temporal Demand; Performance; Effort; and Frustration. Furthermore, fifteen pairwise comparisons are administered following the six scales and combined to produce a global workload score for the respondent. Vigilance tasks have been shown to be highly demanding as measured by the NASA-TLX, with the scales for Mental Demand and Frustration typically the strongest contributors to workload (Warm et al., 1996; Warm et al., 2008).

The concept of stress is also critical to understanding how observers perform on tasks. Many early theories of stress placed heavy emphasis on external factors and the human response to them (Hockey & Hamilton, 1983; Selye, 1976), while other conceptions of stress focused more on internal adaptability to the environment (Hancock & Warm, 1989). Lazarus' (1991) transactional model reframed stress in terms of a human-environment interaction (see Matthews, 2001). Stress now concerned the characteristics of the tasks, human performance on the task, human appraisals of performance, and human coping mechanisms during the task. Matthews et al. (1999) utilized transactional theory when developing the Dundee Stress State Questionnaire (DSSQ), a subjective measure of stress. The DSSQ identifies eleven primary factors related to stress, which constitute three secondary factors: task engagement, distress, and worry. The DSSQ has been used to measure stress in numerous studies examining vigilance (Warm et al., 2008). Vigilance tasks have been shown to elicit reductions in task engagement and increases in distress as time on task increases (Szalma et al., 2004; Warm, Matthews, & Finomore, 2008).

Knowledge of Results (KR)

To counter the negative effects of vigilance , many researchers have investigated the utility of training individuals on monitoring tasks. A popular training method has been to provide feedback regarding performance in the form of knowledge of results (KR; Baker, 1959a). There are a variety of ways in which KR can be implemented in a task, including full KR for responses (hits and false alarms) and failures to respond (misses; Becker, Warm, Dember, & Hancock, 1995; Szalma, Hancock, Dember, & Warm, 2006), providing different types of KR (hit, miss, or false alarm, or a combination of these; Chinn & Alluisi, 1964; Dittmar, Warm, & Dember, 1985), and manipulating types of training (Becker et al., 1994; Szalma, Miller, Hitchcock, Warm, & Dember, 1999; Teo, Schmidt, Szalma, Hancock, & Hancock, 2012).

Kluger and DeNisi (1996) offer insights into the benefits provided by KR in their Feedback Intervention Theory (FIT), which is a general theory of feedback effectiveness applicable to a wide variey of tasks. The authors argue feedback improves performance when it focuses attention on *task-learning processes*, or processes involved with developing knowledge and skills related to the task. Performance can also be improved if feedback directs attention to *task-motivational processes*, which are conceptualized as observers' goal-setting behaviors and energetic capabilities. Thus, Kluger and DeNisi (1996) argue that feedback effectiveness results from learning and motivation processes. The current dissertation separates as structural and energetic. Learning can be structural, which involves acquiring knowledge about discriminations required throughout the task. Structural improvements relate to FIT's notion of task-learning processes, which the current dissertation links to characteristics of the presented stimuli. Learning also may occur at the energetic level, focusing instead on observers' coping mechanisms, goal setting, and motivation. Energetic improvements associated with KR training would be would be associated with FIT's task-motivational processes.

Purpose

Despite substantial research on training with KR, there is still a question of whether KR benefits are attributable to improvements in task learning, improvements in motivation and coping (task-motivation processes), or some combination of the two (Salmoni, Schmidt, & Walter, 1984). The primary purpose of this study is to systematically examine KR training to better understand how KR improves performance in vigilance tasks. The following set of studies seeks to answer whether KR helps observers are learning to distinguish signals from non-signals, or whether KR provides information that facilitates adaptation to task demands and more efficient allocation of resources. In the current dissertation, I administered training using several tasks to prepare observers for the final vigil. Vigilance performance was evaluated by analyzing signal detection measures of sensitivity and response bias (Green & Swets, 1966). Additionally, perceived mental workload and stress was measured using the NASA-TLX and short-form DSSQ, respectively (Hart & Staveland, 1988; Matthews, Emo, & Funke, 2005).

Possible Findings

Study 1

Study 1 attempted to distinguish between learning components involved in KR training for vigilance. Study 1 utilized an adapted Solomon four-groups design to examine this difference between possible structural and energetic benefits of KR training. To train observers for signal discrimination and task pacing, I manipulated pre-vigil training. I used a two alternative forced choice (2-AFC) task, in which observers were presented with two stimuli presented successively (one signal and one non-signal) on each trial, and were asked to identify whether the critical signal was presented first or second. Additionally, observers receiving pre-vigil training completed a brief series of practice trials similar in nature but shorter in duration relative to the full vigil. This provided observers experience with the pace of the task, as well as general information about how often signals appear compared to non-signals.

To examine energetic benefits of KR training, Study 1 included a training vigil containing KR feedback. This vigil was significantly longer in duration than the 2AFC task and practice trials combined, and provided observers the opportunity to practice setting task-related goals and developing regulation strategies for maintaining attention to the display ahead of completing the transfer vigil. While these propositions may not appear related to the task at first glance, they may be critical to mitigating the effects that perceived mental workload and stress can have on those completing vigilance tasks.

Considering the multiple explanations for the benefits of KR training for vigilance, there were several possible patterns of results, each with its own theoretical explanation. Before explaining these possible patterns, there are assumptions regarding these independent variables that should be made clear. First, I did not expect the combination of these independent variables (i.e. pre-vigil training and KR during the training vigil) to be detrimental to observers in terms of either performance or subjective ratings of mental workload and stress. In general, adding more aspects of training for observers to use prior to completing the transfer vigil should have improved performance. Additionally, the event rate at which trials were presented to observers was held constant throughout, so as not to influence observers' subjective ratings of mental workload and stress. The event rate chosen has been utilized in a similar paradigm previously, and has been shown to elicit moderate mental workload scores from observers (Fraulini, Claypoole, Dewar, & Szalma, 2016; Szalma & Teo, 2012). These assumptions help to constrain the discussion of our findings and focus them on the variables manipulated in the coming studies.

With the previous assumptions in mind, we may now proceed with discussion of possible patterns of results. The following possible patterns relate only to performance measures, not necessarily mental workload and stress. Study 1 may have produced results that indicate a main effect for KR, such that both groups receiving KR feedback during their training vigils outperform observers who do not receive KR, but no effect for pre-vigil training. In this case, KR during training would have provided observers with task-related information other than the discrimination, which the pre-vigil training provides. The pre-vigil training, comprised of the 2AFC task and a number of practice trials, would not be providing information regarding signal discrimination and expectancy beyond the KR training vigil. Moreover, improved performance in the No-KR condition for observers receiving pre-vigil training would lead me to conclude the pre-vigil training provided structural knowledge for the vigilance task. In this scenario, we would have been able to conclude that KR provided observers with the knowledge energetic benefits required to pace and motivate one for vigilance tasks, which is separate from knowledge of signal vs. non-signal discrimination.

Another possible pattern of results for Study 1 performance was that which revealed a main effect for pre-vigil training only, such that all observers receiving pre-vigil training outperform all observers who did not receive pre-vigil training. In this case, the pre-vigil training would be providing information regarding the discrimination criteria between signals and non-signal required for the training and transfer vigils. With this pattern, KR effectiveness would be eliminated by the pre-vigil training, indicating that KR provides information regarding task structure, potentially the signal vs. non-signal discrimination, but that it does not provide training on the energetic aspects of the task. In other words, this pattern of results would indicate that KR only provides training for the discrimination and not for sustaining attention.

A third pattern of performance results possible in Study 1 would have been main effects for both pre-vigil training and KR, but no interaction between the two variables. This pattern would have manifested itself with observers receiving KR performing better than those not receiving KR, as well as with observers receiving pre-vigil training performing better than those not receiving pre-vigil training. This possible pattern of results would have demonstrated the separate benefits associated with the pre-vigil training (knowledge strictly relating to discrimination between signals and non-signals) and KR (knowledge pertaining to motivation and required coping mechanisms). These benefits would not have depended on each other to occur, however, as they would not be bringing increases or decreases to performance when combined or selectively removed. In other words, the benefits of pre-vigil training and the training vigil would be additive.

There also could have been the pattern in which an interaction emerged, such that KR improves performance on the transfer vigil, but adding pre-vigil training to KR maximizes performance effects relative to KR without pre-vigil training. If there are distinct benefits to performance provided by pre-vigil training and KR, then combining these procedures may yield better performance than either alone. This would manifest as a pre-vigil training by KR interaction in which KR improves performance, but the magnitude of the effect is lesser when pre-vigil training is also provided.

There could have been other interactive patterns of performance results, however, that differ from the additive or multiplicative effects detailed above. There also could have been the a pre-vigil training by KR interaction where observers receiving KR performed equally well regardless of whether they receive pre-vigil training, but those who receive pre-vigil training and no KR outperformed observers who did not receive pre-vigil training or KR during the training vigil. These results would have led me to conclude that while pre-vigil training may not add benefits beyond those provided by KR, it can still improve performance on vigilance tasks relative to receiving neither pre-vigil training nor KR. Additionally, this pattern would have demonstrated overlap in the type of knowledge conveyed to observers through these independent variables. If pre-vigil training and KR provided different information about the task, exposing observers to both variables conceivably would have an additive effect on performance.

Current Studies and Hypotheses

The current set of studies sought to answer the following question: Does KR training improve performance through learning to distinguish signals from non-signals, or are improvements based on individuals' acclimating to task parameters other than signal discrimination, such as event rate or knowledge of results? I proposed a sequence of three experiments with the hope of distinguishing these two explanations for KR effectiveness.

Study 1 utilized an adapted Solomon four-groups design in order to establish the benefit of training observers with signal discriminability training and a small number of practice trials. Independent variables in Study 1 included pre-vigil training (discriminability/practice trials vs. no pre-vigil training) and KR provided during a training vigil (KR vs. No KR). Observers began by completing the pre-task short-form DSSQ. Observers in the pre-vigil training condition then completed those tasks. Observers completing conditions devoid of pre-vigil training completed a card sorting task for the average period of time required to complete the pre-vigil training (5 minutes) before continuing. This was done in order to equate the conditions for time in the experiment. Observers then completed the training vigil, either with or without KR. Following the training vigil, all observers completed the post-task short-form DSSQ, as well as the NASA-TLX. Observers in all experimental conditions then completed a transfer vigil of the same task, but without KR. Finally, observers completed the post-task short-form DSSQ and the NASA-TLX. For Study 1, I outlined several hypotheses in terms of performance, stress, and mental workload based on the underlying mechanisms of the pre-vigil and KR training.

Study 1

Hypothesis 1

Observers receiving pre-vigil training will achieve higher levels of sensitivity during both training and transfer compared to those who do not receive pre-vigil training.

With regard to the training vigil, I believe the pre-vigil training will acclimate observers to the differences between signals and non-signals more quickly than those not receiving pre-vigil training. With regard to the transfer vigil, I expect this knowledge with respect to signal-noise discrimination to extend beyond the training vigil to the longer transfer vigil.

Hypothesis 2

Observers receiving KR during the training vigil will display a more conservative response criterion during both training and transfer compared to those who do not receive KR during the training vigil.

With regard to the training vigil, I believe the KR will acclimate observers to parameters such as signal rate and subjective feelings of motivation more quickly than those not receiving KR during the training vigil. While these factors are important to vigilance performance, they are extraneous to strict discrimination of signals and non-signals associated with sensitivity. With regard to the transfer vigil, I expect this knowledge with respect conservatism of responses to extend beyond the training vigil to the longer transfer vigil.

Hypothesis 3

Observers receiving pre-vigil training or KR will experience higher levels of self-reported task engagement and lower levels of self-reported distress post-training and post-transfer, as measured by the short-form DSSQ, than those who do not receive pre-vigil training or KR.

Hypothesis 4

Observers receiving pre-vigil training or KR will experience lower levels of global subjective mental workload post-training and post-transfer, as measured by the NASA-TLX, than those who do not receive pre-vigil training or KR.

In addition to the above hypothesis for global mental workload, I expect the Mental Demand and Frustration scales to be the dominant contributors to the predicted differences in global mental workload, in accordance with Warm and colleagues (1996).

Table 1. Study 1 Manipulations.

Group	**Discrimination Training**	**Practice**	**Vigilance Training**	**Transfer Vigil**
1) 2AFC/KR	2AFC NKR	Detection Task NKR	KR	NKR
2) 2AFC/NKR	2AFC NKR	Detection Task NKR	NKR	NKR
3) No 2AFC/KR	--	--	KR	NKR
4) No 2AFC/NKR	--	--	NKR	NKR

Study 2

Study 2 is designed to examine the necessity of pre-vigil training as an active process for the observer. This study examined the effects of a passive, or "exposure" type of pre-vigil training, with the objective of lowering mental workload and stress on observers. This manipulation for Study 2 involved exposing observers to the pre-vigil training, but not requiring them to respond to critical signals. All observers received pre-vigil training, but those in the exposure condition were told to pay attention for critical signals, but not actively respond to them. Observers in the pre-vigil condition requiring responses received the same pre-vigil training, but were required to respond to critical signals. All observers then completed a training vigil, either with or without KR, as in Study 1. They completed the post-task DSSQ and NASA-TLX following the training vigil, then moved on to complete the transfer vigil, again the same task but without KR. For this study, I developed the following set of hypotheses:

Hypothesis 1

Observers receiving KR during the training vigil will display a more conservative response criterion during both training and transfer compared to those who do not receive KR during the training vigil.

This hypothesis mirrors the prediction for KR for study 1. I predict KR will affect response criterion due to its ability to reveal information involving signal rate, as well as help observers deal with the monotony of the task through the use of motivational and coping strategies.

Hypothesis 2

Observers receiving exposure training or KR will experience higher levels of self-reported task engagement and lower levels of self-reported distress post-training and post-transfer, as measured by the short-form DSSQ, than those who do not receive pre-vigil training or KR.

Hypothesis 3

Observers receiving exposure or KR will experience lower levels of global subjective mental workload post-training and post-transfer, as measured by the NASA-TLX, than those who do not receive pre-vigil training or KR.

While I do not predict differences between the active and passive pre-vigil trainings in terms of sensitivity, I do believe there will be differences with respect to stress and mental workload. The exposure pre-vigil training should elicit lower ratings of stress and mental workload, as they do not require the observer to actively respond to stimuli prior to the training vigil.

Table 2. Study 2 Manipulations.

Group	**Signal Training**	**Signal Training**	**Vigilance Training**	**Transfer Vigil**
1) 2AFC/KR	2AFC NKR	Detection Task NKR	KR	NKR
2) 2AFC/NKR	2AFC NKR	Detection Task NKR	NKR	NKR
3) Exposure/KR	Exposure	Exposure	KR	NKR
4) Exposure/NKR	Exposure	Exposure	NKR	NKR

Study 3

Study 2 was expected to reveal that exposure training can bring about similar performance results as active vigilance training. After showing the efficacy of this training method for vigilance, Study 3 examined possible effects of exposure to pre-vigil training on transfer of training for vigilance. In Study 3, observers receives pre-vigil training exposure to one of two tasks, labeled as Tasks A and B. Tasks A and B were the same task type (i.e. they required cognitive discrimination of signals vs. non-signals.). Next, observers completed a training vigil of Task A, either with or without KR. Finally, all observers completed a transfer vigil of Task B. This study examined whether exposure to one task assists observers on a related task. Positive implications of this third study would be more efficient training methods, both in terms of time (rather than having to administer entire training vigils on a new task) and observers' cognitive resources. I developed the following set of hypotheses for Study 3:

Hypothesis 1

Sensitivity on the transfer task will be greater for observers receiving exposure training to Task B than observers receiving exposure to Task A.

Observers who complete exposure training with Task B will be familiar with the differences between signals and non-signals in the transfer task (also Task B) compared to those who complete exposure training with Task A.

Hypothesis 2

Observers receiving Task B exposure training will experience lower levels of global subjective mental workload post-transfer, as measured by the NASA-TLX, than those who receive Task A exposure training.

Hypothesis 3

Observers receiving Task B exposure training will experience higher levels of self-reported task engagement and lower levels of distress post-transfer, as measured by the short-form DSSQ, than those who receive Task A exposure training.

Exposure to Task B during the training process will have a positive effect on observers' perceptions of stress and mental workload compared to those who are first introduced to Task B in the transfer task.

Hypothesis 4

Observers receiving Task B exposure training will experience lower levels of global subjective mental workload post-training and post-transfer, as measured by the NASA-TLX, than those who receive Task A exposure training.

Hypothesis 5

Observers receiving KR training will experience lower levels of global subjective mental workload post-training and post-transfer, as measured by the NASA-TLX, than those who do not receive KR training.

Hypothesis 6

Observers receiving KR training will experience higher levels of self-reported task engagement and lower levels of distress post-training and post-transfer, as measured by the short-form DSSQ, than those who do not receive KR training.

Table 3. Study 3 Manipulations.

Group	Exposure	Vigilance Training	Transfer Vigil
1) Exposure A/KR	Exposure to Digit Task	Digit Task KR	Lexical Task NKR
2) Exposure A/NKR	Exposure to Digit Task	Digit Task NKR	Lexical Task NKR
3) Exposure B/KR	Exposure to Lexical Task	Digit Task KR	Lexical Task NKR
4) Exposure B/NKR	Exposure to Lexical Task	Digit Task NKR	Lexical Task NKR

CHAPTER TWO: LITERATURE REVIEW

Vigilance is the ability to maintain attention to stimuli over a long period of time (Davies & Parasuraman, 1982; Warm & Jerison, 1984). The vigilance decrement, the robust finding of performance declines in vigilance tasks (often within fifteen minutes), is a major cause for concern among vigilance researchers. Aside from performance costs, vigilance tasks have been shown to elicit higher levels of mental workload and stress among observers (Warm et al., 2008a; Warm et al., 2008b). These findings have implications beyond the laboratory, as many occupations require the ability to monitor displays for long periods of time (Karimi, Eder, Eskandari, Zou, Hedner, & Grote, 2013; Jorm & O'Sullivan, 2012). This study seeks to achieve greater understanding of a key component of a traditional vigilance training method, knowledge of result (KR). There are two key research questions for the present studies. First, these studies examined whether observers are learning to distinguish signals from non-signals, or if they are learning to adapt to other task demands and to allocate attentional resources more efficiently. Addressing this question will facilitate the development of more efficient methods of improving performance. Second, on a more applied level, these studies investigated if there are ways to improve the process of training for vigilance so observers can achieve and maintain acceptable levels of performance. The three studies presented in this work systematically explored these two questions.

Before outlining the three studies, it is necessary to review the existing literature. The review will begin by taking an in-depth look at the history of vigilance research, including early theories regarding observer expectancies and arousal. This will segue into a discussion on information processing and resource depletion models that reflect modern views of vigilance performance. This will include further presentation and explanation of the Parasuraman and Davies (1977) vigilance taxonomy, a development that helped to organize and direct vigilance research within a common predictive framework. Following presentation of past vigilance literature will be a description of mental workload and stress and their importance in vigilance. These subjective states will provide a more complete picture of the effects these tasks can impose on observers. Finally, previous research on KR and how it has been used in training for vigilance will be reviewed.

Vigilance: A Brief History

Researchers in the 1940s were prompted to study long-duration monitoring tasks in the context of the Second World War. The British Royal Air Force, faced with mounting losses courtesy of Axis U-boats, desperately needed to improve detection of enemy vessels (Hancock, 2013; Warm, 1984). As a result, Norman Mackworth was commissioned to study the issue and suggest potential solutions. These studies involved the famous "Clock Test," in which observers were tasked with responding when the hand on a clock made a jump twice as large as the typical jump. Mackworth (1948; 1950) found a consistent decline in performance after approximately one half hour on watch. Mackworth (1948) also noted that observers tended to miss signals when they occurred in a close time period following a previous signal. He provided several explanations for these findings, including extinction for the conditioned response (the signal), as well as increased inhibition when observers were provided a response prompt (Mackworth, 1948). Mackworth (1950) also provides suggestions for improving performance, advocating for shorter shifts in real-world settings.

Expectancy Theory

Early vigilance researchers sought to develop mechanisms to explain the vigilance decrement. Many researchers during this time focused their efforts on evaluating expectancy theory. Expectancy theory stated observers' expectancies for the present task are set by his or her previous experience with the task, notably signal frequency (Deese, 1955). Based on these expectancies, observers dynamically shift their predictions for target appearance based on how the task has progressed to that point. Baker (1958; 1959a; 1959b) later expanded on Deese's expectancy theory by outlining several key components that could affect observers' expectancies. The components included: average signal rate; regularity of the inter-signal interval; knowledge of result; knowledge of signal location; and signal intensity. Although their research provided an explanation for observers' perspective of vigilance tasks, the expectancy theory proposed by Deese and Baker does not provide a clear mechanism for the decline in perceptual sensitivity. However, expectancy theory can explain criterion setting, such that the expectancies regarding signal frequency determines the degree of conservatism in responding (Frankmann & Adams, 1962). Other theories of the time, including Scott's (1957) sensory habituation theory, focused on describing the underlying behavioral mechanisms that may bring about the vigilance decrement, but ultimately could not be used to predict performance on such tasks.

Resource Theory

Another consideration for vigilance researchers was mental capacity prolonged monitoring tasks. Resource theory states that humans possess a limited capacity for information processing. As a task becomes more difficult, or a second task is introduced, our capacity for information processing decreases, bringing about decreased levels of performance, as well as other subjective consequences. Moray (1967) introduced the comparison of this mental capacity to a computer, a device which is inherently limited in its information processing capabilities. The mechanism by which resources are depleted over time has been the cause of much debate. Originally considered a singular pool of mental capacity that could be distributed to task or tasks at hand (Kahneman, 1973), theorists soon began to deviate from this singular concept of resources. Navon and Gopher (1979) proposed that, although the system is comprised of one resource, it holds distinct capacities that can be allocated separately depending on the information processing demands of the task. This provides a distinct model from the "single pool" concept of resources that could explain differential effects on performance depending on the type or types of tasks employed (Humphreys & Revelle, 1984; Pachella, 1974).

Previous models adhering to a single pool of resources detailed a sort of bottleneck that would occur when multiple tasks requiring high levels of information processing were presented simultaneously, similar to the attentional bottleneck proposed by Broadbent (1957). An answer to this conundrum was presented by Wickens (1984; 2002) in the form of multiple resource theory. Figure 1 displays the four dimensions through which resources are taxed in Wickens' (2002) model. The basic tenet of multiple resource theory is that as the overlap between resources required to complete a task or tasks grows, the faster conflict for available resources grows and the quicker performance declines.

Vigilance researchers have utilized resource theory to explain typical decrements in performance. Warm et al. (1996) link the vigilance decrement to the cognitively-demanding nature of vigilance tasks, where a decline in performance represents the depletion of cognitive resources. More recent efforts in the field of vigilance have focused on linking resource depletion and the vigilance decrement through physiological indices. Warm and Parasurman (2007) showed a connection between declines in vigilance performance and declines in cerebral blood flow velocity (CBFV). Similar results have been found in other studies utilizing CBFV with vigilance tasks (Funke et al., 2010; Shaw, Finomore, Warm, Matthews, 2012; Warm, Matthews, Parasuraman, 2009). Despite these advances in these physiological indices of gauging vigilance performance, there remain issues with their use due to the highly-variable nature of brain activity, as well as relatively-high cost (Helton et al., 2007; Parasuraman, Warm, & See, 1998).

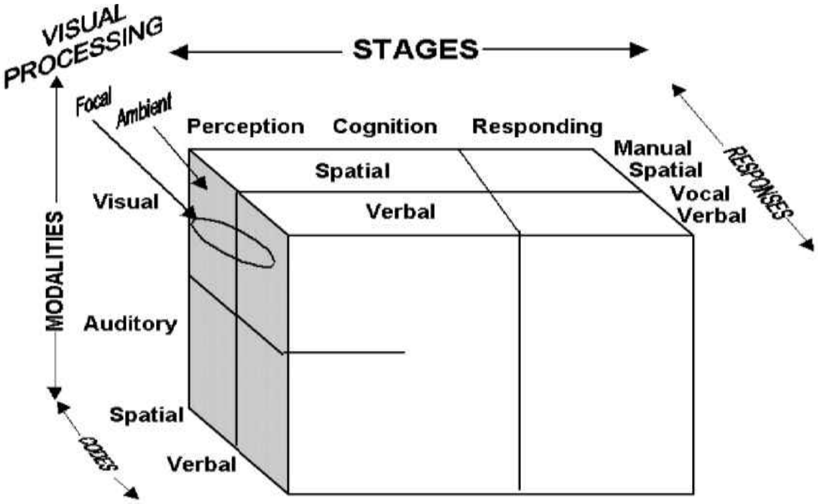


Figure 1. Wickens' Multiple Resource model.

Mindlessness Theory of Vigilance

In recent years, researchers have proposed a competing theory of sustained attention to explain performance decrements over time. The mindlessness theory of vigilance argues that performance declines as a result of observers' inability to maintain attention, as opposed to a conscious decision either to commit or withhold a response (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). This concept is contrasted with the resource depletion model discussed previously. Robertson and colleagues (1997) used the Sustained Attention to Response Task (SART) to create a novel vigilance paradigm in which observers were required to respond to frequent non-signals while withholding responses for critical signals. The SART employed by Robertson et al. (1997) utilized a high event rate of approximately 52 events-per-minute, though the duration of the vigil itself was less than five minutes.

According to mindlessness theorists, repeated responding to non-signals causes observers to lose focus on the purpose of the task and focus on task unrelated thoughts (TUTs) that can occur when observers do not fully utilize their cognitive capacity and the excess capacity is used for processing internal information irrelevant to the task (Giambra, 1995). This shift toward TUTs can result from either attentional shifts toward the TUTs, or attentional shifts away from the present task. In either case, TUTs are assumed to be more compelling than the current task (Antrobus, Singer, Goldstein, & Fortgang, 1970).

Sustained attention researchers in support of the resource depletion model of vigilance have challenged mindlessness theory. Many studies have shown that vigilance tasks using a myriad of formats impose a high degree of mental workload and stress upon observers (Hitchcock et al., 2003; Galinsky, Rosa, Warm, & Dember, 1993; Grier et al. 2003; Szalma et al., 2004; Szalma et al., 2006; Warm et al., 2008). Recently, researchers have shown greater performance decrements when multiple sources of cognitive demand are imposed on observers

(Head & Helton, 2014; Helton & Russell, 2011). The usefulness of the SART as an adequate paradigm for measuring vigilance performance also has been questioned (Dillard et al., 2014; Helton, Weil, Middlemiss, & Sawers, 2010). Clearly, there is ambiguity in the field of sustained attention regarding the source, as well as the underlying mechanisms, of the vigilance decrement.

Vigilance Taxonomy

The critical issue with early vigilance research was the lack of a taxonomic framework under which research should be conducted (Jerison, 1970; Scerbo, 1998; Warm & Dember, 1998). There was the elemental finding that performance declined as time on task increased; however, the great range of tasks employed by researchers made it difficult to grasp theoretical underpinnings of the vigilance decrement, especially since correlations of performance across task types were generally low. An answer to this problem emerged when Parasuraman and Davies (1977) developed the vigilance taxonomy. The two authors sought to unify vigilance research by compiling a set of characteristics that had been shown, to that point, to moderate vigilance performance.

Parasuraman and Davies identify four dimensions that have been shown to affect performance on vigilance tasks: event rate (fast or slow); task discrimination type (simultaneous or successive); sensory modality (auditory or visual); and source complexity (single or multiple sources). A visual description of the taxonomy can be found in Figure 2. Perhaps the most important dimensions of the Parasuraman and Davies taxonomy are task discrimination type and event rate. Discrimination type may be divided into those requiring either simultaneous or successive judgments. Simultaneous tasks require observers to make comparative judgments of stimulus elements in the display. Successive tasks, on the other hand, require observers to make judgments on stimuli relative to a representation held in working memory (Parasuraman, 1979). Due to the demands on mental capacity caused by holding this representation in working memory, successive tasks are deemed more difficult than simultaneous tasks. Additionally, this effect has been shown to be additive in nature, such that adding successive tasks to a dual-task paradigm can cause decreases in overall performance (Gluckman, Dember, & Warm, 1988). Subsequent studies expanded on this premise by proposing links to multiple storage and cognitive processes in vigilance tasks involving working memory, much in line with Wickens' (2002) multiple resource theory (Caggiano & Parasuraman, 2004; Helton & Russell, 2013; Matthews, Warm, Shaw, & Finomore, 2014).

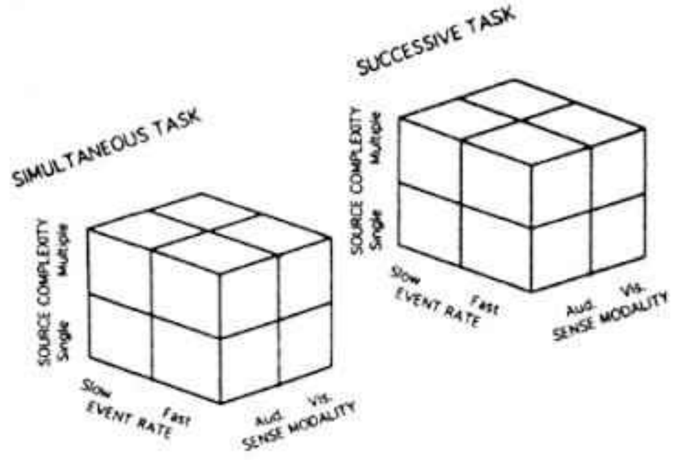


Figure 2. Parasuraman and Davies (1977) vigilance taxonomy, from Warm & Dember (1998).

Along with task discrimination type, event rate has been shown to greatly influence performance on vigilance tasks. Event rate is generally categorized as either low or high, with more than 24 events/minute categorized as high and fewer than 24 events/minute categorized as low. Performance on vigilance tasks is inversely related to event rate (Davies & Parasuraman, 1982; Warm & Jersison, 1984). In addition, higher event rates have been shown to have a greater effect in successive tasks rather than simultaneous tasks (Lanzetta, Dember, Warm, & Berch, 1987). More recent work, though, has shown this effect may be limited to tasks requiring detection of signal absence rather than presence (Hollander et al., 2004).

Koelega, Brinkman, Hendriks, and Verbaten (1989) proposed another dimension to the taxonomy: the distinction between cognitive and sensory tasks. The authors found a decrement in sensitivity in sensory tasks, but not in cognitive tasks, which they interpreted as relating to the familiarity of cognitive stimuli (letters and numbers). However, when See et al. (1995) investigated the cognitive/sensory distinction, they found a relationship with sensitivity for both cognitive and sensory tasks. Moreover, See and colleagues (1995), in their meta-analysis detailing the sensitivity decrement in vigilance, found the magnitude of the decrement to be positively related to event rate in cognitive tasks, yet negatively related to event rate in sensory tasks.

Signal Detection Theory

One of the primary methods of measuring performance on vigilance tasks is through use of signal detection theory (SDT). Signal detection theory seeks to model decision making in terms of responses to stimuli defined *a priori* as signals or non-signals (Green & Swets, 1966). The theory presents four possible response outcomes for observers. *Hits* (H) are defined as the observer indicating the presence of a signal and the signal is present in the environment. *False alarms* (FA) are defined as the observer indicating the presence of a signal and the signal is not present in the environment. *Misses* (M) are defined as the observer not indicating the presence of a signal, but a signal is present in the environment. Finally, *correct rejections* (CR) are defined as the observer not indicating the presence of a signal and the signal is not present in the environment.

SDT provides insights into the observers' ability to distinguish and choose between signals and non-signals. This can be done through measures of *sensitivity* and *response bias*. Sensitivity refers to observers' ability to detect critical signals amongst noise in the environment. A representation of these two concepts can be found in Figure 3. There are several statistics that can be used as measures of sensitivity, but most vigilance researchers use the parametric *d'* or the nonparametric *A'* (Green & Swets, 1966; Pollack & Norman, 1964). Sensitivity generally has been shown to decrease in vigilance tasks as time increases (See et al., 1995). Put differently, as time on task increases, observers' ability to distinguish signals from non-signals decreases.

Also critical to SDT analysis is the concept of response bias, typically measured as β, although several other indices exist (See, Warm, Dember, & Howe, 1997). Response bias can be thought of as observers' criterion for a response indicating a signal is present in the environment. Generally, observers' response bias ranges from *liberal* to *conservative*. Observers are deemed to have a liberal response bias if they are more likely to indicate the presence of a signal in the environment than the absence of a signal. Observers have a conservative response bias, though, if they are more likely to indicate the absence of a signal in the environment than the presence of a signal. Observers in vigilance tasks tend to become more conservative in their response bias over time (See et al., 1997), presumably because of increased awareness that critical signals for detection occur rarely (Craig, 1978).

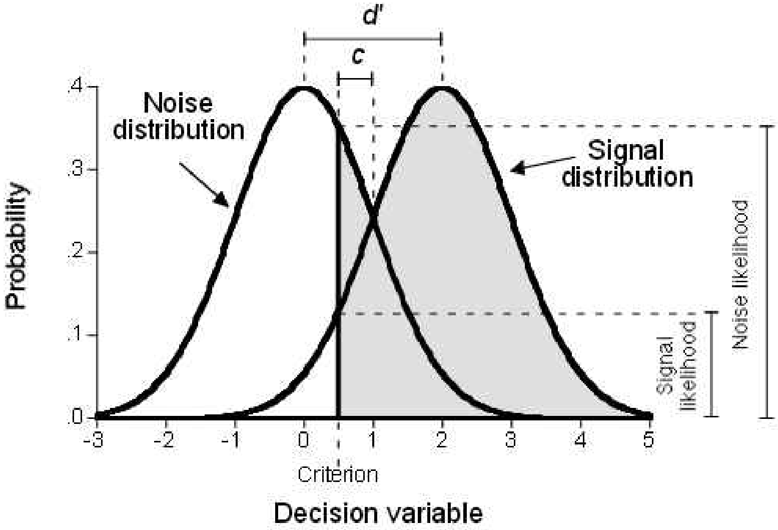


Figure 3. A visual representation of sensitivity (labeled *d'*) and response bias (labeled *c*) in the signal detection decision space. Taken from Stanislaw & Todorov (1999).

Mental Workload

Aside from performance outcomes that arise during vigilance tasks, there are also affective consequences of prolonged monitoring. One of these is perceived workload. Unfortunately for researchers, mental workload has been a difficult concept to clearly define. Modern descriptions of workload in vigilance revolve around the idea of depleting cognitive resources as time on task increases (Johnson & Proctor, 2004; Warm, 1984). Hart & Staveland (1988) posit mental workload is not a necessary byproduct of completing a task, but rather the result of a combination of factors, including the nature of the task, the environment, and the ability of the observer. In relation to the Parasuraman & Davies (1977) vigilance taxonomy, mental workload has been shown to directly related to event rate, and inversely related to signal salience (Dember et al.,1993; Galinsky, Dember, & Warm, 1989; Gluckman, Dember, Warm, Theimann, & Hancock, 1988). Overall, mental workload tends to be inversely related to performance in vigilance tasks (Warm et al., 2008), which would point toward a resource-depletion explanation for the vigilance decrement.

Mental workload can be operationalized in terms of performance, physiological responses, or self-report. O'Donnell and Eggemeier (1986) outline critical components of psychometric evaluation that should be considered when measuring mental workload. Two of these components, sensitivity and diagnosticity, relate to our current discussion. Sensitivity as O'Donnell and Eggemeier (1986) define it differs from our previous term relating to signal detection theory. Here, sensitivity refers to the ability of a measure to detect changes in perceived workload as a function of changes in task load. If a variable that is proposed to elicit an increase in mental workload (e.g. increase in event rate, decrease in signal salience) is manipulated by the researcher, a sensitive workload instrument should detect an increase in observers' perceived mental workload.

Given the theoretical basis of workload measured, i.e., that resources are multifaceted in nature and are comprised of several dimensions, it stands to reason that tasks may vary in the patterns of effects across these dimensions. The diagnosticity of a measure involves a measure's ability to differentiate the sources of mental workload across different dimensions. Diagnosticity has been a troubling issue for mental workload researchers, as observers themselves have difficulty assessing their own subjective experiences (Nisbett & Wilson, 1977).

The measurement of mental workload was improved when Hart and Staveland (1988) introduced the NASA – Task Load Index (NASA-TLX). These authors argued that mental workload can be provoked by a myriad of factors that may or may not be related to the task. Observers may become overwhelmed by the physical nature of a task, the mental strain required by the task, or even a preconceived notions of task difficulty. The NASA-TLX thus consists of six scales to probe observers on their levels of mental workload following a task. A version of the NASA-TLX can be found in Appendix A. These six scales are each rated by the observer on a hundred-point scale (typically using multiples of five) following the task. Following completion of the six scales, respondents complete fifteen pairwise comparisons of the scales in order to evaulate the relative importance of each source during the task. These pairwise comparisons are then used to compute weighted ratings and to compute a global workload score.

Since its publication in 1988, the NASA-TLX has been the predominant method of measuring subjective mental workload in the field of human factors (Reid & Nguyen, 1988; Warm et al. 2008; Wickens & Hollands, 2000). It has been utilized to examine and improve methods in air traffic control, power plant management, control of unmanned vehicles, and medical practices (Hart, 2006). With regards to vigilance, the NASA-TLX has provided evidence that vigilance tasks impose a high degree of mental workload, therein supporting a resource depletion explanation to the vigilance decrement (Grier et al., 2003; Helton et al. 2005; Hitchcock et al., 1999). Warm and colleagues (1996) were also able to show the Mental Demand and Frustration scales of the NASA-TLX tend to be the primary drivers of mental workload in vigilance tasks.

Stress

In addition to effects on mental workload, vigilance researchers have also examined observers' stress responses when faced with a vigilance task. Early attempts to categorize stress focused primarily on environmental factors that would negatively affect performance (Hockey &

Hamilton, 1983). Many theorists took the involvement of environmental factors further by linking observers' environment to behavioral or psychophysical states. Along these lines, Hancock and Warm (1989) reviewed a series of studies in which physiological indices are used to show the stressful nature of vigilance tasks. Addressing the lack of an applicable model of stress, these authors developed a dynamic model of stress and sustained attention. This model presents the concept of a physiological and psychological zones of adaptability, in which observers are neither hypo- nor hyper-stressed, but have effectively responded to environmental demands. Should the task begin to produce stress in the form of underload or overload, the observer would fall out of his or her zone of adaptability, resulting in maladaptive responses to the task. The model is illustrated in Figure 4.

Although the Hancock and Warm (1989) model presented a structure describing the dynamic nature of stress, the process of measuring and quantifying task-induced stress remains difficult. Assessments of stress tended to revolve around vague definitions of arousal and motivation, often termed "affect" (Watson & Tellegan, 1985). Overall affect, whether positive or negative, were proposed to interact with emotions and other individual differences to produce effects on stress (Reisenzein, 1994). Still, these theories did not provide explanations for dynamic stress responses during performance. Hockey (1997) presented a theoretical model describing compensatory mechanisms for dealing with stress during a task. Drawing upon previous work in regulatory systems (Hockey & Hamilton, 1983; Hockey, 1986), as well as Broadbent's (1971) integration of energetic factors into an information processing model, Hockey (1997) outlines two levels of control. The lower level is automatic, one utilized when task demands are routine and performance goals are well-known. Output (i.e., performance) from this lower level is relatively-stable. This is contrasted with the higher level, in which effortful control is exerted by the operator when the demands of the task increase. The author details how operators begin with the lower level as their default, but an *effort monitor* is responsible for identifying task demands that exceed the capacity of the lower level. When this occurs, the operator decides whether to change task goals or allocate more effort to the task. Furthermore, Hockey suggested decrements brought on by these increases in effort and regulation should be seen in measurement of stress, whether by performance, secondary tasks, or self-report measure. The Hockey compensatory model can be found in Figure 5.

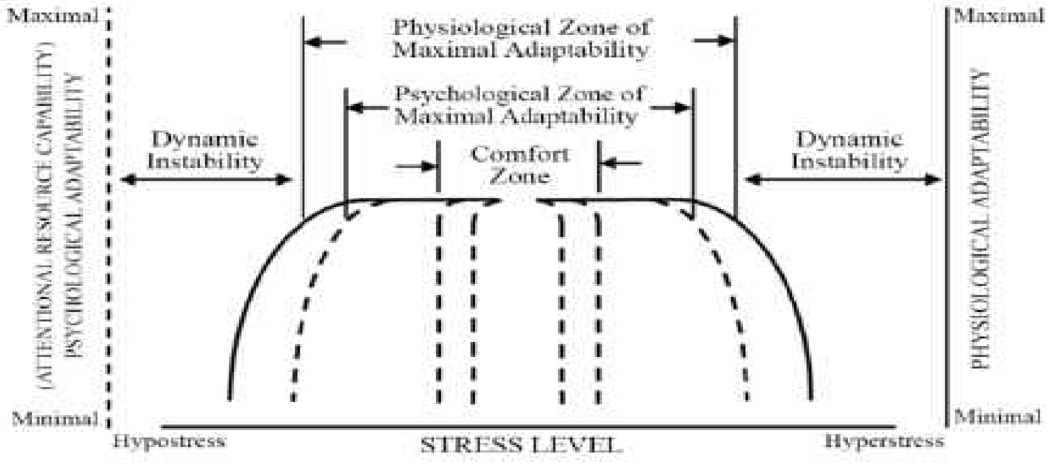


Figure 4. Hancock and Warm (1989) Dynamic Model of Stress and Sustained Attention.

Soon after the development of Hockey's (1997) compensatory model, Matthews and colleagues (1999) developed the Dundee Stress State Questionnaire (DSSQ) to quantify the multiple dimensions of task-induced stress. The DSSQ sought to combine models of stress based on arousal with individual difference variables, such as emotion, motivation, and anxiety. The questionnaire draws heavily upon Lazarus' (1991) transactional theory of emotion, specifically the concept that appraisal and coping play major roles in our overall cognitive state. The DSSQ measures three convergent factors for stress: task engagement; distress; and worry (Matthews et al., 2002). These authors discuss task engagement as a self-regulatory process combining enthusiasm and interest in a given task (Matthews et al., 1999). Task engagement may be high for short-term tasks requiring working memory, but it tends to decline with long, monotonous tasks. They describe distress as an analog to Hockey's (1997) concept of overload, in which mental strain is induced due to a combination of increasing task, environmental, or subjective demands. Matthews et al., (2002) define worry in terms of the cognitive components of state anxiety. Their explanation of worry relates to a definition set forth by Wells and Matthews (1994), in which the authors describe are concerned with the relationship between their social environment and the task, rather than actual task demands.

The DSSQ has been particularly helpful to vigilance researchers in search of explanations for performance. For instance, the secondary scale for task engagement has been shown to predictive of sensitivity in vigilance tasks (Helton, Shaw, Warm, Matthews, & Hancock, 2008; Helton, Matthews, & Warm, 2009; Shaw, Matthews, Warm, Finomore, Silverman, & Costa Jr., 2010; Szalma et al., 2004). Additionally, research on cerebral blood flow velocity (CBFV) has been used to link task engagement scores to the readiness to mobilize resources (Matthews, Warm, Reinerman-Jones, Langheim, Washburn, & Tripp, 2010). Increases in distress and decreases in worry are also typical of vigilance tasks (Helton et al., 2009; Helton, Dember, Warm, & Matthews, 1999; Szalma et al., 2004; Temple, Warm, Dember, Jones, LaGrange, & Matthews, 2000). Differences in the three primary DSSQ factors also have been linked to individual difference variables such as optimism, extraversion, and neuroticism (Szalma et al., 2006; Szalma & Taylor, 2011).

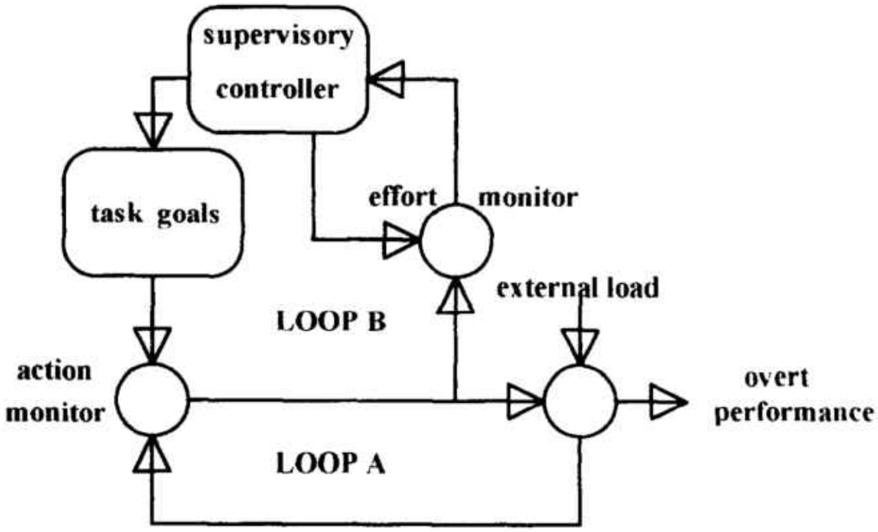


Figure 5. Hockey (1997 compensatory control model of performance regulation.

Training and Knowledge of Results

With the theoretical and practical importance of vigilance, training for this capacity has been an important research goal. A manipulation that has been utilized in vigilance research for decades is knowledge of result (KR). KR is a source of feedback that follows a response by the observer (Adams, 1968; Salmoni et al., 1984). Importantly, KR often provides information regarding the accuracy of a response that is separate from the response itself. Therefore, KR is useful as a training tool that can be removed to examine observers' ability on a task in a transfer vigil following training.

Indeed, KR has been used in numerous studies dating back over sixty years to train operators for correct responses, with varying results (Chinn & Alluisi, 1964; Colquhoun, 1966;

Mackworth, 1964; Wiener; 1968; Wiener & Attwood, 1968). One problem for improving training effectiveness is that the mechanisms underlying KR effects are not well understood. Several reviews of KR literature have distinguished between learning task properties to aid future performance on the task, and operators' motivation for performing the task (Annett, 1969; Kluger and DeNisi, 1996; Salmoni et al., 1984).

Kluger and DeNisi (1996) provide a theoretical model for the effects KR and other forms of feedback can have at different levels for the operator. *Feedback Intervention Theory* (FIT) divides cognitive mechanisms into a hierarchy of processes, each linked together, which regulates task performance when feedback is present. The bottom rung on the hierarchy are *task-learning processes,* which involve acclimating the operator to task parameters; namely, what constitutes a correct or incorrect response. These processes improve performance by helping operators to establish an accurate mental model for correct responses. Next in the hierarchy are *task-motivational processes*. These processes reflect effort on the part of operators to integrate knowledge regarding correct responses gained from feedback into their ongoing task performance. This level acts as a middle ground for the other two levels of the hierarchy, shaping performance on the task dynamically as operators change their attitudes and/or goals for the task. At the top of the hierarchy are *meta-task processes*. This level is comprised of several processes that are related to the self and may divert attentional resources away from the task. Generally, these concerns center on increases in task demands and a subsequent inability to cope with those demands via diminishing cognitive resources. Operators may begin to lose motivation for performing the task and disengage from goals related to it.

Researchers have applied KR techniques to investigate potential benefits during vigilance tasks. Generally, KR to observers during a vigilance task has been shown to increase speed and accuracy (Baker, 1959; Buck, 1966; McCormack, 1959; McCormack, Binding, & Chylinski, 1962; Sipowicz, Ware, & Baker, 1962; Wiener, 1968). Moreover, KR has been examined in a number of ways in relation to its effects on vigilance. For instance, Dittmar and colleagues (1985) studied the differences between KR for hits, misses, or false alarms in tasks requiring simultaneous or successive discrimination, in accordance with the vigilance taxonomy (Parasuraman & Davies, 1977). These authors observed that perceptual sensitivity, measured by *A'*, decreased over time across both tasks when KR and a no-KR control were provided, but not when hit KR and false alarm KR were provided. Dittmar et al. (1985) attributed these findings to hit and false alarm KR providing direct information about the accuracy of an overt response by the observers, whereas miss KR only occurs after a failure to respond. Also, observers' scores for β became more conservative over time, although scores for observers in the no-KR control, miss KR, and false alarm KR conditions were more conservative than observers in the hit KR condition. The authors cited Chinn and Alluisi's (1964) explanation for this effect, who argued this pattern of effects may stem from the general lack of penalty for errors of commission. So long as observers were not penalized for committing a false alarm, they continued to utilize hit KR as a means of gathering information about signals.

These findings demonstrate the distinction between KR as a learning tool and KR as a vehicle for motivation. Similar findings are presented using partial-KR, which involves providing observers KR intermittently during training (Szalma, Hancock, Warm, Dember, & Parsons, 2006; Warm, Hagner, & Meyer, 1971; Wiener, 1963). Additional motivational effects for KR have been reported in studies that provide incentives for performance (Warm, Kanfer, Kuwada, & Clark, 1972; Wiener, 1969). Learning effects of KR have been examined in the context of KR validity, or whether the feedback provided to observers provides correct or incorrect information about the accuracy or speed of response. Results in such studies have been mixed, with observers receiving invalid KR performing almost as well, if not as well, as observers receiving valid KR (Mackworth, 1964; Warm, Epps, & Ferguson, 1974). Findings showing some benefit for invalid KR has led researchers to conclude there must be some motivational factors inherent in KR (Dember & Warm, 1979; Warm & Jerison, 1984).

Along with KR, a primary concern for researchers investigating training is the degree to which training with KR transfers to a task in which the feedback has been withdrawn. Transfer can be either *general* and *specific,* although early theorists presented these distinctions along a continuum of similarity of training and transfer tasks(Osgood, 1948). General transfer involves training observers on one task and testing for improved performance on a different task. Specific transfer, on the other hand, involves training observers on one task and testing for improved performance on the same task, or a similar task within the same task category (Underwood, 1966). Although not directly testing for transfer differences, Wiener (1967) hypothesized that training for vigilance should bring about general transfer because the skills enhanced by KR are high-level motivational and learning traits, such as maintaining alertness and understanding differences between signals and non-signals.

To examine this claim more closely, Becker, Warm, Dember, and Howe (1994) looked into the effects of KR on both specific and general transfer in vigilance. Observers were divided into composite-KR (group received hit, miss, and false alarm feedback) and no-KR groups, as well as groups comparing specific (simultaneous-simultaneous or successive-successive) and general (simultaneous-successive or successive simultaneous) transfer. The authors reported evidence for specific transfer in both the simultaneous and successive tasks, but they did not observe general transfer. Additionally, in the specific transfer conditions, KR was shown to counteract the vigilance decrement in terms of correct detections. A stark decline in correct detections was seen in the general transfer conditions, as well as in the specific transfer condition without KR.

Szalma (1997) also investigated the effects of KR on transfer of training. These authors reported specific transfer of training, which aligned with findings reported by Becker et al. (1994). Furthermore, Szalma (1997) found that KR training brought about an increase in observers' level of conservatism when responding, in line with previous findings for KR and response bias (Davies & Parasuraman, 1982; See et al., 1997). A visual representation of their results can be found in Figure 6. The present series of studies examined the methods by which we use knowledge of result to train observers for vigilance. After examining the possible structural and energetic components of KR in Studies 1 and 2, Study 3 investigated how the novel exposure condition elicits transfer of training in the same (specific) and different (general) tasks during transfer.

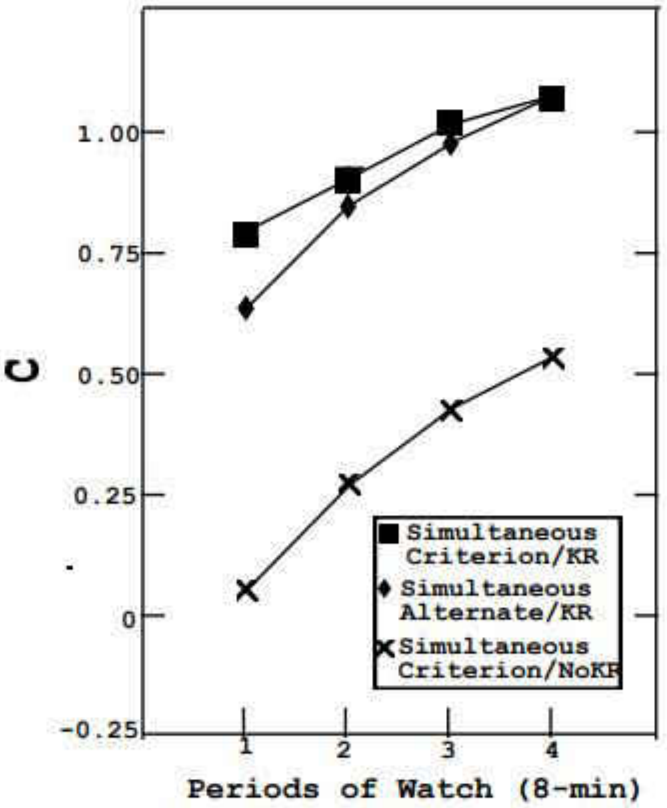


Figure 6. Results from Szalma (1997).

CHAPTER THREE: METHODOLOGY

All three experiments were completed on Optiplex 745 personal computers. The studies were executed using SuperLab 4.5 software. G*Power analysis indicated that, given the number of independent groups and periods-on-watch, 120 observers per study were required to achieve a medium effect size of partial $\eta^2 = .09$. All observers were recruited using the University of Central Florida SONA Research Participation System (SONA) and were compensated with course credit. Observers were required to be a minimum of 16 years old, and were required to report normal or corrected-to-normal vision. Observers were required to manipulate a "QWERTY" keyboard in order to respond to stimuli. In addition to the experimental task and questionnaires, observers provided demographic information, including age and gender.

Study 1

Procedure

Upon arriving for the study, observers were assigned at random to one of four experimental groups. Observers were asked to turn off their cell phones and other devices before completing the study. They then read the informed consent form and provided demographics information. Next, they completed the pre-task short-form DSSQ using UCF Qualtrics Survey Software. The 20-item short-form DSSQ also includes the three secondary factors (task engagement, distress, and worry) included in the full DSSQ (Matthews, Emo, & Funke, 2005). Reliability scores for the short-form DSSQ compared favorably with those of the full DSSQ (Matthews & Zeidner, 2012), while the short-form version shows similar sensitivity to changes in task demands (Matthews, Szalma, Panganiban, Neubauer, & Warm, 2013).

Following completion of the pre-task short-form DSSQ, Study 1 was completed using SuperLab 4.5 software. Study 1 utilized a modified version of the task employed by Szalma and Teo (2012). Independent variables for Study 1 included pre-vigil training, in the form of discrimination training and a relatively-small number of practice trials, and KR presented during the full training phase of the task. Study 1 implemented an adapted Solomon four-groups design as a means of examining the effects of the independent variables compared to a control group where neither is present. Observers receiving pre-vigil training first completed a two-alternative-forced-choice (2-AFC) task in order to confirm their ability to discriminate critical signals from non-signals. Critical signals were defined as a two-digit number in which the difference between the two digits is 1, 0, or -1. An example of a critical signal is presented in Figure 7. A non-signal was defined as any two-digit number in which the difference between the two digits is not 1, 0, or -1. On each trail, observers in this condition saw two digit pairs presented successively. Each stimulus was presented for 1500 milliseconds (ms) each with a 500 ms inter-stimulus interval (ISI), one containing a critical signal and one containing a non-signal, Observers were then prompted to identify which trial contained a critical signal. Observers completed 20 such trials, 10 in which the critical signal appeared in the first slide, and 10 in which the critical signal appeared in the second slide. Observers who did not receive pre-vigil training completed a card sorting task for a period equivalent to the average time (e.g. 5 minutes) needed for pre-vigil training.

After completing of the 2-AFC task, observers in the pre-vigil training condition received a series of thirty practice trials that mimic the structural demands of the full vigil. Observers were instructed that they needed to monitor a display for critical signals, but were not told when critical signals would occur. Critical signals were defined as two-digit numbers in which the difference between the two digits is 1, 0, or -1, just as in the 2-AFC task. There were instructed to press the space bar if they believed a critical signal had been shown and to not respond if they believed no critical signal had appeared on the screen. A visual description of the Study 1 manipulations can be found in Table 3-1.

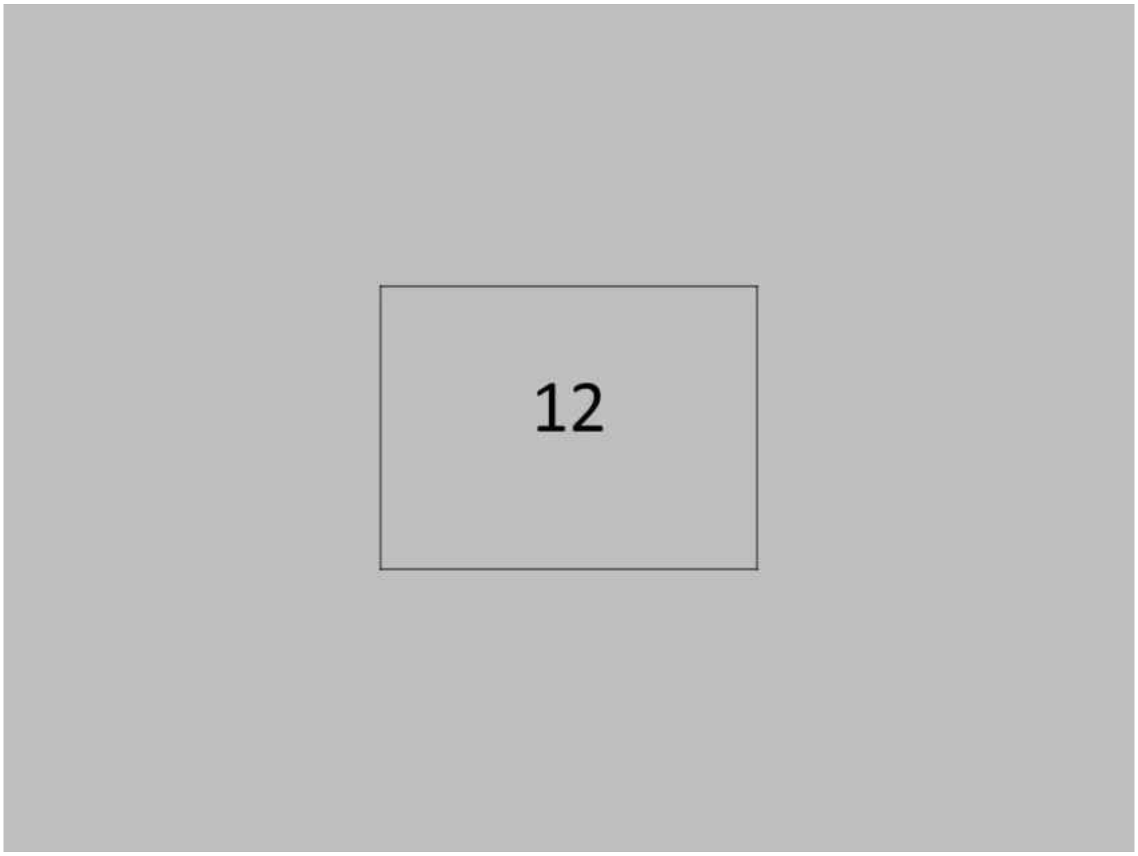


Figure 7. Study 1 critical signal example.

Following the pre-vigil training manipulation, all observers completed a training vigil. The training vigil was similar to the set of practice trials. All observers were instructed to monitor for critical signals. Observers were instructed to press the Space Bar when they believed a critical signal had appeared on the screen, and to withhold from responding when they believed a non-signal had appeared on the screen. Observers completed two blocks of 130 trials during the training vigil, 10 of which were be critical signals and 120 of which were be non-signals. Each trial lasted for 2000 milliseconds (ms), during which time observers must respond to critical signals by pressing the Space Bar, or withhold responding for non-signals. The stimuli were present on the screen for 1500 ms, which was followed by a 500 ms inter-stimulus interval (ISI). These durations have been shown in pilot work to elicit declines in performance and mental workload associated with vigilance tasks. The training vigil lasted a total of eight minutes and 20 seconds, or two blocks of 4 minutes and ten seconds each.

Table 4. Study 1 Manipulations.

Group	**Discrimination Training**	**Practice**	**Vigilance Training**	**Transfer Vigil**
1) 2AFC/KR	2AFC with KR	Detection Task NKR	KR	NKR
2) 2AFC/NKR	2AFC with KR	Detection Task NKR	NKR	NKR
3) No 2AFC/KR	--	--	KR	NKR
4) No 2AFC/NKR	--	--	NKR	NKR

Following each of the 10 critical signals, observers in the KR condition received feedback indicating a correct detection or a miss. Observers also received false alarm feedback if they respond to a non-signal. Observers in the no-KR condition received “Saved” indicating their responses had been saved. Following completion of the training vigil, observers completed the post-training short-form DSSQ and NASA-TLX. These measures were counterbalanced to avoid order effects. Next, all observers completed the transfer vigil. The transfer vigil was identical for observers in all four experimental conditions. Observers completed five blocks of 130 trials consisting of 10 critical signals, defined as two-digit numbers in which the difference between the two digits is 1, 0, or -1, and 120 non-signals. Each trial lasted for 2000 ms, 1500 ms of which included the stimuli on screen, and 500 ms of which were a blank ISI. Observers were instructed to press the Space Bar when they believed a critical signal had appeared on the screen, and to withhold from responding when they believed a non-signal had appeared on the screen. For all observers, no KR was presented following critical signals in the transfer vigil. The full vigil lasted approximately 21 minutes. Following completion of the transfer vigil, observers completed the NASA-TLX and post-task short-form DSSQ. They then were thanked for their time and allowed to leave.

Study 2

Procedure

As in Study 1, observers were randomly assigned to one of four experimental conditions upon arrival for the study. Observers were asked to turn off their cell phones and other devices before completing the study. They then completed the informed consent process and provided demographics information. Next, they completed the pre-test short-form DSSQ using UCF Qualtrics Survey Software.

Following completion of the pre-task short-form, Study 2 was completed using SuperLab 4.5 software. The experimental task employed in Study 2 was identical to the task employed by Study 1. Independent variables for Study 2 again included type of pre-vigil training, in the form of discrimination training and a relatively-small number of practice trials, and KR presented during the training phase of the task. As in Study 1, observers in Study 2 who received pre-vigil training completed a 2-AFC task and 30 practice trials. Those observers not receiving pre-vigil training, though, did not complete a card sorting task. Instead, these observers were exposed to the pre-vigil training procedure. The 2-AFC task and practice trials appeared on screen in the same manner, but those in the exposure condition were told they should not to respond. They instead were told to follow the 2-AFC task and practice trials as they appeared on the screen in order to acclimate them to the task. A visual description of the Study 2 manipulations can be found in Table 3-2.

Following completion of the pre-vigil/exposure training, observers completed either KR or No KR training vigils. The KR and No-KR conditions were identical to those in Study 1. Those in the KR training condition received hit or miss feedback following the presentation of critical signals, as well as false alarm feedback if they responded to a non-signal. Observers in the No-KR condition received feedback indicating their response had been saved following all critical signals, as well as following responses to non-signals, should they occur.

Following completion of the training vigil, observers completed the post-training short-form DSSQ and NASA-TLX. These measures were counterbalanced to avoid order effects. Next, all observers completed the transfer vigil, which was identical to that of Study 1. Observers received no feedback at any point during the transfer vigil. Following completion of the transfer vigil, observers completed the NASA-TLX and post-task short-form DSSQ. They then were thanked for their time and dismissed.

Table 5. Study 2 Manipulations.

Group	**Signal Training**	**Signal Training**	**Vigilance Training**	**Transfer Vigil**
1) 2AFC/KR	2AFC with KR	Detection Task NKR	KR	NKR
2) 2AFC/NKR	2AFC with KR	Detection Task NKR	NKR	NKR
3) Exposure/KR	Exposure	Exposure	KR	NKR
4) Exposure/NKR	Exposure	Exposure	NKR	NKR

Study 3

Procedure

As in the previous two studies, observers were randomly assigned to one of four experimental groups upon arrival for the study. Observers were asked to turn off their cell phones and other devices before completing the study. They then completed the informed consent process and provide demographics information. Next, they completed the pre-test short-form DSSQ using UCF Qualtrics Survey Software.

Following completion of the surveys, Study 3 was completed using SuperLab 4.5 software. Study 3 utilized two experimental tasks, each of which required a cognitive manipulation to complete. Task A was identical to the task employed by Studies 1 and 2. Observers were asked to identify critical signals, defined as two-digit numbers in which the difference between the two digits was 1, 0, or -1. Non-signals were defined as two-digit numbers in which the difference is not 1, 0, or -1. Task B was a lexical decision task, in which observers were required to identify critical signals defined as two-letter words. In Task B, non-signals were defined as two-letter pairs (one of which was a vowel) that were not words. There was an equal number of two-letter non-words that contained no vowels and one vowel (no two-letter non-words comprised of two vowels were presented). This task was used to create equivalent information loads on observers for signals and non-signals (two-digit numbers, compared to two-letter words). Observers in Study 3 were split into groups based on which task (Task A or Task B) they are exposed to prior to the training vigil, as well as whether or not they receive KR during the training vigil. A visual description of the Study 3 manipulations can be found in Table 3-3.

Following completion of the task exposure, observers completed a training vigil on Task A. Observers in the KR groups received hit, false alarm, and miss feedback in the same manner as Studies 1 and 2. Observers in the No-KR groups were informed that their responses were saved in the same manner as Studies 1 and 2. Following completion of the training vigil, all observers completed a transfer vigil on Task B with no feedback provided. Although the transfer vigil utilized Task B, the time parameters with regard to stimulus duration and vigil length were equivalent to the transfer vigils employed by Studies 1 and 2. Following completion of the full transfer vigil, observers completed the NASA-TLX and post-task short-form DSSQ. They then were thanked for their time and allowed to leave.

Table 6. Study 3 Manipulations.

Group	Exposure	Vigilance Training	Transfer Vigil
1) Exposure A/KR	Exposure to Digit Task	Digit Task KR	Lexical Task NKR
2) Exposure A/NKR	Exposure to Digit Task	Digit Task NKR	Lexical Task NKR
3) Exposure B/KR	Exposure to Lexical Task	Digit Task KR	Lexical Task NKR
4) Exposure B/NKR	Exposure to Lexical Task	Digit Task NKR	Lexical Task NKR

Statistical Analyses

Study 1

Performance

A 2 (pre-vigil training: 2-AFC and practice vs. none) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 2) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B")* during the training vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

A 2 (pre-vigil training: 2-AFC and practice vs. none) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 5) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B"*) during the transfer vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

Mental Workload

A 2 (pre-vigil training: 2-AFC and practice vs. none) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for each of the six scales of the post-training and post-transfer NASA-TLX, as well as for global workload scores.

Stress

A 2 (pre-vigil training: 2-AFC and practice trials vs. none) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for the difference scores for the task engagement and distress factors of the pre-task short-form DSSQ with the post-training short-form DSSQ and the post-training short-form DSSQ with the post-transfer short-form DSSQ.

Study 2

Performance

A 2 (pre-vigil training: active responding vs. exposure) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 2) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B"*) during the training vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

A 2 (pre-vigil training: active responding vs. exposure) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 5) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B"*) during the transfer vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

Mental Workload

A 2 (pre-vigil training: active responding vs. exposure) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for each of the six scales of the post-training and post-transfer NASA-TLX, as well as for global workload scores.

Stress

A 2 (pre-vigil training: active responding vs. exposure) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for the difference scores for task engagement and distress of the pre-task short-form DSSQ with the post-training short-form DSSQ and the post-training short-form DSSQ with post-transfer short-form DSSQ.

Study 3

Performance

A 2 (pre-vigil training: Digit vs. Lexical) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 2) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B"*) during the training vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

A 2 (pre-vigil training: Digit vs. Lexical) by 2 (KR: training KR vs. no training KR) by 2 (period on watch: 1 – 5) repeated measures ANOVA were performed for sensitivity (measured by *A'*) and response bias (measured by *B"*) during the transfer vigil. Identical analyses were performed for hits and false alarms to further examine effects on sensitivity and response bias.

Mental Workload

A 2 (pre-vigil training: Digit vs. Lexical) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for each of the six scales of the post-training and post-transfer NASA-TLX, as well as for global workload scores.

Stress

A 2 (pre-vigil training: Digit vs. Lexical) by 2 (KR: training KR vs. no training KR) between-subjects ANOVA were performed for the difference scores for the task engagement and distress factors of the pre-task short-form DSSQ with the post-training short-form DSSQ and the post-training short-form DSSQ with the post-transfer short-form DSSQ.

CHAPTER FOUR: RESULTS

Study 1

Descriptive Statistics

One hundred and twenty seven observers were recruited from SONA to take part in Study 1 (80 females, 47 males). Observers ranged in age from 18 to 29 with a mean age of 19.63 (*SD* = 2.43). These observers were split evenly for both the KR (60 NKR, 60 KR) and Practice (60 NP, 60 P) groups.

Vigilance Performance: Training

Correct Detections

There was a significant main effect for period on watch on proportion of correct detections during training collapsed across all groups (F [1,123] = 19.981, $p < .0005$, $\eta^2 = .140$). As shown in Figure 8, observers made fewer correct detections in Period 2 compared to Period 1.

Additionally, analyses revealed an interaction between the KR and practice conditions, such that observers in the no practice condition correctly identified a higher percentage of critical signals during the training vigil when provided than those who did not receive KR (F [1,116] = 7.143, p = .009, η2 = .058). These results can be found in Figure 9. No other main effects or interactions were found for correct detections during the training vigil.

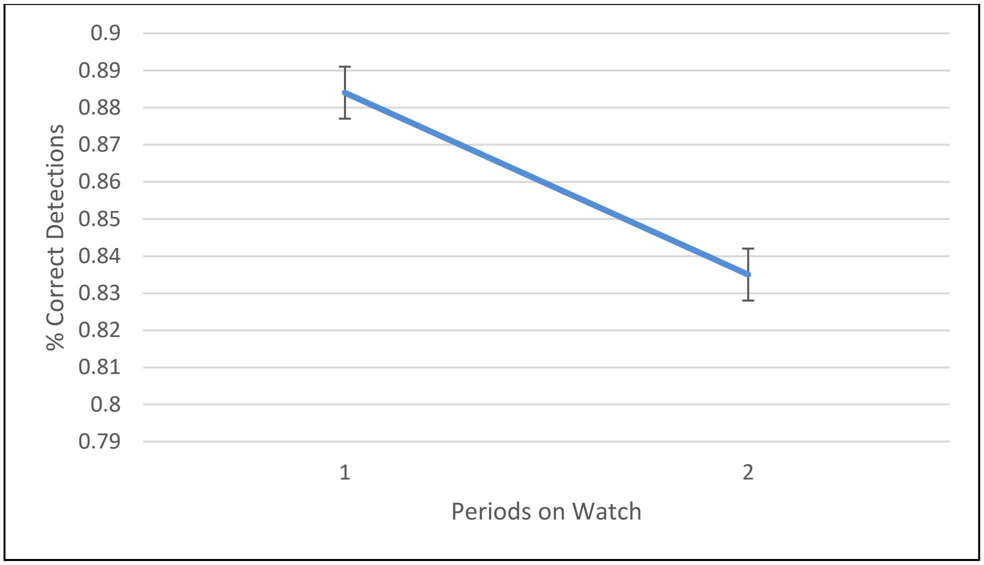


Figure 8. Proportion of correct detections during the training vigil, collapsed across all groups.

False Alarms

There was a significant main effect for period on watch on false alarms during training collapsed across all groups (F [1,123] = 24.264, $p < .0005$, $\eta^2 = .165$). As shown in Figure 10, observers committed fewer false alarms in Period 2 compared to Period 1.

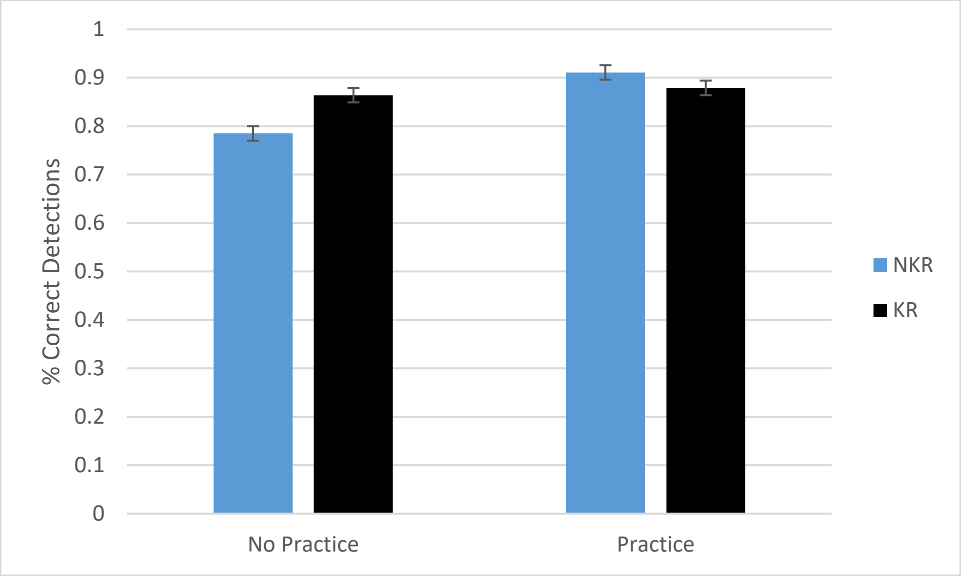


Figure 9. Proportion of correct detections during the training vigil for the Practice and No Practice groups.

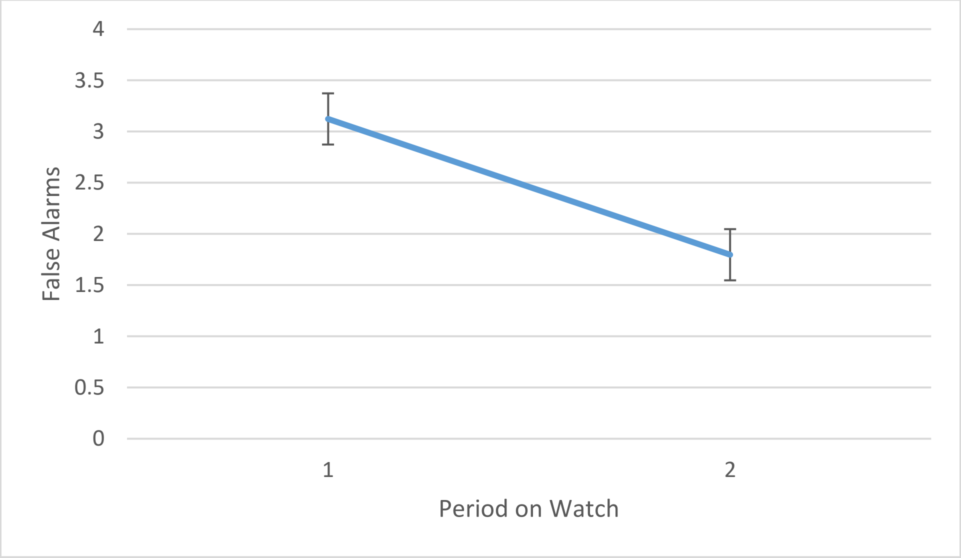


Figure 10. False alarms during the training vigil, collapsed across all groups.

Additionally, analyses revealed a main effect for practice, such that observers in the practice conditions committed fewer false alarms during the training vigil than those who did not receive practice (*F* [1,123] = 7.684, $p = .006$, $\eta^2 = .059$). These results can be found in Figure 11. No other main effects or interactions were found for false alarms during the training vigil.

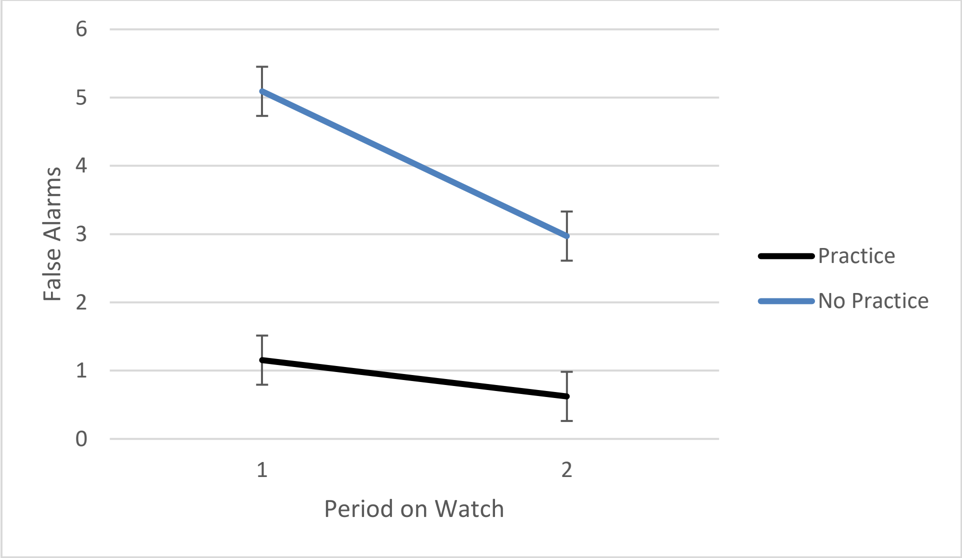


Figure 11. False alarms during the training vigil for the Practice and No Practice groups.

Sensitivity

Analyses did not reveal a main effect for sensitivity, as measured by *A'*, for period on watch when collapsed across groups. However, analyses did reveal that observers receiving practice exhibited higher levels of sensitivity during the training vigil than those who did not receive practice (*F* [1,123] = 4.688, $p = .032$, $\eta^2 = .037$). These results can be found in Figure 12. No other main effects or interactions were found for sensitivity during the training vigil.

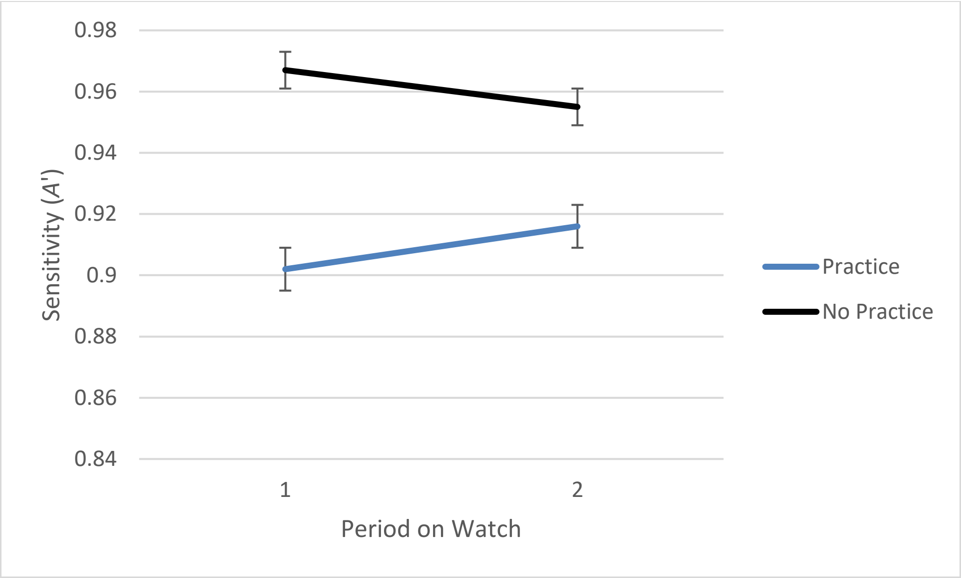


Figure 12. Sensitivity during the training vigil for the Practice and No Practice groups.

Response Bias

There was a significant main effect for period on watch on response bias, as measured by *B''*, during training collapsed across all groups (F [1,123] = 45.097, $p < .0005$, $\eta^2 = .268$). As shown in Figure 13, observers displayed a more conservative response criterion in Period 2 compared to Period 1. Additionally, there was a main effect for the practice condition, such that observers who received practice displayed a more conservative response criteria than those who did not receive practice (F [1,123] = 45.097, $p < .0005$, $\eta^2 = .268$). This finding is shown in Figure 14.

Stress: Training

Task Engagement

There were no significant main effects or interactions for task engagement in the training vigil.

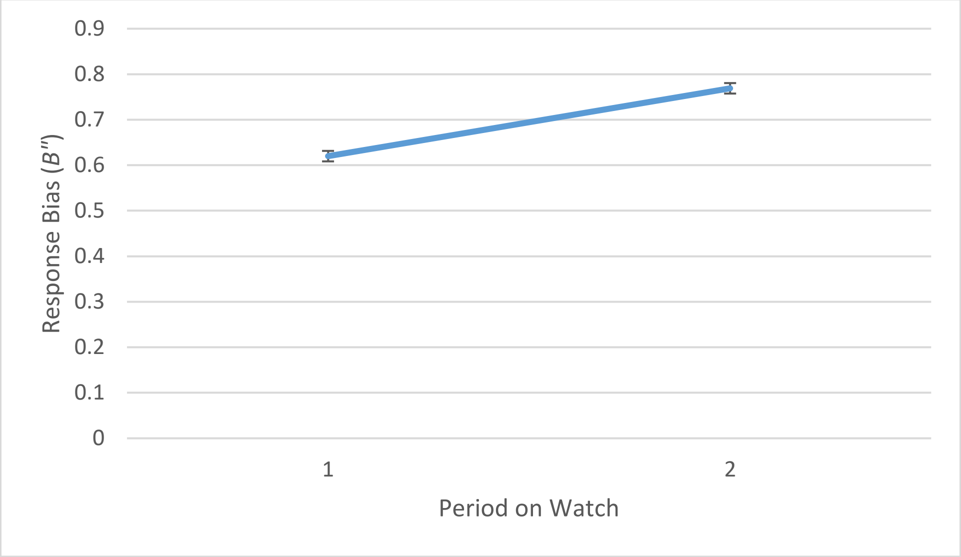


Figure 13. Response bias during the training vigil, collapsed across all groups.

Distress

Analyses revealed a significant effect for distress following the training vigil, such that distress difference scores were higher following training for those who did not receive practice than for those who did receive practice (F [1,126] = 13.054, $p < .0005$, $\eta^2 = .097$). These findings can be found in Figure 14. No other main effects or interactions were found for distress during the training vigil.

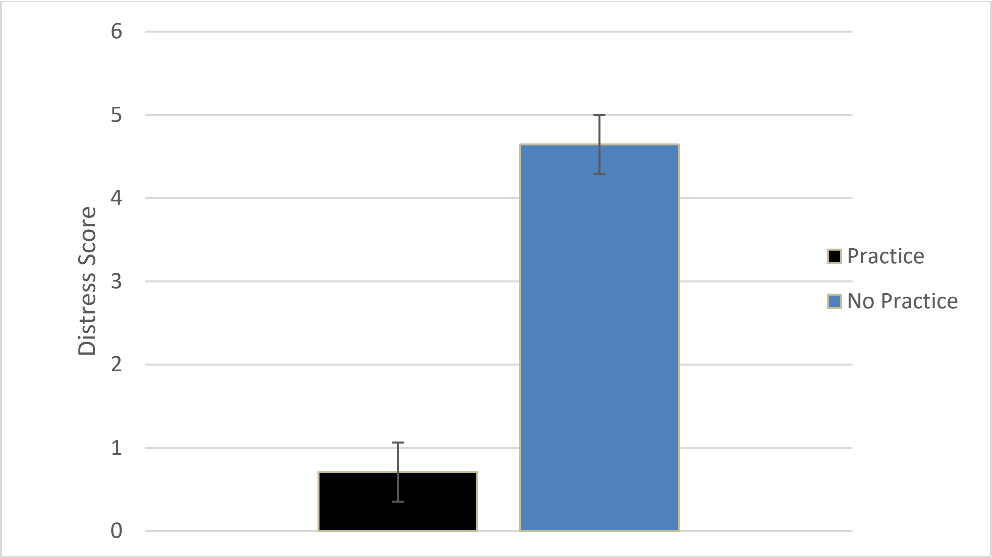


Figure 14. Distress difference scores for the Practice and No Practice groups following training.

Mental Workload: Training

Analyses did not reveal significant differences in global mental workload following the training vigil as measured by the NASA-TLX. Examination of the six NASA-TLX scales, however, did reveal a significant difference for the Frustration scale, such that those who received practice prior to the training vigil reported lower levels of frustration than those who did not receive practice (*F* [1,127] = 7.200, $p = .008$, $\eta^2 = .055$). These results can be found in Figure 15. Additionally, analyses revealed an interaction between the KR and practice condition, such that for observers who did not receive practice, those who received KR outperformed those who did not receive KR (*F* [1,127] = 4.218, $p = .042$, $\eta^2 = .033$). This finding can be found in Figure 16. No other main effects or interactions were found for mental workload during the training vigil.

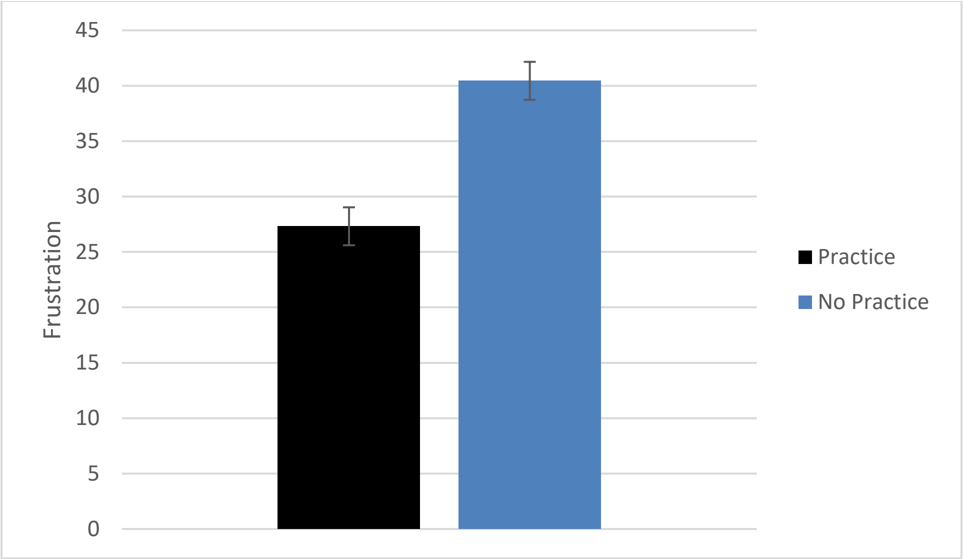


Figure 15. Frustration scores for the Practice and No Practice groups following training.

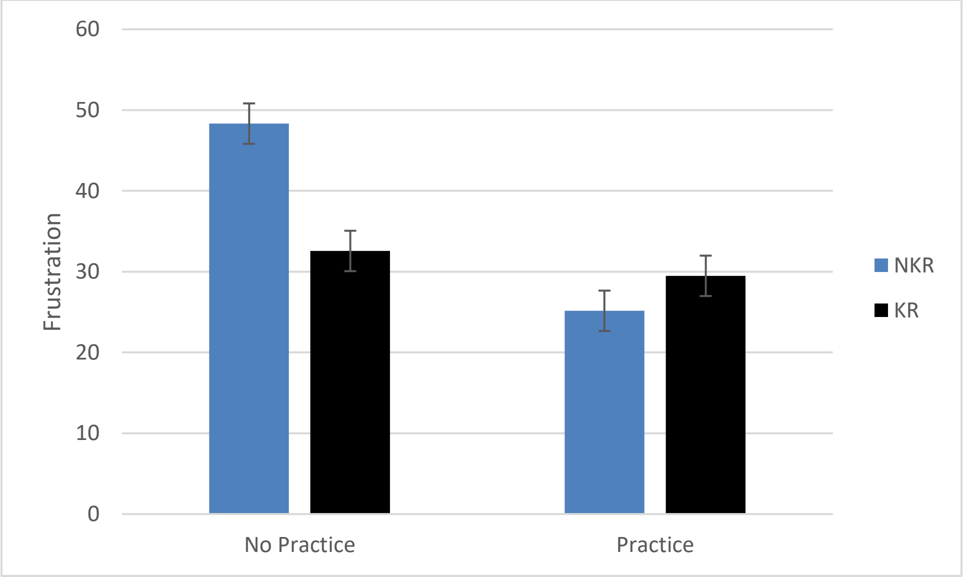


Figure 16. Frustration scores for the Practice and KR conditions following training.

Vigilance Performance: Transfer

Correct Detections

Analyses revealed an interaction for proportion of correct detection between the practice and KR conditions, such that KR improved performance in the No Practice condition compared to the No KR condition, but this effect disappeared in the practice condition (*F* [1,123] = 3.891, $p = .051$, $\eta^2 = .031$). These findings can be found in Figure 17. No other main effects or interactions were found for correct detections during the transfer vigil.

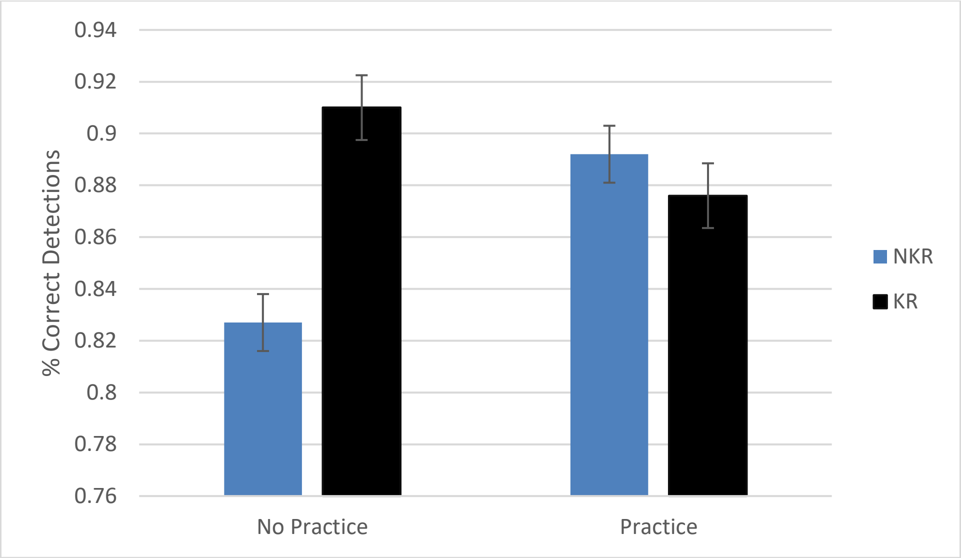


Figure 17. Proportion of correct detections during the transfer vigil for the Practice and KR conditions.

False Alarms

Sphericity was violated with regard to period on watch ($\chi 2$ (9) = 174.816, $p < .0005$). As such, this analysis made use of a Hyunh-Feldt correction. The effect for period on watch on false alarms during transfer collapsed across all groups was significant (*F* [2.547, 313.287] = 3.403, $p = .024$, $\eta^2 = .027$), such that false alarms decreased as time on task increased. These findings can be found in Figure 18. Additionally, analyses revealed an interaction between the Practice and KR conditions for false alarms, such that false alarms were lower for observers who received KR in the No Practice condition than for observers who did not receive KR (*F* [1,123 = 5.080, *p* = .026, η^2 = .040). In the Practice condition, though, observers who received KR committed more false alarms than observers who did not receive KR. These findings can be found in Figure 19.

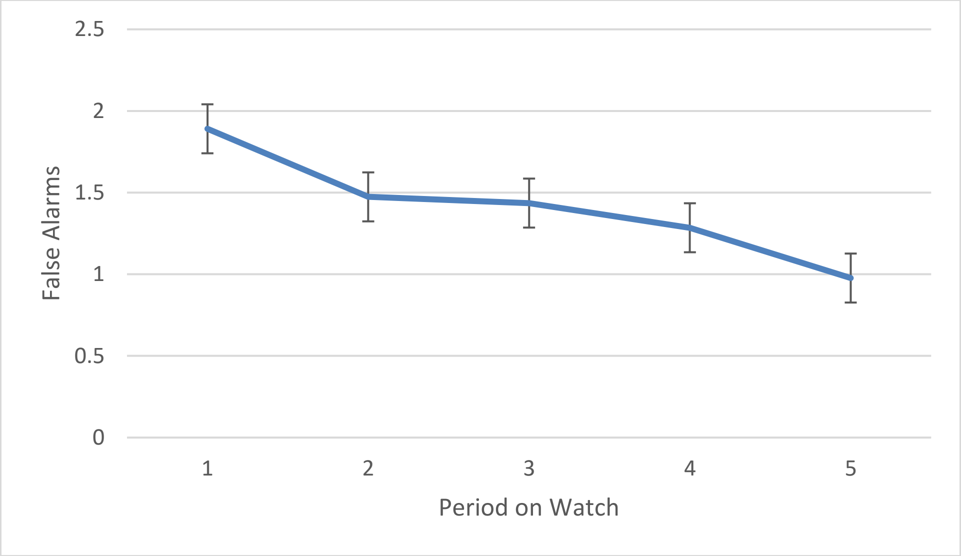


Figure 18. False alarms during the transfer vigil, collapsed across all conditions.

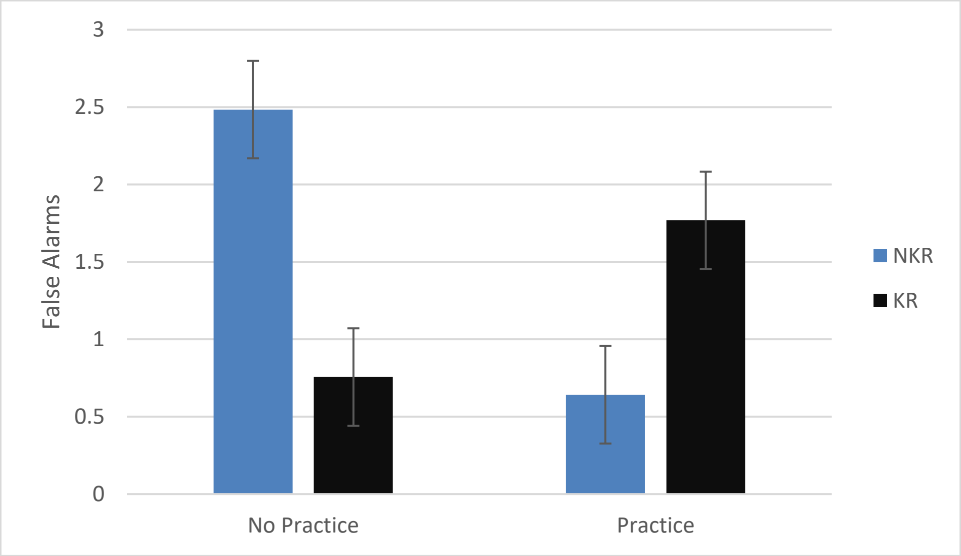


Figure 19. False alarms during the transfer vigil for the Practice and KR conditions.

Sensitivity

Analyses revealed an interaction for sensitivity between the practice and KR conditions, such that KR improved performance in the No Practice condition compared to the No KR condition, but this effect disappeared in the practice condition (F [1,123] = 4.939, p = .028, η^2 = .039). These findings can be found in Figure 20. No other main effects or interactions were found for correct detections during the transfer vigil.

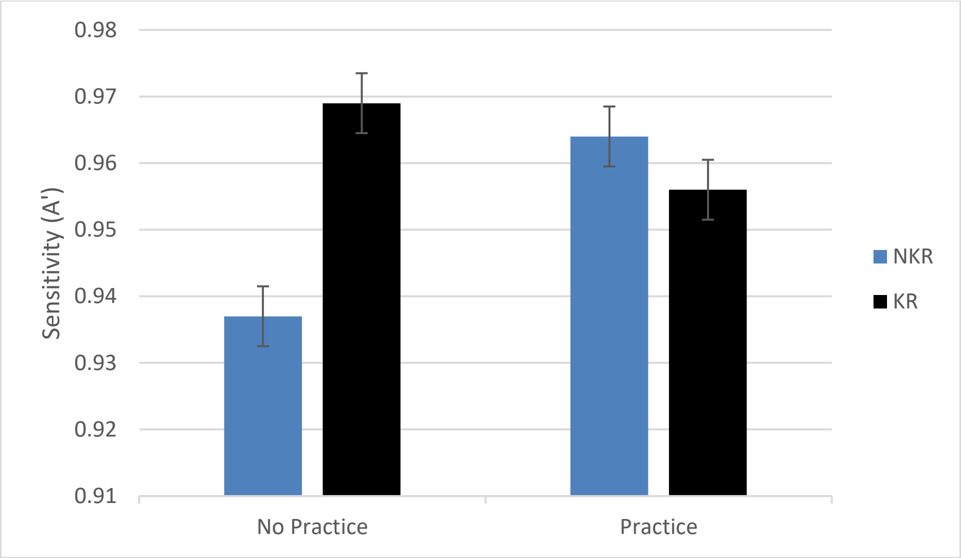


Figure 20. Sensitivity as measure by *A'* during the transfer vigil for the Practice and KR conditions.

Response Bias

Sphericity was violated with regard to period on watch ($\chi 2$ (9) = 39.943, p < .0005). As such, this analysis made use of a Hyunh-Feldt correction. Analyses revealed a main effect for period on watch on response bias, such that observers became more conservative in their responses as time on task increased (F [3.626, 445.988] = 3.519, p = .010, η^2 = .028). These findings can be found in Figure 21. No other main effects or interactions were found for correct detections during the transfer vigil.

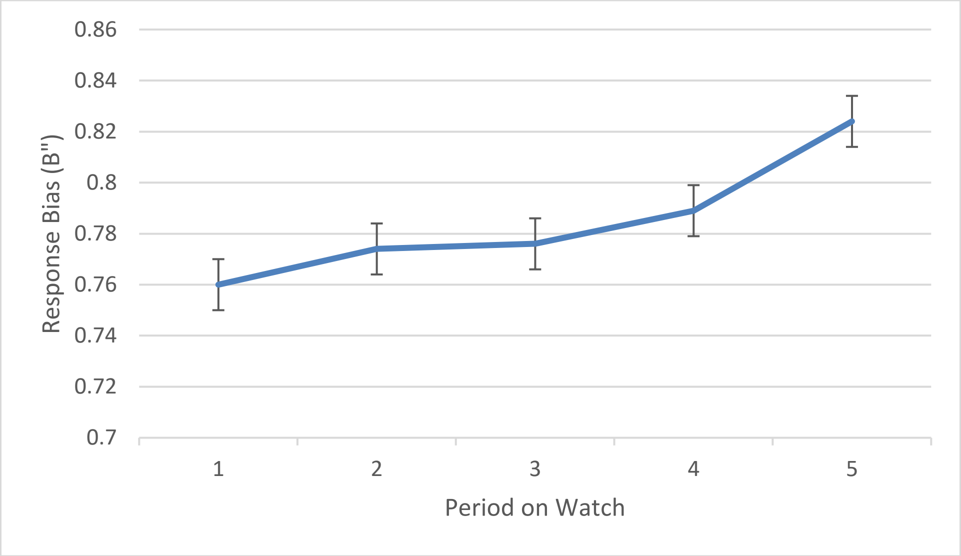


Figure 21. Response bias, as measured by *B”*, during the transfer vigil, collapsed across all conditions.

Stress: Transfer

Task Engagement

Analyses revealed a significant effect for task engagement following the transfer vigil, such that task engagement scores fell less following transfer for those for those who received KR than for those who did not receive KR (F [1,119] = 4.671, $p = .033$, $\eta^2 = .038$). These findings can be found in Figure 22. No other main effects or interactions were found for task engagement during the transfer vigil.

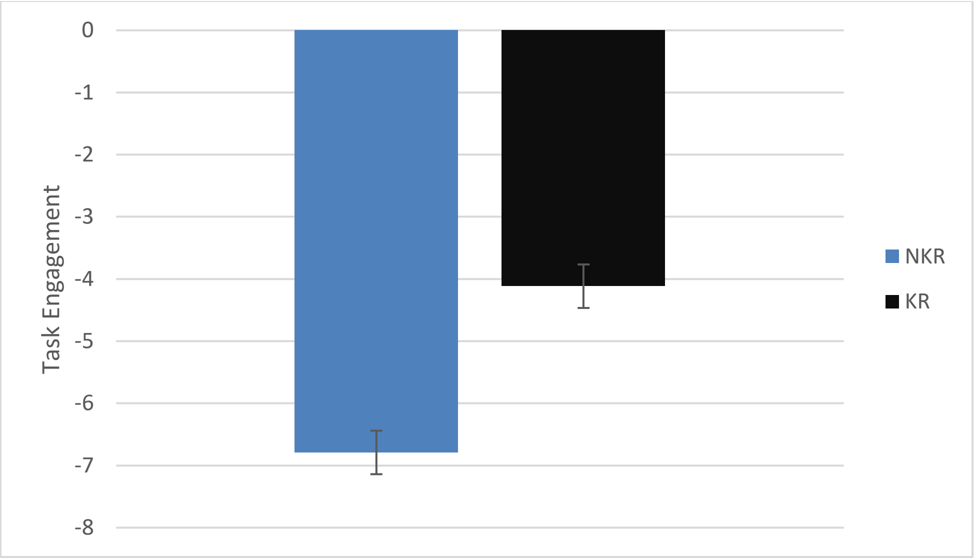


Figure 22. Task Engagement difference scores for the KR and No KR groups following transfer.

Distress

Analyses revealed Levene's test for Equality of Error Variances was violated for post-task distress (*F* [1,120] = 3.003, *p* = .033). As such, a one-way ANOVA with a Brown-Forsythe correct was used to analyze post-task distress. A significant effect for distress following the transfer vigil, such that distress scores fell following transfer for those who did not receive practice, but rose for those who did receive practice (*F* [1, 120] = 4.107, *p* = .045). These findings can be found in Figure 23. No other main effects or interactions were found for distress during the transfer vigil.

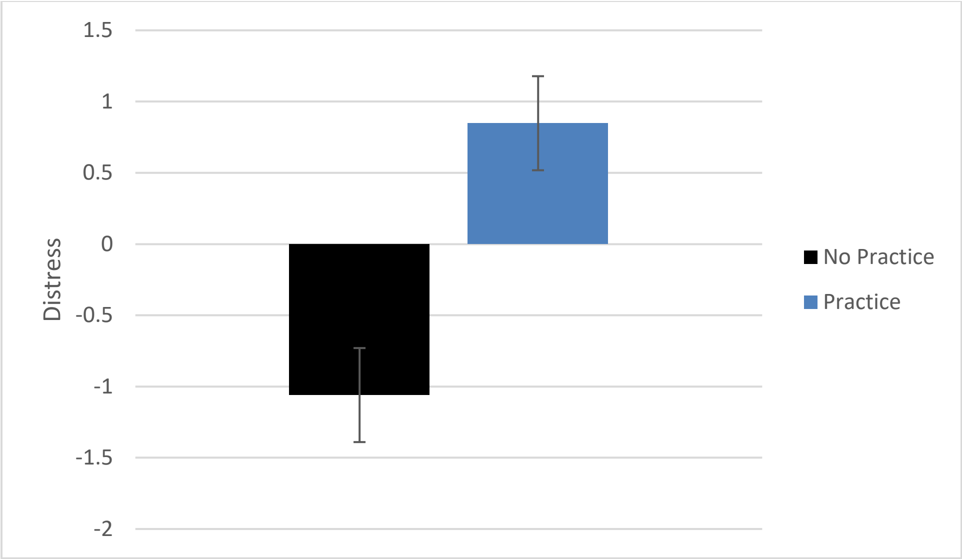


Figure 23. Distress difference scores for the Practice and No Practice groups following transfer.

Mental Workload: Transfer

Analyses did not reveal significant differences in global mental workload following the transfer vigil as measured by the NASA-TLX. Examination of the six NASA-TLX scales, however, did reveal differences for the Frustration scale for both the Practice and KR variables. Those who received practice prior to the training vigil reported lower levels of frustration than those who did not receive practice (F [1,122] = 4.916, p = .028, η^2 = .039). Additionally, those who received KR during the training vigil reported lower levels of frustration than those who did not receive KR (F [1,122] = 5.848, p = .017, η^2 = .046). These results can be found in Figure 24 and 25, respectively. No other main effects or interactions were found for mental workload during the transfer vigil.

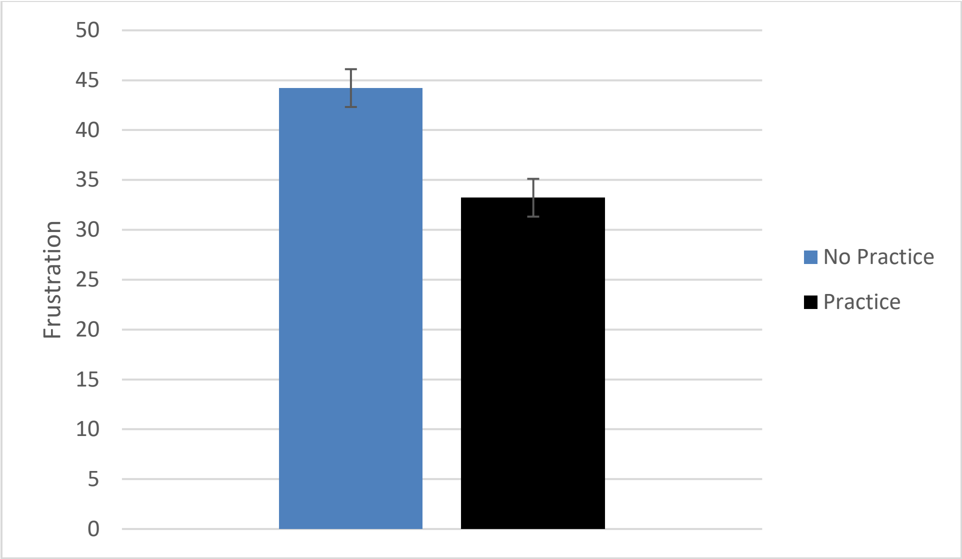


Figure 24. Frustration scores for the Practice and No Practice groups following transfer.

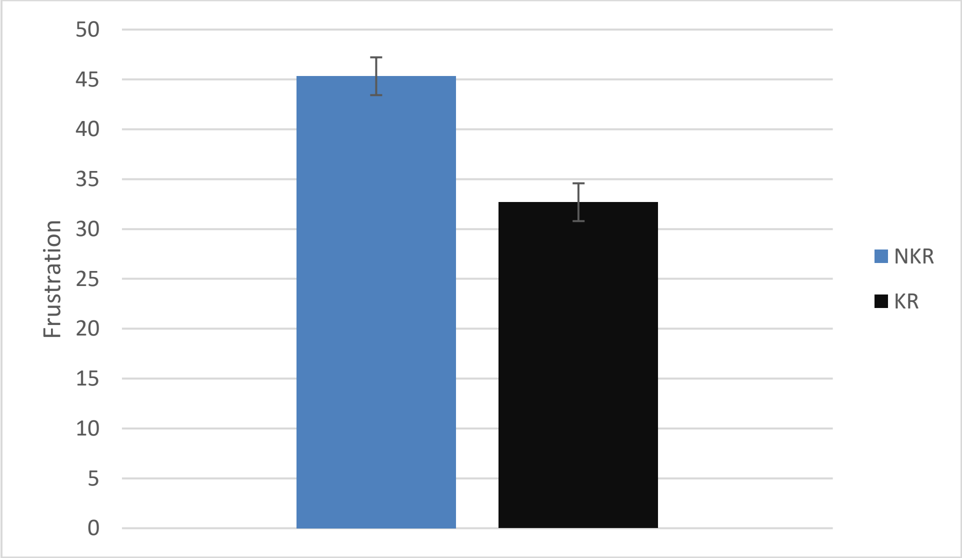


Figure 25. Frustration scores for the KR and No KR groups following transfer.

Study 2

Descriptive Statistics

One hundred and nineteen observers were recruited from SONA to take part in Study 2 (72 females, 47 males). Observers ranged in age from 17 to 49 with a mean age of 20.51 (*SD* = 4.56).

Vigilance Performance: Training

Correct Detections

There was a significant main effect for period on watch on proportion of correct detections during training collapsed across all groups (F [1,116] = 9.446, $p = .003$, $\eta^2 = .075$). As shown in Figure 26, observers made fewer correct detections in Period 2 compared to Period 1. No other main effects or interactions were found for proportion of correct detections during the training vigil.

False Alarms

There was a significant main effect for period on watch on false alarms during training collapsed across all groups (F [1,116] = 7.542, $p = .007$, $\eta^2 = .061$). As shown in Figure 26, observers committed fewer false alarms in Period 2 compared to Period 1. No other main effects or interactions were found for false alarms during the training vigil.

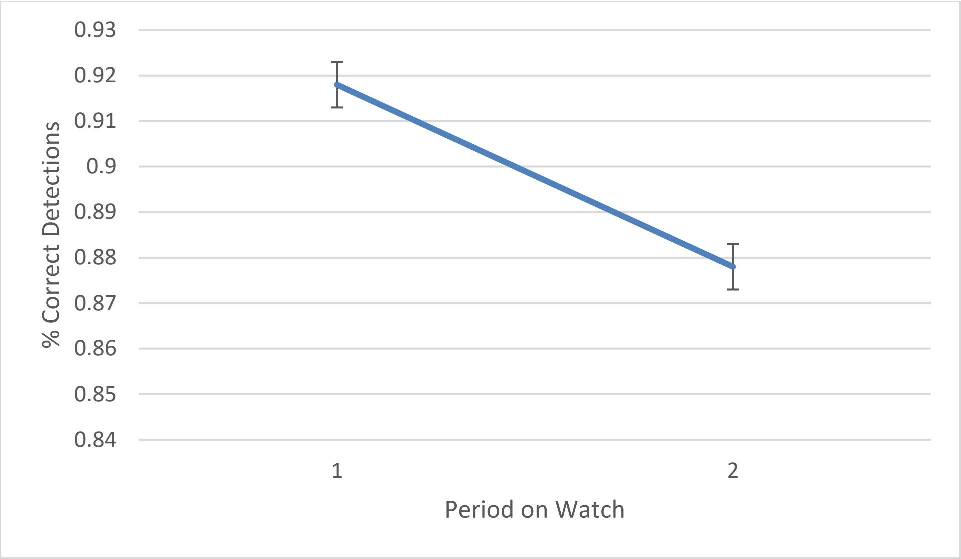


Figure 26. Proportion of correct detections during the training vigil, collapsed across all groups.

Sensitivity

There were no significant main effects or interactions for sensitivity in the training vigil.

Response Bias

There was a significant main effect for period on watch on response bias during training collapsed across all groups (*F* [1,115] = 15.984, $p < .0005$, $\eta^2 = .122$). As shown in Figure 28, observers displayed a more conservative response criterion in Period 2 compared to Period 1.

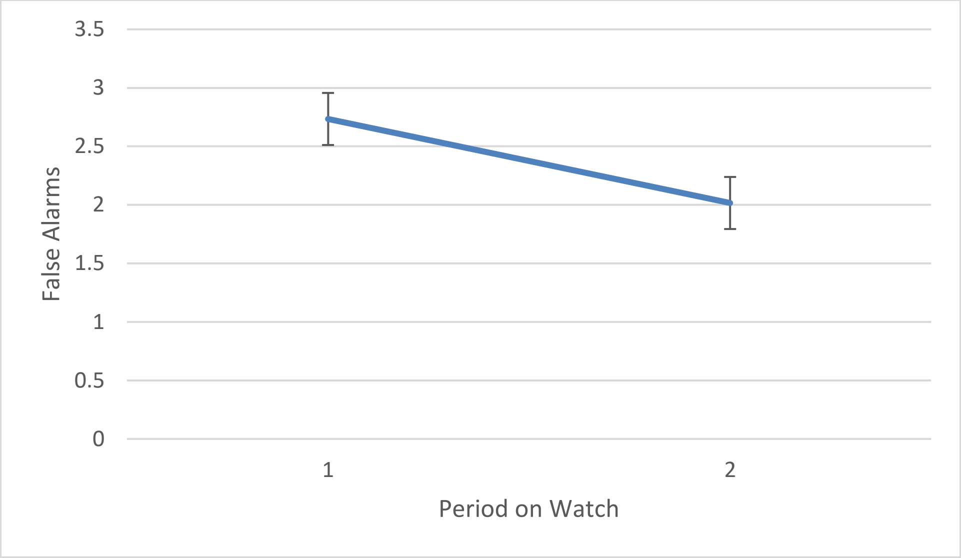


Figure 27. False alarms during the training vigil, collapsed across all groups.

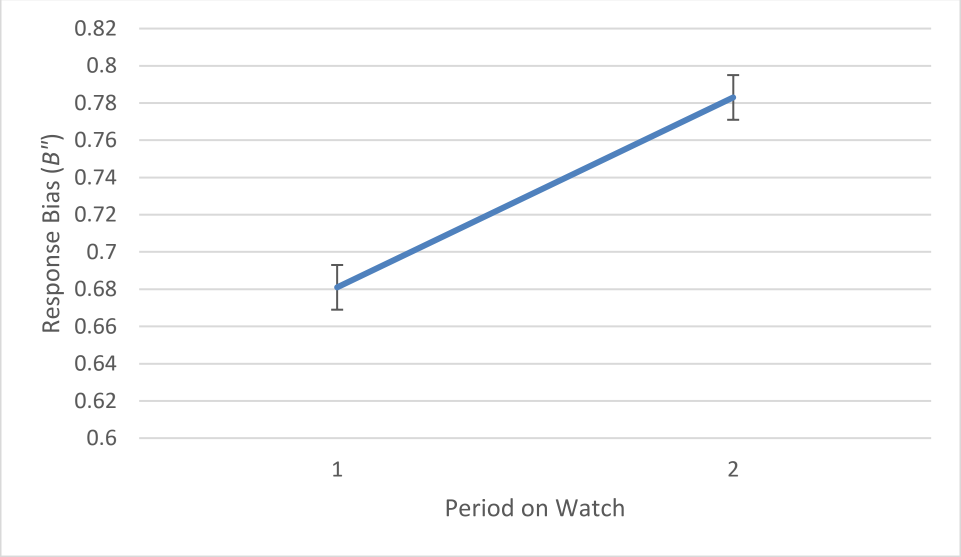


Figure 28. Response Bias, as measured by *B”*, during the training vigil, collapsed across all groups.

Stress: Training

There were no significant main effects or interactions following the training vigil.

Mental Workload: Training

Analyses of NASA-TLX data following the training vigil reveal a significant difference for global mental workload in the practice condition, as those who received mere exposure to the stimuli prior to the training vigil reported higher global mental workload than those who received practice (*F* [1,109] = 5.054, *p* = .027, η^2 = .044). These results can be found in Figure 29.

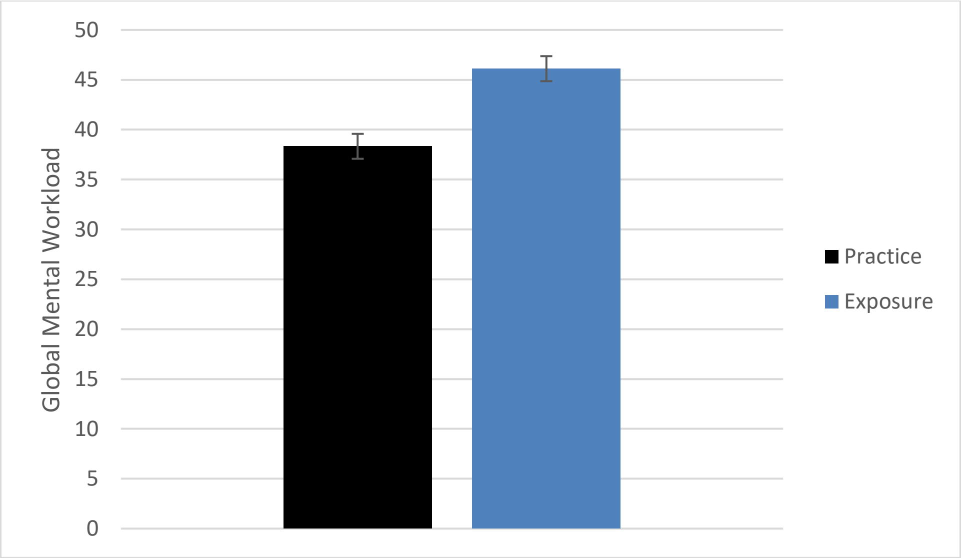


Figure 29. Global mental workload scores for the Practice and Exposure groups following the training vigil.

Additionally, examination of the six NASA-TLX scales revealed a significant difference for the Mental Demand scale, such that those who received practice prior to the training vigil reported lower levels of mental demand than those who received exposure to the stimuli (*F*

[1,108] = 7.769, p = .006, η^2 = .067). These results can be found in Figure 30. No other main effects or interactions were found for mental workload during the training vigil.

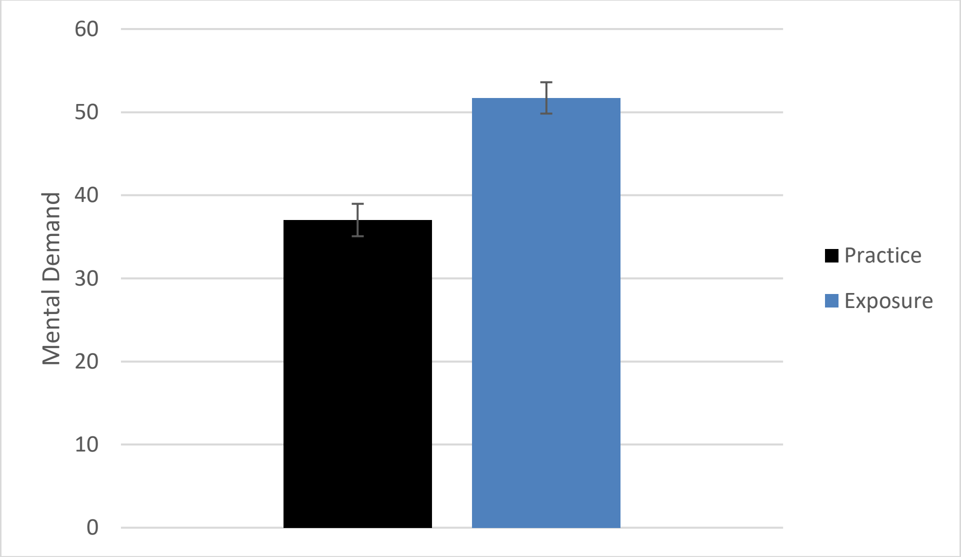


Figure 30. Mental Demand scores for the Practice and Exposure groups following the training vigil.

Vigilance Performance: Transfer

Correct Detections

There were no significant main effects or interactions for proportion of correction detections in the transfer vigil.

False Alarms

There were no significant main effects or interactions for false alarms detections in the transfer vigil.

Sensitivity

There were no significant main effects or interactions for sensitivity in the transfer vigil.

Response Bias

Sphericity was violated with regard to period on watch ($\chi2$ (9) = 32.338, p < .0005). As such, this analysis made use of a Hyunh-Feldt correction. Analyses revealed a main effect for period on watch on response bias, such that observers became more conservative in their responses as time on task increased (*F* [3.571, 440.257] = 3.5326, $p = .012$, $\eta^2 = .028$). These findings can be found in Figure 31. No other main effects or interactions were found for correct detections during the transfer vigil.

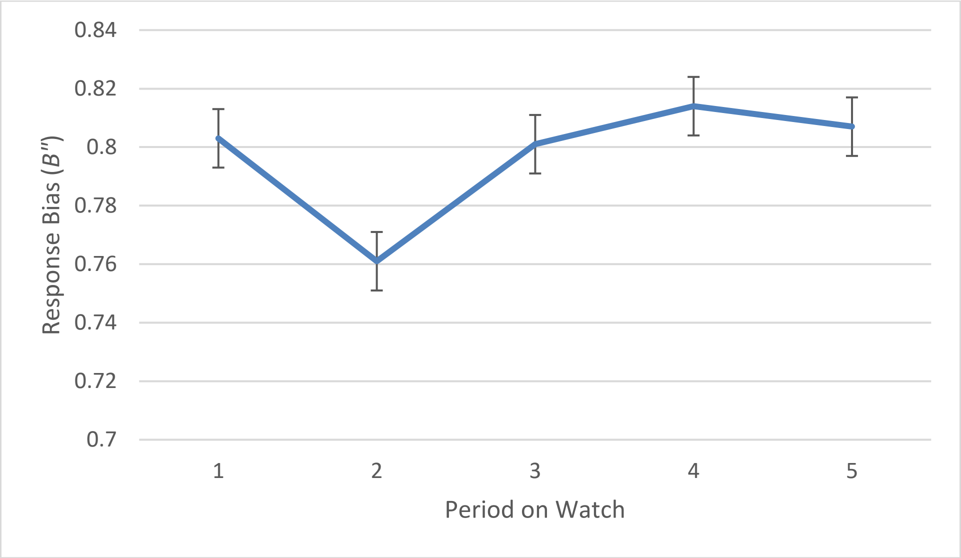


Figure 31. Response bias scores, as measured by *B''*, for the transfer vigil, collapsed across all groups.

Stress: Transfer

There were no significant main effects or interactions following the training vigil.

Mental Workload: Transfer

Analyses of NASA-TLX data following the transfer vigil reveal a significant difference for global mental workload in the practice condition, as those who received mere exposure to the stimuli prior to the training vigil reported higher global mental workload following the transfer vigil than those who received practice (*F* [1,105] = 8.240, *p* = .005, $\eta^2 = .073$). These results can be found in Figure 32.

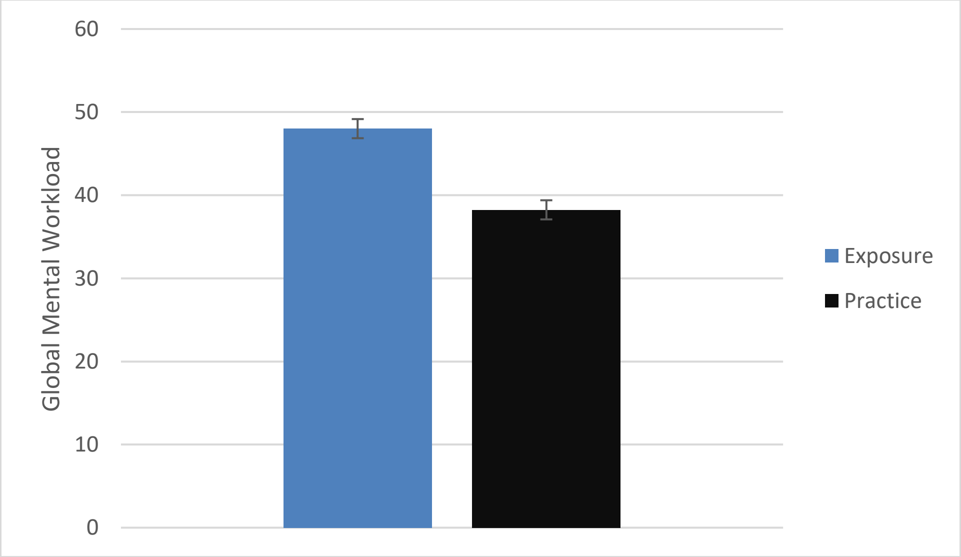


Figure 32. Global mental workload scores following transfer for the Practice and Exposure groups.

Additionally, examination of the six NASA-TLX scales revealed significant differences for mental demand for both practice and KR. For the Practice condition, those who received practice prior to the training vigil reported lower levels of mental demand than those who received exposure to the stimuli (*F* [1,105] = 13.182, *p* < .0005, $\eta^2 = .112$). These results can be found in Figure 33. For KR, those who received KR during the training vigil reported lower levels of mental demand following the transfer vigil than those who did not receive KR during training (*F* [1,105] = 4.250, *p* = .042, η^2 = .039). These results can be found in Figure 34.

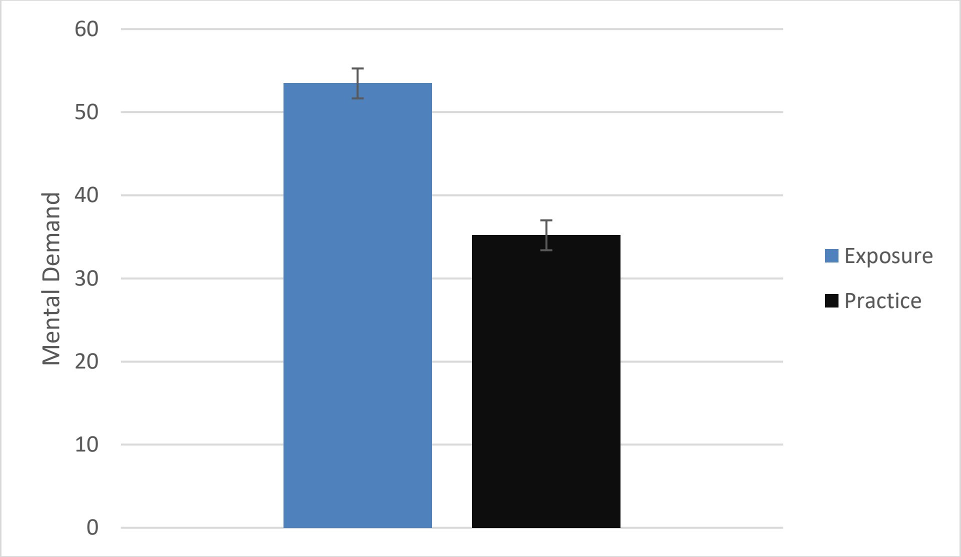


Figure 33. Mental Demand scores following transfer for the Practice and Exposure groups.

Finally, examination of the Effort scale of the NASA-TLX revealed a significant difference between the Practice and Exposure groups such that observers who received practice prior to the training vigil reported lower ratings of Effort following transfer than those who received exposure to the stimuli (*F* [1,105] = 11.649, *p* = .001, η^2 = .100). These findings can be found in Figure 35. No other main effects or interactions were found for mental workload during the transfer vigil.

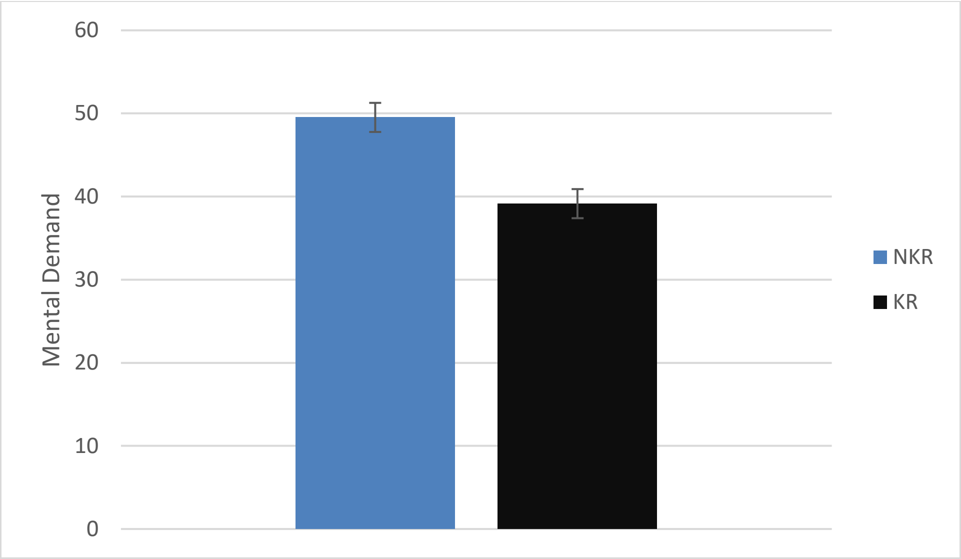


Figure 34. Mental Demand scores following transfer for the KR and No KR groups.

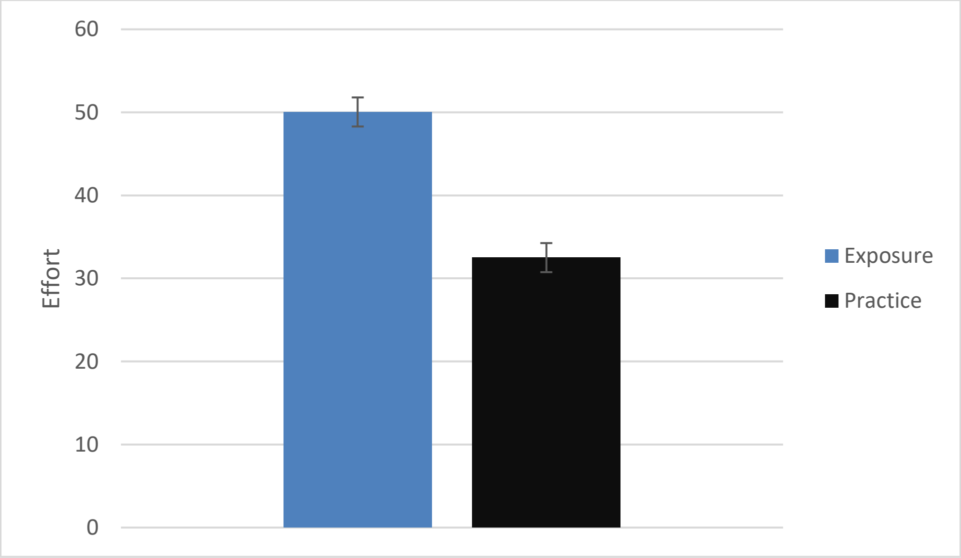


Figure 35. Effort scores following transfer for the Practice and Exposure groups.

Study 3

Preliminary Data for Lexical Task

In order to equate the stimuli for the lexical task with those of the digit task, a preliminary experiment was run to test observers' ability to discriminate two-letter words from two-letter non-words. Ten observers (six females, four males) were recruited from SONA to take part in this preliminary experiment. Observers ranged in age from 18 to 23 with a mean age of 18.60 (*SD* = 1.49). Observers completed a vigil identical in duration and stimulus duration to the transfer vigils utilized in Studies 1 and 2. Twenty distinct two-letter words were used as critical signals. For the critical signals, any stimulus that was not correctly detected at a rate of 70% was not used in Study 3. Instead, these stimuli were replaced by critical signals that were correctly detected at least 70% of the time. Likewise, any neutral stimuli that were incorrectly identified more than 10% of the time by observers were excluded. In sum, three critical signals ("go," "oh," and "ad") were removed from use in Study 3. No neutral stimuli were removed. A list of the 17 critical signals used in Study 3 can be found in Appendix C.

Descriptive Statistics

One hundred and thirty nine observers were recruited from SONA to take part in Study 3 (84 females, 55 males). Observers ranged in age from 16 to 38 with a mean age of 18.45 (*SD* = 2.03).

Vigilance Performance: Training

Correct Detections

There was a significant main effect for training on proportion of correct detections during training, such that those who received digit exposure prior to the training vigil correctly detected a higher proportion of critical signals than those who received lexical exposure (*F* [1,135] = 4.065, *p* = .046, η2 = .029). These findings can be found in Figure 36. Additionally, there was a significant main effect for KR on proportion of correct detections during training, such that those who received KR during the training vigil correctly detected a higher proportion of critical signals than those who did not receive KR (*F* [1,135] = 5.045, *p* = .026, η2 = .036). These findings can be found in Figure 37. No other main effects or interactions were found for proportion of correct detections during the training vigil.

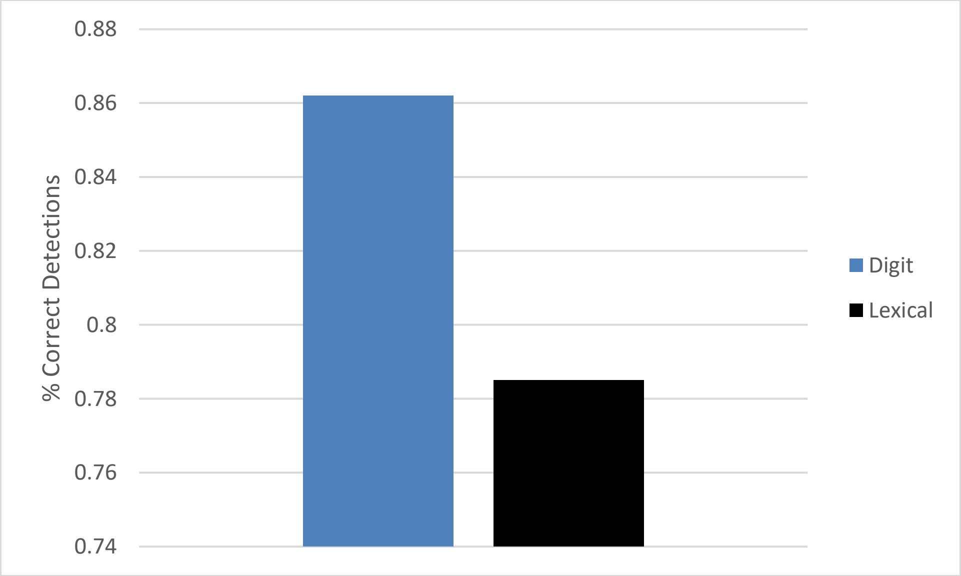


Figure 36. Proportion of correct detections during training for the Digit and Lexical conditions.

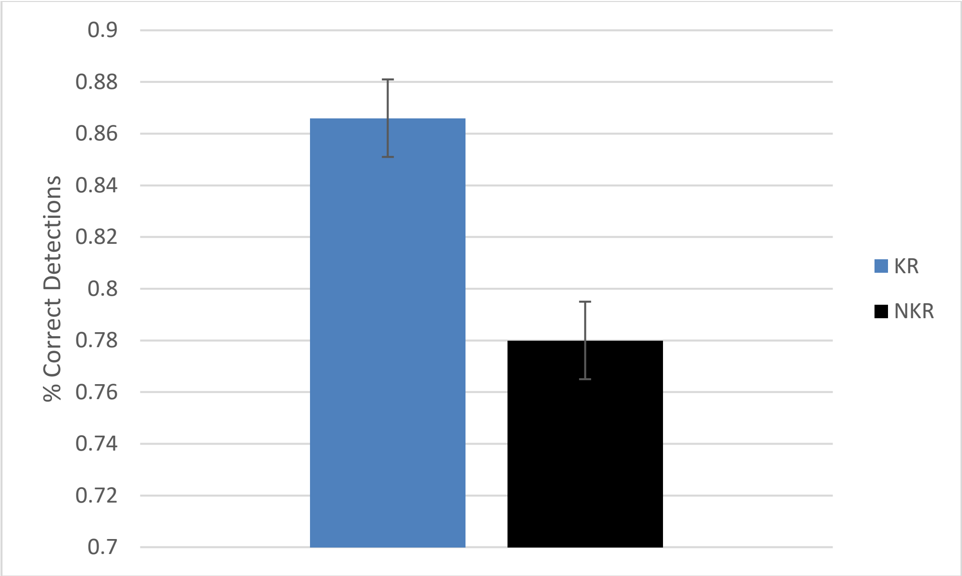


Figure 37. Proportion of correct detections during training for the KR and No KR conditions.

False Alarms

There was a significant main effect for period on watch on false alarms during training collapsed across all groups (*F* [1,135] = 4.205, *p* = .042, η^2 = .030). As shown in Figure 38, observers committed fewer false alarms in Period 2 compared to Period 1. No other main effects or interactions were found for false alarms during the training vigil.

Sensitivity

There were no main effects or interactions were found for sensitivity during the training vigil.

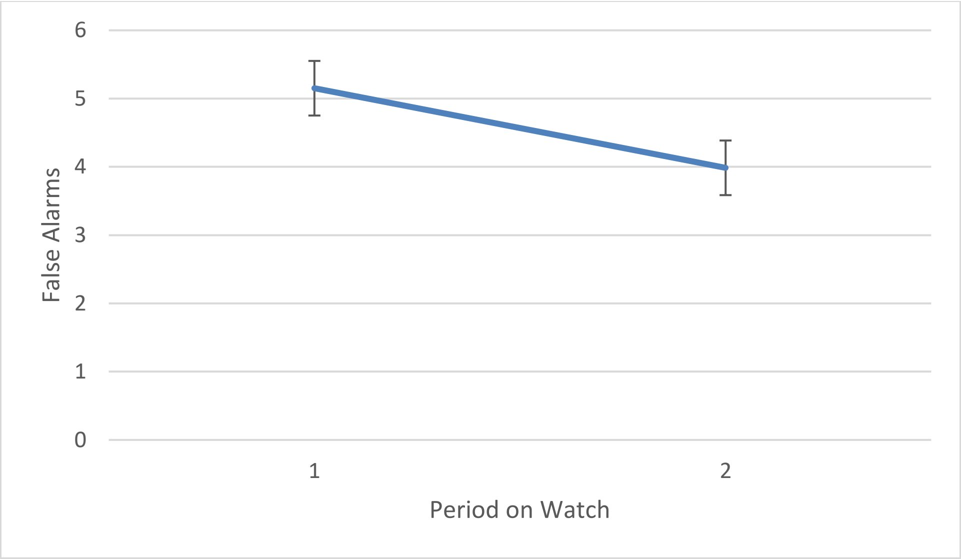


Figure 38. False alarms during training, collapsed across groups.

Response Bias

There was a significant main effect for period on watch on response bias during training collapsed across all groups (F [1,135] = 20.742, $p < .0005$, $\eta^2 = .133$). As shown in Figure 39, observers displayed a more conservative response criterion in Period 2 compared to Period 1. No other main effects or interactions were found for response bias during the training vigil.

Stress: Training

There were no significant main effects or interactions following the training vigil.

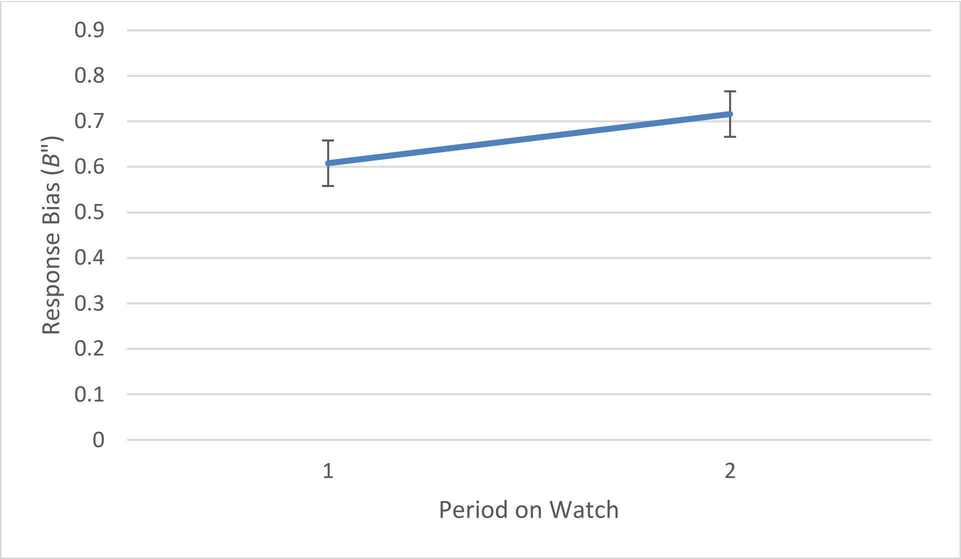


Figure 39. Response bias during training collapsed across all groups.

Mental Workload: Training

Analyses did not reveal significant differences in global mental workload following the training vigil as measured by the NASA-TLX. Examination of the six NASA-TLX scales, however, did reveal a significant difference for the Frustration scale, such that those in the Digit conditions had lower ratings of frustration following training than those in the Lexical group (F [1,116] = 6.288, $p = .014$, $\eta^2 = .051$). These results can be found in Figure 42. No other main effects or interactions were found for mental workload during the training vigil.

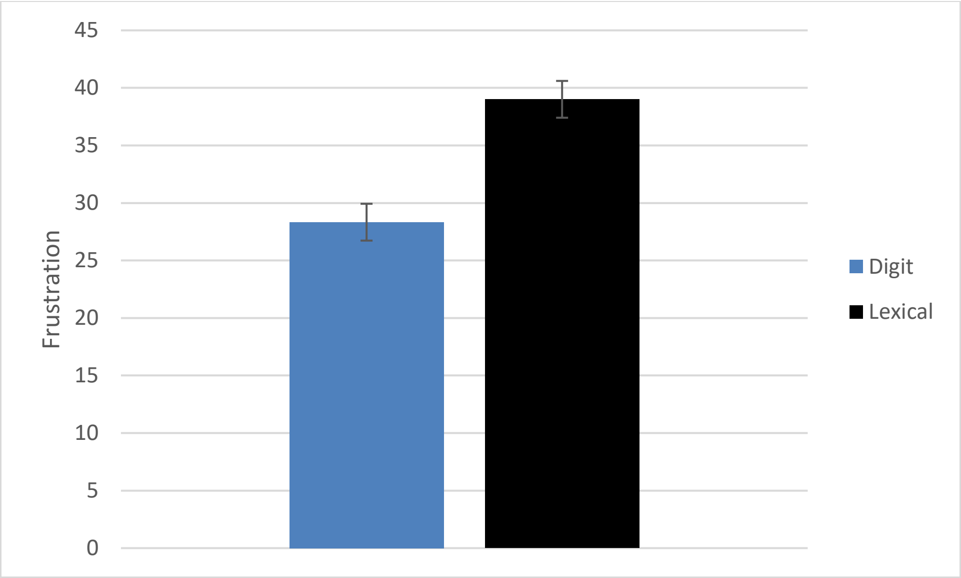


Figure 40. Frustration scores following training for the Digit and Lexical conditons.

Vigilance Performance: Transfer

Correct Detections

There were no significant main effects or interactions for proportion of correction detections in the transfer vigil.

False Alarms

There were no significant main effects or interactions for false alarms in the transfer vigil.

Sensitivity

Analyses revealed a significant main effect for sensitivity in the transfer vigil, such that observers in the lexical task exposure condition were better able to distinguish signal from noise during the transfer vigil than observers in the digit task exposure condition (F [1,135] = 4.387, p = .038, η^2 = .031). These results can be seen in Figure 41.

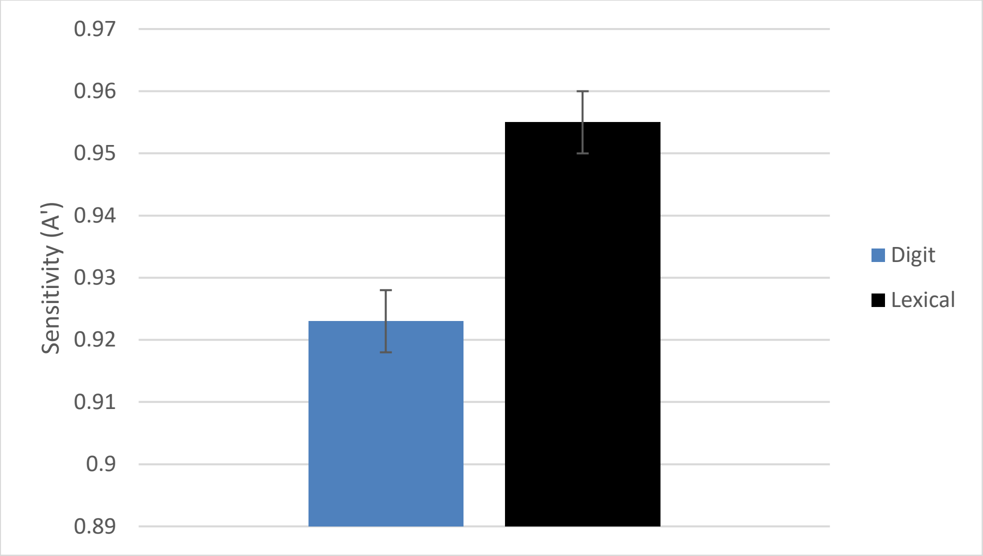


Figure 41. Sensitivity during the transfer vigil for the Lexical and Digit conditions.

Response Bias

There were no significant main effects or interactions for response bias in the transfer vigil.

Stress: Transfer

Analyses for task engagement differences scores from post-training to post-transfer revealed a trend toward an interaction between the training and KR conditions (F [1,132] = 3.533, p = .062, η^2 = .026). Following the transfer vigil, observers in the lexical exposure condition who did not receive KR reported a greater drop in task engagement than those who did receive KR. Conversely, observers in the digit exposure condition who received KR reported larger declines in task engagement than observers who did not receive KR. These findings can be found in Figure 42.

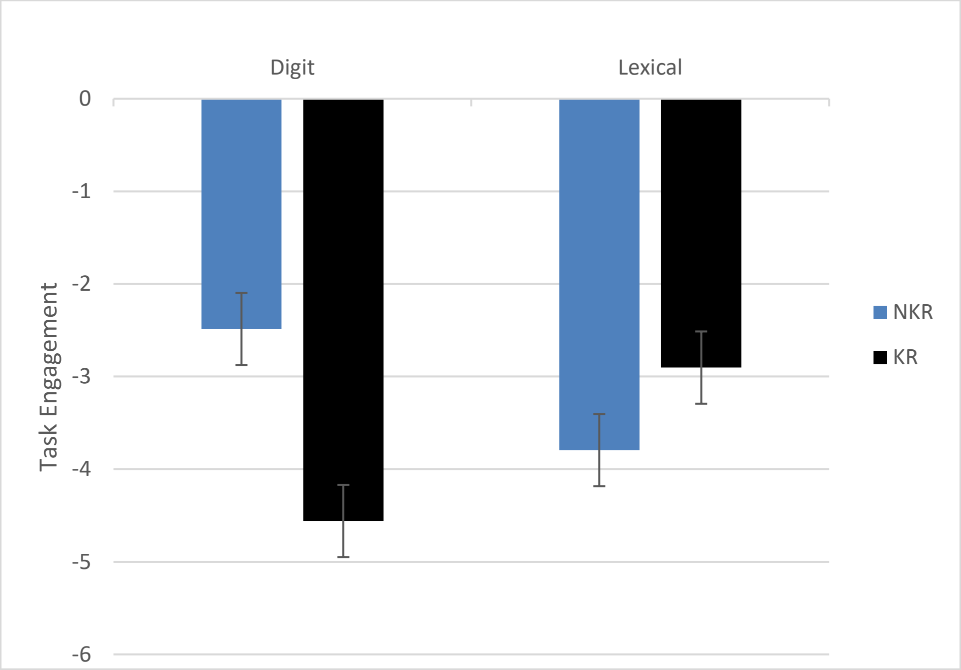


Figure 42. Task engagement difference scores from post-training to post-transfer for the Training and KR conditions.

In addition to the interaction for task engagement, analyses revealed an interaction for distress difference scores from post-training to post-transfer (F [1,132] = 4.873, p = .029, η^2 = .036). For observers in the lexical exposure condition, those who received KR reported a decrease in distress from training to transfer, whereas observers who did not receive KR reported a slight increase in distress. Conversely, observers in the digit exposure condition who received KR reported a greater increase in distress than those who did not receive KR. These findings can be found in Figure 43.

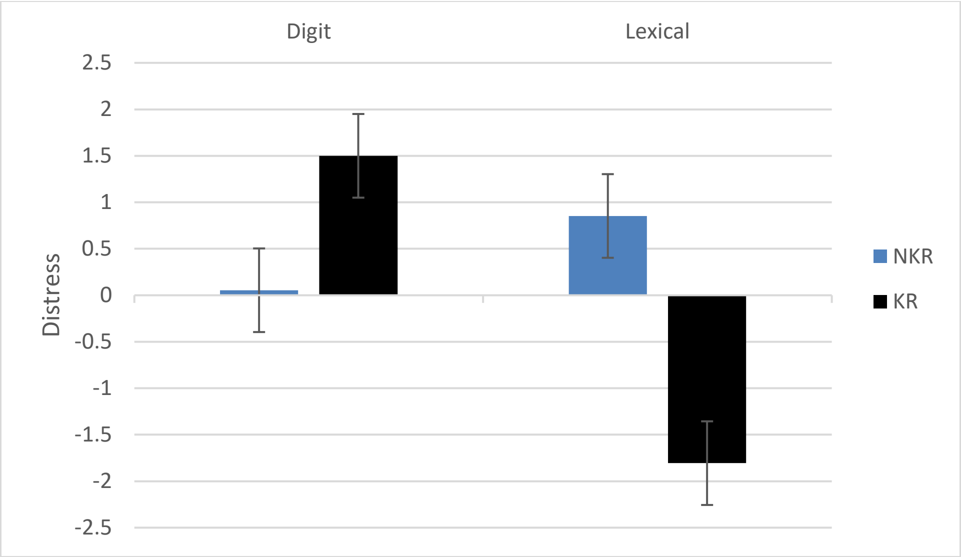


Figure 43. Distress difference scores from post-training to post-transfer for the Training and KR conditions.

Mental Workload: Transfer

Analyses revealed no main effects or interactions for global mental workload following the transfer vigil. Further examination of the NASA-TLX scales, however, revealed an interaction for the Frustration scale (F [1, 134] = 5.978, p = .016, η^2 = .043). It was found that observers in the lexical exposure condition who received KR reported lower levels of frustration than those who received KR. Conversely, observers in the digit exposure condition who received KR reported higher levels of frustration than those who did not receive KR. These findings can be seen in Figure 44.

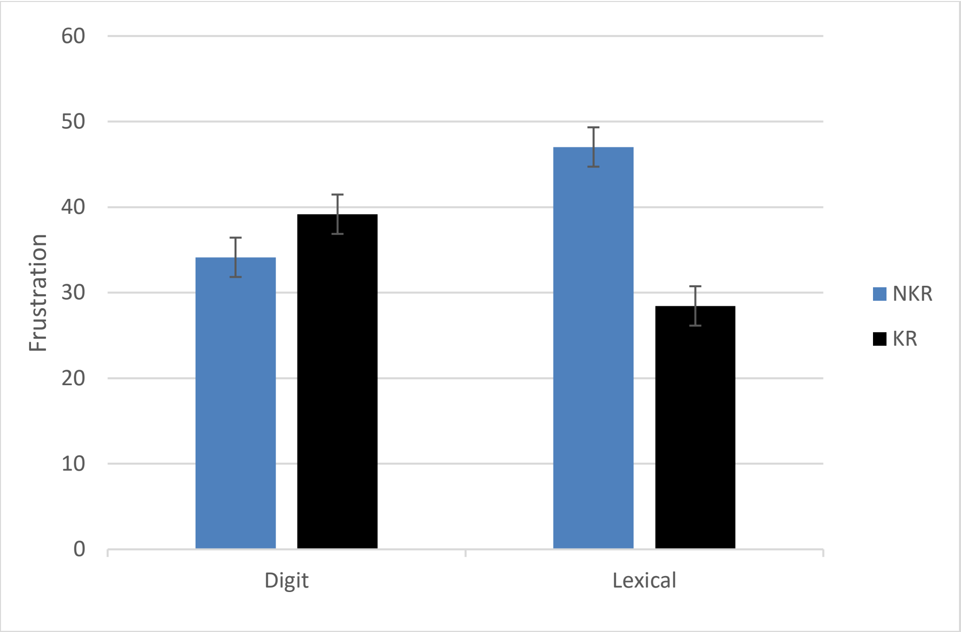


Figure 44. Frustration scores following the transfer vigil for the Training and KR conditions.

CHAPTER 5: DISCUSSION

Since World War II, vigilance research has sought to understand the variables that may contribute to performance declines during long duration tasks. The field has made considerable progress in that time, marked by the development of a taxonomy explaining reliable experimental manipulations (Davies & Parasurman, 1977), as well as a host of training techniques designed to ameliorate performance decrements (Szalma et al., 2006). Knowledge of results (KR) training is one of the most common training techniques in this field. Providing observers with information regarding the validity of their responses has been shown to improve performance (Becker et al., 1994; Szalma et al., 1999), as well as provide positive influence on observers' subjective states (Becker et al., 1995; Warm et al., 1996).

Despite the extensive literature of sustained attention tasks utilizing KR for training, little is understood about the mechanisms by which KR improves objective and subjective performance on vigilance tasks. Kluger and DeNisi (1996) provided a framework for research involving feedback with their Feedback Intervention Theory, touting the importance of higher-level motivational effects feedback may accentuate. This dissertation was developed with FIT in mind, highlighting the potential benefits KR may bring not only to task-learning, but also to motivation, goal setting, and task coping.

The central research questions for this dissertation asked: "does KR training improve performance through learning to distinguish signals from non-signals, or are improvements based on individuals' acclimating to task parameters other than signal discrimination, such as event rate, source complexity, or their own feelings of fatigue and motivation?"; if signal and non-signal discrimination can be taught more briefly, can this be done in a relatively-passive manner that will not tax observers' stress and mental workload?"; and "if this process can be completely passively, will it then transfer to a different task?" I sought to answer this question by isolating the learning process for signal and non-signal discrimination. This dissertation examined these research questions through manipulations of KR and what I termed "pre-vigil training." This pre-vigil training included a 2AFC task, where observers gained knowledge of critical signals and neutral stimuli, and a brief series of practice trials to show observers how the task would proceed. Drawing from the dissertation's first study, the pre-vigil training was then administered in a manner that would reduce strain on observers by removing the need to respond during training. Unfortunately, findings from the dissertation's three studies do not provide clear answers to either of the key research questions. Specific findings from each of the three studies are discussed in this section, including effects relating to vigilance performance, stress, and mental workload. Furthermore, this section will include discussion of the dissertation's limitations, implications of the work, and possible future directions that could arise from its findings.

Study 1

Before investigating the hypotheses related to Study 1, it is important to note that evidence for the typical vigilance decrement in this study is not clear. Although there was a significant decline in correct detections in both the training and transfer vigils across groups, perceptual sensitivity, as measured by *A'*, did not decrease as a function of time on task in either vigil. This is in stark contrast to other studies using similar task parameters and stimuli (Szalma & Teo, 2012; Fraulini, Claypoole, Dewar, & Szalma, 2016). There was, however, a conservative shift in response bias, as measured by *B"*, across all groups for both the training and transfer vigils.

Study 1 found partial support for hypothesis 1, which predicted that observers receiving pre-vigil training would display higher levels of sensitivity during both training and transfer compared to those who do not receive pre-vigil training. Observers did not differ based on the pre-vigil training variable in their ability to distinguish between signals and non-signals. This may have been due to several reasons. First and foremost, it is possible that this manipulation may not have been strong enough to bring about significant differences between groups. This possibility is further amplified by the fact that observers then completed a training vigil with these same stimuli. Analyses did identify interactions for proportion of correct detections, false alarms, and sensitivity in the transfer vigil. These interactions all supported the claim that KR does provide knowledge of signal vs. non-signal discrimination, as observers who received KR during training in the No Practice condition tended to outperform those who did not receive KR, but this effect did not appear in the Practice condition. Moreover, the pre-vigil training did not appear to provide any added benefit for signal vs. non-signal discrimination above that provided by KR. Therefore, it appears the pre-vigil training this study utilized provided observers similar benefits for signal vs. non-signal discrimination as KR.

Study 1 also did not find support for hypothesis 2, which predicted that observers receiving KR during the training vigil would display a more conservative response criterion during both training and transfer compared to those who do not receive KR during the training vigil. Moreover, there were no significant effects whatsoever for KR as it related to performance in either the training or transfer vigil. There may be several causes for KR's lack of effectiveness. It may be the case that KR may not be providing any additional benefit beyond what is provided by either pre-vigil training or the training vigil itself (i.e. without provision of KR). This would appear to cast doubt upon the propositions of Kluger and DeNisi's (1996) FIT, which argued in favor of the motivational benefits of KR beyond knowledge relating to signal vs. non-signal discrimination. Another possibility, however, is that observers may not have been sufficiently motivated by the task to engage in task-motivational processes. It has been proposed that motivation is a neglected concept when it comes to human factors research (Hancock, 2017; Szalma, 2014). It very well may be the case that while motivation itself was a key component of this hypothesis, the task and its parameters themselves did not elicit activation of these higher-level processes.

In addition to Study 1's hypotheses relating to vigilance performance, there were hypotheses for both independent variables and their potential effects on stress and mental workload. It was hypothesized that observers completing the pre-vigil training would report lower levels of stress, as measured by the short-form DSSQ, both post-training and post-transfer than observers who did not complete pre-vigil training. Specifically, it was believed that observers who received pre-vigil training report higher task engagement and lower distress than their no pre-vigil training counterparts. Partial support for this hypothesis was found. Following training, the no pre-vigil training group reported higher levels of distress than those in the pre-vigil training groups. Surprisingly, though, observers who received pre-vigil training saw their self-reported levels of distress rise post-transfer from their post-training levels, while those in the no pre-vigil training groups saw their self-reported levels of distress decrease. This could be due to multiple reasons. First, it could be that any effect on distress induced by the experimental manipulation during the training vigil has dissipated by the end of the transfer vigil. In other words, both sides may simply be regressing to the mean. Another possibility, though, is that observers in the pre-vigil training groups may be reacting negatively to having that training removed prior to the transfer task. This is contrasted with the no pre-vigil training groups, who never experienced the benefit of this training.

Study 1 also hypothesized that observers receiving KR during training would report lower levels of stress, as measured by the short-form DSSQ, both post-training and post-transfer than observers who did not receive KR during training. I believed this would manifest in higher levels of task engagement and lower levels of distress for observers who received KR during training compared to those who did not receive KR during training. Study 1 found partial support for this hypothesis, as the KR group did report higher levels of task engagement following the transfer vigil than the No KR group. Despite this finding, there may have been reasons why this hypothesis was not completely supported. As Kluger and DeNisi (1996) reported, nearly a third of studies reporting the use of feedback found no benefit to its use. It may have been the case here that observers did not require KR to understand the task's event and signal rates, which would diminish KR's effectiveness. Also, there may have been crossover between the two experimental manipulations in the effects they had in acclimating observers to the task. Although KR and the pre-vigil training should be affecting observers' learning in different ways, there may be overlap that clouds differentiation for subjective factors for stress.

In addition to hypotheses relating to stress, Study 1 proposed a series of hypotheses for ratings of mental workload as measured by the NASA-TLX. Study 1 hypothesized that observers receiving KR during training or pre-vigil training would report lower levels of mental workload, as measured by the NASA-TLX, both post-training and post-transfer than observers who did not receive either KR during training or pre-vigil training, respectively. Hypotheses relating to mental workload were partially supported by the Study 1 results. Neither the KR nor pre-vigil training manipulations results in significant differences in global mental workload for either the training or transfer vigils. Further examination of the NASA-TLX scales, however, indicated significant differences for the Frustration scale for both experimental manipulations. Observers who received KR during training or pre-vigil training reported lower levels of Frustration following the transfer vigil than those who did not receive either KR during training or pre-vigil training, respectively. Findings relating to Frustration are especially intriguing, as this scale is considered a driver of high mental workload in vigilance tasks (Warm et al., 1996). It appears that both manipulations eased observers' feelings of frustration, which is consistent with other earlier findings in vigilance (Becker, Warm, Dember, & Parasuraman, 1991; Warm, Dember, Parasuraman, 1991). While these deficits in frustration were not necessarily paired with declines in performance on either vigil, they may reflect drops in cognitive resource capacity that may indicate a vulnerability to performance declines (Yeh & Wickens, 1988).

Study 2

Much like Study 1, the results from Study 2 do not provide clear evidence for the vigilance decrement across all observers. Study 2 found no significant effects of period on sensitivity, as measured by *A'*, when collapsed across all observers. This study did find main effects, however, for response bias, such that observers displayed a more conservative response bias a function of time on task in both the training and transfer vigil.

Study 2 found evidence to support hypothesis 1, which predicted that observers receiving exposure to the pre-vigil training would not display higher levels of sensitivity during both training and transfer compared to those who were forced to actively respond to the pre-vigil training. Observers did not differ based on the pre-vigil training variable in their ability to distinguish between signals and non-signals. These results are encouraging for the use of exposure as a method of teaching observers the differences between sets of signals and non-signals, as they provide evidence that actively responding to both the 2AFC and practice trials did not add any additional benefit for the transfer vigil. Again, the possibility exists that observers gained equivalent knowledge of signal vs. non-signal discrimination from completing the training vigil rather than through this pre-vigil variable. Even in this event, though, it is encouraging for this type of manipulation that differences in sensitivity were not found for active responding and mere exposure.

Study 2 also did not find support for hypothesis 2, which predicted that observers receiving KR during the training vigil would display a more conservative response criterion during both training and transfer compared to those who do not receive KR during the training vigil. Moreover, there were no significant effects whatsoever for KR as it related to performance in either the training or transfer vigil. Again, as in Study 1, it may be the case in Study 2 that KR may not be providing any additional benefit beyond what is provided by either pre-vigil training or the training vigil itself. This raises potential questions involving both the propositions set forth by Kluger and DeNisi (1996) about feedback and higher-level processing, as well as the task's ability to elicit those degrees of cognitive monitoring. It very well may be the case that while motivation itself was a key component of this hypothesis, the task and its parameters themselves did not bring about activation of these higher-level processes. In order to examine this proposition more closely, a set of hypotheses was developed to assess KR's effect on both mental workload and stress.

Study 2 found partial support for predictions relating KR and effects on mental workload and stress. I predicted that observers receiving KR during the training vigil would report higher levels of task engagement and lower levels of distress post-training and post-transfer, as measured by the short-form DSSQ, than those observers who did not receive KR training. Additionally, I predicted that observers receiving KR during the training vigil would report lower levels of mental workload than observers who did not receive KR during the training vigil. Unfortunately, the current data and analyses did not provide support for the hypotheses linking KR and perceived stress. This finding conflicts with the findings relating to KR from Study 1, where observers who received KR during training report a lower drop in task engagement post-transfer than observers who did not receive KR. These findings from Study 2 do not support to the model set forth by Kluger & DeNisi (1996), where the authors discuss the positive effects of feedback as they relate to operators' subjective feelings toward the task. This may be reflective of the hit-or-miss nature of KR as a training method in general, where Kluger & DeNisi (1996) noted that feedback was not beneficial for observers in approximately one third of experimental studies. For mental workload, observers who did not receive KR during training reported higher levels of mental demand than observers who received KR, which aligns with resource depletion accounts of vigilance.

Regarding subjective effects of exposure training, Study 2 hypothesized effects for both mental workload, as measured by the NASA-TLX, and perceived stress, as measured by the short-form DSSQ. For mental workload, it was hypothesized that observers who received exposure training prior to the training vigil would experience lower levels of global mental workload both post-training and post-transfer than those observers who did not receive exposure training. The reason for this prediction was I believed the active component of responding to stimuli during practice would elicit higher feelings of mental workload than merely observing stimuli as they are presented on a screen. Unfortunately, this was not the case, as observers in the exposure condition reported higher levels of global mental workload post-training and post-transfer than observers in the practice condition. Further analyses of the NASA-TLX scales indicated that observers in the exposure condition also reported higher levels of mental demand post-training and post-transfer than observers in the practice condition, as well as higher ratings of effort. These findings indicate the exposure condition imposed a greater degree of mental workload on observers than the practice conditions, which required observers to actively respond to stimuli. It may be the case that not responding to stimuli imposes a toll during knowledge acquisition. Observers may be finding it more draining mentally to retain knowledge about signals and non-signals without the act of responding. Conversely, the action associated with responding to stimuli during this phase of the experiment may provide some benefit to encoding stimuli information. Regardless, the mental workload findings from Study 2 do not support the use of the exposure process as a training method for vigilance.

Study 2 revealed no significant effects for perceived stress following either the training or transfer vigil for the pre-vigil training condition. Therefore, the findings for Study 2 did not provide support for the hypothesis that proposed observers receiving exposure training would experience higher levels of self-reported task engagement and lower levels of distress post-training and post-transfer than those who do not receive exposure training. Unlike findings for mental workload, which appeared to show that observers in the exposure experienced greater degrees of resource depletion as a result of receiving the exposure training, findings from the short-form DSSQ do not show subjective benefits or decrements associated with subjective ratings of stress. These conflicting results may be due to the strength of the manipulation. While the practice and exposure processes both take place early in the experiment, they do not last nearly as long as either the training or transfer vigils. Thus, the effects of this manipulation may not have been strong enough to affect ratings of stress taken following the longer training and transfer vigils.

Study 3

Much like Studies 1 and 2, the results from Study 3 do not provide clear evidence for the vigilance decrement across all observers. Study 3 found no significant findings for correct detections or sensitivity, as measured by *A'*, when collapsed across all observers. This study did find a main effect in the training vigil, however, for response bias, such that observers displayed a more conservative response bias a function of time on task.

Study 3 examined whether the exposure condition, which was shown to elicit equivalent results for vigilance performance compared to the active practice condition, could be used to train observers for a different transfer task than they received during the training vigil. The findings for Study 3 did provide support for hypothesis 1, which proposed that sensitivity on the transfer task would be greater for observers receiving exposure to the lexical task stimuli than observers receiving exposure to the digit task stimuli. This finding indicates that exposing observers to a different task than the task on which they are trained increases vigilance performance on the exposed task. Historically, research examining transfer of training in vigilance has produced mixed results (Becker et al., 1994; Szalma et al., 1999). Though I expected to find a benefit for exposing observers to the new task prior to the training vigil, this may have been caused in part by psychophysical differences between the two tasks. Although steps were taken in this study to calibrate the discrimination difficulty in the lexical task to be equivalent to that of the digit task, no direct comparison was made to examine difficulty between the two tasks (e.g. a 2-AFC task). Thus, this study cannot demonstrate with certainty that these two tasks, though utilizing different methods of discrimination, are similar in terms of overall difficulty.

In addition to hypotheses in Study 3 relating to vigilance performance for the transfer task, I also hypothesized observers exposed to the transfer task prior to the training vigil would report lower levels of stress and mental workload following the training and transfer vigils than observers not exposed to the transfer task. Similar to the previous hypothesis for sensitivity, the results of Study 3 did provide at least partial support the hypotheses for stress and mental workload. While no main effects for the training condition were found, analyses did reveal interactions for task engagement, distress, and frustration following the transfer vigil, such that observers in the lexical condition who received KR during training reported a smaller decline in task engagement and larger decline in distress following the transfer vigil than observers in the lexical task condition who did not receive KR. Conversely, though, observers in the digit task condition who received KR reported a larger decline in task engagement and a smaller decline in distress than those in the digit task condition who did not receive KR. At first glance, this is a confusing pattern of results, as KR appears to assist those in the lexical condition but hurt those in the digit condition. Fortunately, Kluger and DeNisi (1996) offer a potential explanation for this phenomenon, as they posit that the effectiveness of KR may require a referent to the correct response in order for the user to adequately learn the task. In the current study, the lexical task condition provided the opportunity for observers to see the lexical task stimuli prior to completing the transfer vigil. Thus, observers who received KR in this condition may have benefited from being exposed to the transfer task stimuli, despite the fact that KR was provided for a separate task. This was not the case for the digit task condition, though, where observers would not have been able to combine KR with the lexical task stimuli.

Like Studies 1 and 2, Study 3 hypothesized that observers receiving KR during the training vigil would display a more conservative response bias during the training and transfer vigils than observers who did not receive KR during the training vigil. This hypothesis was not supported, as there were no differences found in either vigil for response bias. Additionally, no differences were found following both the training and transfer vigils for stress or mental workload. Thus, it does not appear that providing KR during training on one task leads to improvements in performance, stress, and mental workload on a separate task. This could be due to observers' inability to apply knowledge gained from KR for the training task to the novel demands of the two-letter words and non-words employed by the transfer task. Furthermore, much like Study 1, the new transfer task may not have activated observers' senses of motivation and coping that could have benefited from KR. This is an issue that requires more research in the future, as it could represent design flaws that may induce decrements during sustained attention tasks (Hancock, 2013).

General Summary

The current set of studies sought to answer two research questions: is it possible to separate the structural and energetic components of KR by employing multiple training techniques for vigilance; and, can knowledge gained from examining the underlying structures of KR lead to the development of more efficient means of training for vigilance? This dissertation proposed three studies in order to systematically examine these research questions. Study 1 found partial support for hypotheses relating to providing practice over no practice, but more importantly, it helps to distinguish the types of learning that may be occurring during this practice segment compared to KR during training. Providing the type of pre-vigil training employed by Study 1 appears to provide similar structural knowledge, or knowledge relating to signal vs. non-signal discrimination, as KR. Moreover, Study 1 did find benefits relating to task engagement and frustration that were not produced by the pre-vigil training.

Study 2 began the process of answering the second research question, which sought to extend the practice manipulation from Study 1 to develop more efficient training methods for vigilance. Surprisingly, requiring observers to respond to stimuli during practice resulted in lower mental workload than allowing them to passively monitor stimuli presented on a screen. This finding points toward the importance of actively responding during practice, which runs counter to the rationale proposed in the research question. Much like Study 1, these findings did not provide definitive evidence regarding the structural components of the task versus the energetic factors present during vigilance tasks. Study 3 extended the exposure procedure by applying it in a task transfer paradigm. The findings for Study 3 revealed interactive effects for mental workload and stress between the training and KR groups. These interactions showed the advantage of KR for transfer of training when observers are exposed to the stimuli used in the transfer task. These findings represent benefits for providing KR when combined with exposing observers to the transfer task stimuli (i.e. structural knowledge of signal vs. non-signal discrimination).

Limitations

Despite the care taken to design and execute an experimentally-sound sequence of studies, there were limitations to this dissertation that may have adversely affected results. Along these lines, one limitation may have been the strength of the practice sessions as a manipulation, which were one of the studies' primary training manipulations. While the vigilance literature contains numerous examples of practice as means to train for vigilance, the time required to complete either the practice or exposure training (approximately five minutes) may not have been long enough to improve observers' ability to distinguish signals from non-signals in the subsequent training and transfer vigils. This limitation may explain why there was no main effect in Study 1 for sensitivity between the Practice and No-Practice groups in the transfer vigil, as the benefits of this short session prior to the training vigil may not have lasted to the transfer vigil. There were benefits to the practice session for the training vigil, though, as it appeared to hasten task learning relative to not receiving practice. Although this is a limitation to the current project, the duration of the practice session was delicate to control, as making it too long may have caused observers to feel subjective effects of vigilance (increased fatigue, lower task engagement, etc.). As a result, this limitation would have been difficult if not impossible to avoid completely.

Another limitation to this dissertation was that the tasks employed may not have been demanding enough to elicit performance and subjective decrements typically associated with vigilance. I selected the due to its ability in previous studies to induce performance decrements (Fraulini et al., 2016; Szalma & Teo, 2012). Unfortunately, the current three studies did not show a pattern of results consistent with traditional vigilance declines in performance. Additionally, the means for the NASA-TLX post-transfer generally hovered around the midpoint of the scale. Though the training and transfer vigils were shorter than many vigilance tasks, I do not feel duration was the primary cause of this lack of cognitive demand. The transfer vigil for this study was longer than several influential vigilance studies (Nuechterlein, Parasuraman, & Jiang, 1983; Temple et al., 2000) and also employed a high event rate (approximately 30 events per minute), per Parasuraman and Davies' (1977) vigilance taxonomy. The primary reason the previous studies utilizing similar tasks found performance decrements and the current set of studies did not most likely involve the previous studies' use of multiple displays to show the two-digit numbers. Although observers in both studies were directed to one display to monitor for critical signals, the mere presence of irrelevant displays, even though they need not be monitored, may have had an effect on observers' performance over time.

Another key limitation to this dissertation was that the stimuli did not accurately depict events that would occur in the real world. Recently, it has been proposed that the degree to which stimuli and task parameters relate to everyday life may play a role in the reverse of performance decrements in vigilance (Hancock, 2013). Several studies have employed tasks to examine the effects of stereoscopic depth on vigilance performance (Funke et al., 2015; Greenlee et al., 2015). Though the stimuli used here had previously elicited performance decrements, the lack of real-world fidelity may help to explain the current lack of such findings. While there are many situations in which one may be required to add or subtract two numbers, it is not often that American college students are forced to do so consecutively for an hour at a time.

Theoretical and Practical Implications

The findings from this dissertation are informative for vigilance both theoretically and practically. The findings of this dissertation also may be used to guide the application of training for vigilance in the future. Specifically, the similarities produced by the exposure and active practice sessions in Study 2 in terms of sensitivity and response bias reveal that active responding may not be a required component of vigilance training. It appears, though, that the act of responding during training does come at some cost, as observers reported higher levels of subjective mental workload when the requirement to respond was removed. This finding ran counter to my hypothesis for mental workload in Study 2, which proposed that removing the requirement to respond would lessen the load on observers' cognitive resources. The present findings represent a performance-workload insensitivity in which greater effort is expended in order to maintain a stable level of performance (Hancock, 1996; Nelson et al., 1991). Thus, the costs associated mental workload may outweigh the benefits associated with implementing a passive form of training for vigilance.

This dissertation also provides evidence that benefits associated with KR in training for vigilance paradigms extend from traditional sensory-based vigilance tasks to cognitive-based tasks requiring mental manipulation of symbolic or alphanumeric stimuli. In their meta-analysis of the sensitivity decrement in vigilance, See et al. (1995) discuss the efforts by Koelega et al.

(1989) and others to examine the performance decrements in vigilance that may stem from sensory- and cognitive-based discrimination. While these authors report instances in which performance on cognitive-based vigilance tasks elicit improvements in sensitivity rather than typical declines, they do not report on instances in which KR was utilized to train for vigilance in cognitive-based tasks. In the same vein, though early studies using KR to train for vigilance provided evidence for general transfer (Weiner, 1968), later studies provided evidence against general transfer and in support of specific transfer (Becker et al., 1994; Szalma et al., 1999). The current dissertation extends the evidence for specific transfer of training in vigilance to cognitive-based tasks.

Finally, this dissertation has provided evidence that the combination of KR and exposure training for transfer task stimuli can lead to higher rates of correct detections and greater sensitivity in vigilance than exposure training alone. Assuming the exposure training provides observers with structural knowledge of signals and non-signals, the current finding implies that KR adds separate knowledge that observers use to improve performance. This separate knowledge base could include not only task parameters such as signal rate and salience, but also observers' abilities to set goals for the task and regulate mounting levels of fatigue. It is important to note that this additive effect for KR was only found when examining effects for task transfer; when the task employed in the transfer vigil matches that of the pre-vigil training and training vigil (as in the first two studies of this dissertation), no added benefit for KR was observed. Kluger and DeNisi (1996) provide a plausible explanation, linking the benefits of KR to cues within a task that help operators reject incorrect hypotheses regarding the task. Observers in the Study 3 digit task condition were unable to link KR feedback to stimuli used in the transfer vigil, whereas observers in the lexical task condition were granted this linkage.

Future Directions

Future research addressing the limitations and implications of this dissertation should examine the exposure condition using a longer, more demanding vigilance task. A potential issue with the current series of studies was the training and transfer vigils may not have been demanding enough to elicit decrements in performance typical of vigilance tasks. As a result, the potential benefits of exposing observers to task stimuli without forcing them to respond during training may have been masked by higher-than-expected performance. It may be the case that when employing longer transfer vigils or more difficult task parameters (e.g. increased event rate), these performance benefits come to bear. Additionally, making these changes may provide more clarity for the performance-workload insensitivity found in the present dissertation.

Another potential avenue would be to examine different types of KR. The present dissertation did not answer how KR benefits observers' structural knowledge of a task (i.e. their ability to distinguish signal from non-signal) manifest differently from energetic knowledge (i.e. task coping, goal setting, etc.), but such answers may lie in deeper investigations of KR. While composite KR (including KR for hits, misses, and false alarms) has been most fruitful in terms of subjective benefits during vigilance, there have also been positive effects for Hit KR with respect to sensitivity and response bias (Dittmar et al., 1985; Szalma et al., 2006). Future research could combine these forms of KR with another training method similar to the current active/passive practice to further examine the differences between the structural and energetic components of feedback.

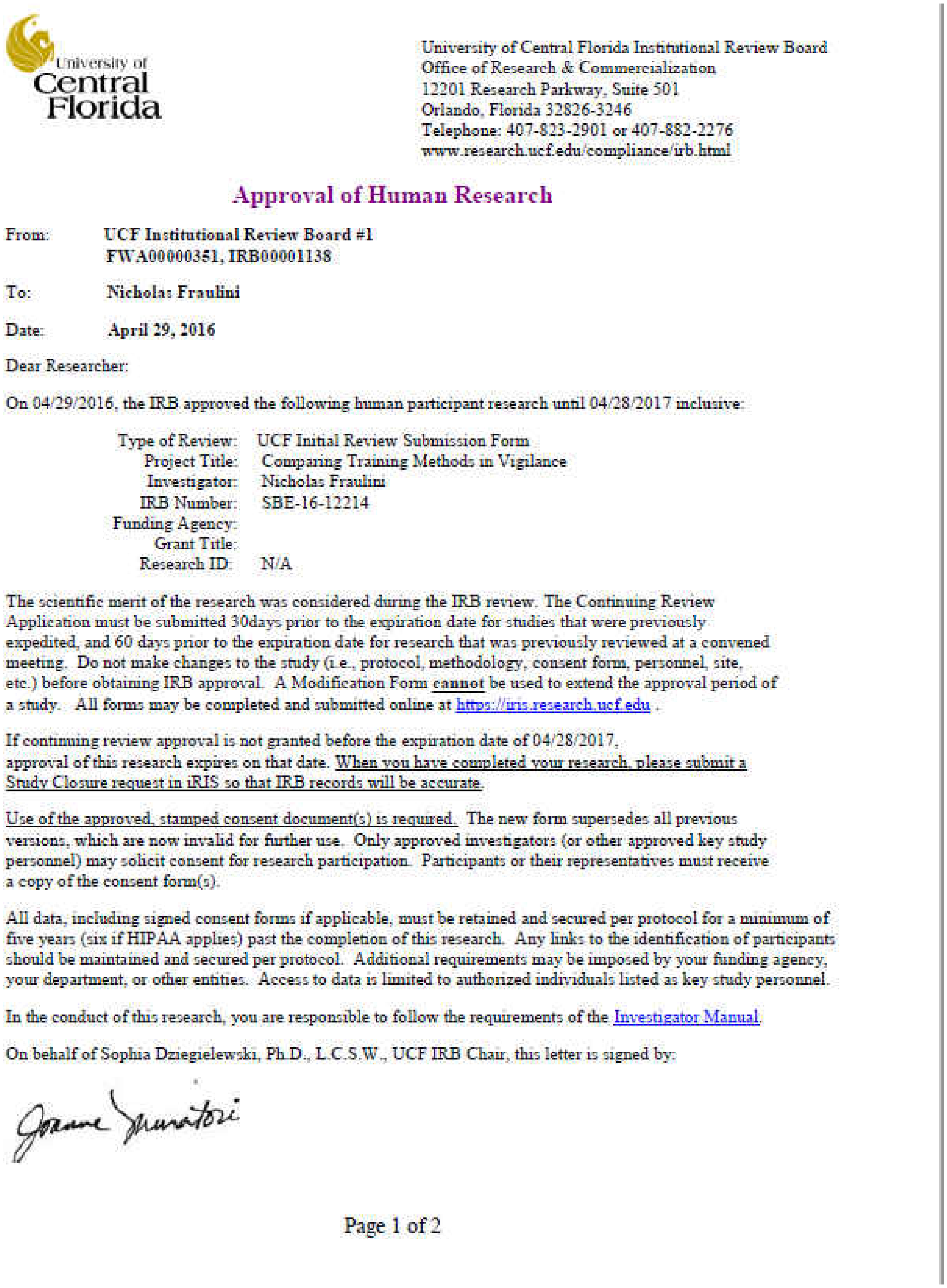
Perhaps the most important avenue for future research emanating from this dissertation is investigating the effects of KR in transfer of training when combined with exposure training. Study 3 of the present dissertation shows that KR may provide added benefits separate from exposure training when the two are paired in a transfer of training vigilance paradigm. The same pattern of results does not occur, though, when the training and transfer task are matched (as in Study 2). Future research should further examine this relationship to better understand how performance is affected by KR and exposure training. Future endeavors could utilize different task types, as the current dissertation utilizes two cognitive tasks to examine transfer of training.

Conclusion

There were two central research questions for this dissertation: 1) does KR training improve performance through learning to distinguish signals from non-signals, or are improvements based on individuals' acclimating to task parameters other than signal discrimination, such as event rate, source complexity, or their own feelings of fatigue and motivation; and, if this process can be completely passively, will it then transfer to a different task? To investigate the first question, I sought to dissect the learning process during training for vigilance by employing two separate training mechanisms and examining both their separate and additive effects on performance, mental workload, and stress. Although the results of this dissertation do not provide clear evidence for the disparate underlying mechanisms associated with vigilance training, the interactive effects found in Study 3 offer hope that disentangling these mechanistic underpinnings is possible.

For the dissertation’s second research question, I did find evidence that the exposure training employed in Study 2 can provide similar performance benefits as those found when employing active responding techniques. These benefits came at an unexpected cost, though, as observers who were not required to respond to target stimuli reported higher levels of mental workload and stress than those forced to actively respond to stimuli. While this finding does provide support to resource depletion explanations of vigilance, it may require researchers to reconsider the cause of diminishing cognitive capacities.

APPENDIX A: IRB APPROVAL LETTERS



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Approval of Human Research

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

To: **Nicholas Fraulini**

Date: **April 29, 2016**

Dear Researcher:

On 04/29/2016, the IRB approved the following human participant research until 04/28/2017 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	Comparing Training Methods in Vigilance
Investigator:	Nicholas Fraulini
IRB Number:	SBE-16-12214
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 04/28/2017, 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:

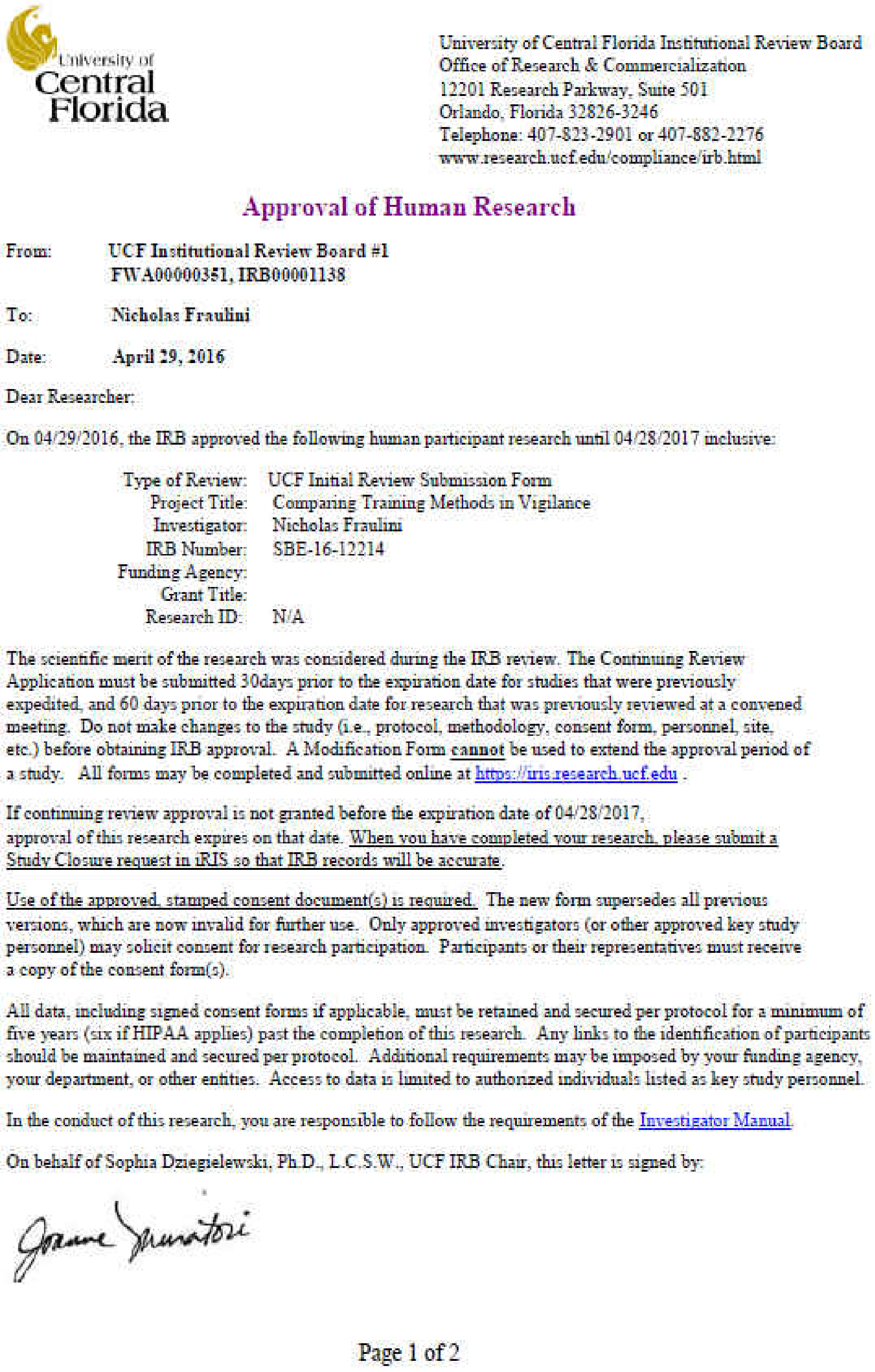
Joanne Muratori

Page 1 of 2

Signature applied by Joanne Muratori on 04/29/2016 05:00:47 PM EDT

IRB Manager

Page 2 of 2



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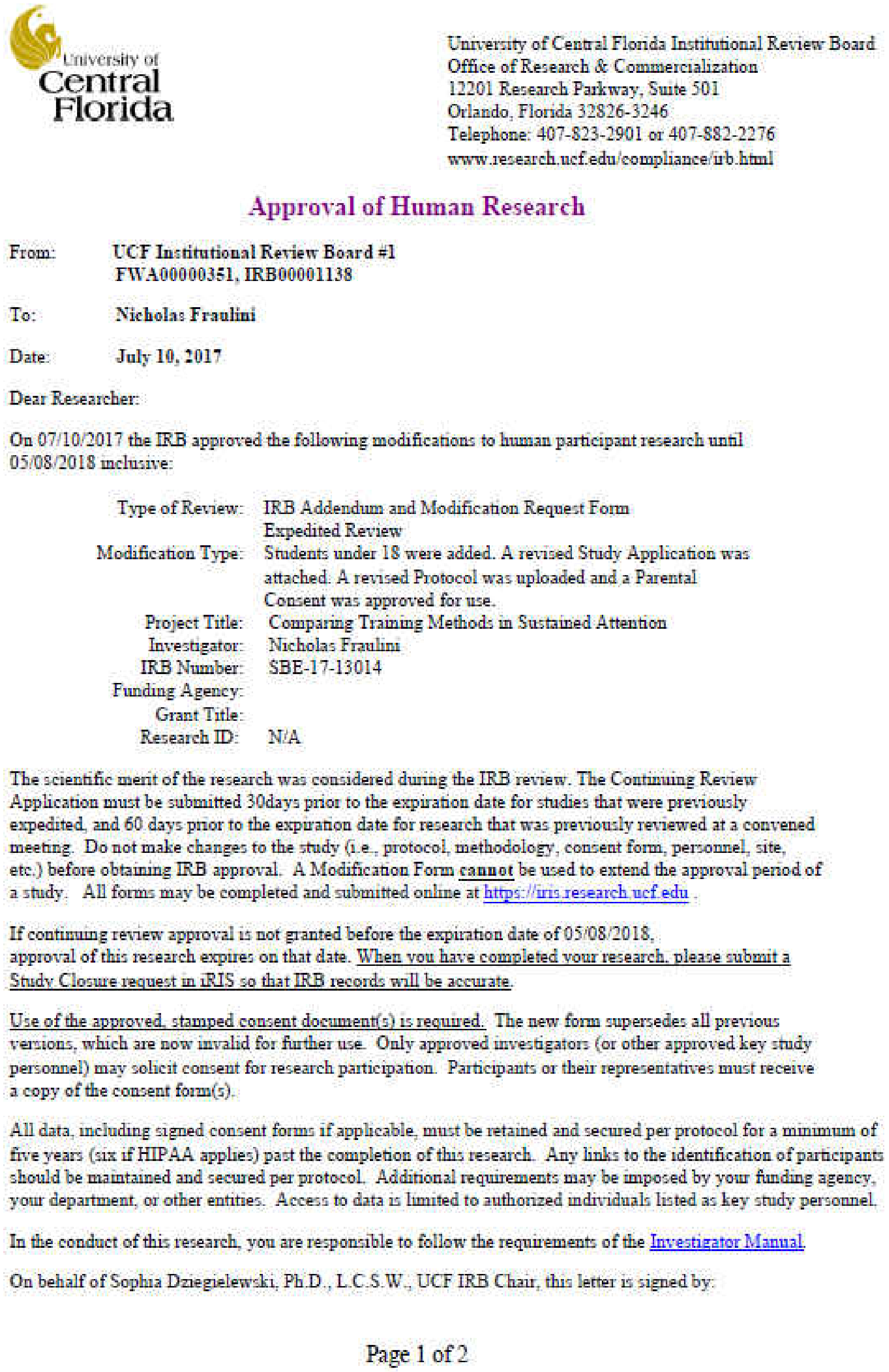
On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Joanne Muratori

Page 1 of 2

Signature applied by Joanne Muratori on 04/29/2016 05:00:47 PM EDT

IRB Manager



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Approval of Human Research

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

To: **Nicholas Fraulini**

Date: **July 10, 2017**

Dear Researcher:

On 07/10/2017 the IRB approved the following modifications to human participant research until 05/08/2018 inclusive:

Type of Review:	IRB Addendum and Modification Request Form Expedited Review
Modification Type:	Students under 18 were added. A revised Study Application was attached. A revised Protocol was uploaded and a Parental Consent was approved for use.
Project Title:	Comparing Training Methods in Sustained Attention
Investigator:	Nicholas Fraulini
IRB Number:	SBE-17-13014
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 05/08/2018, 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.

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On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

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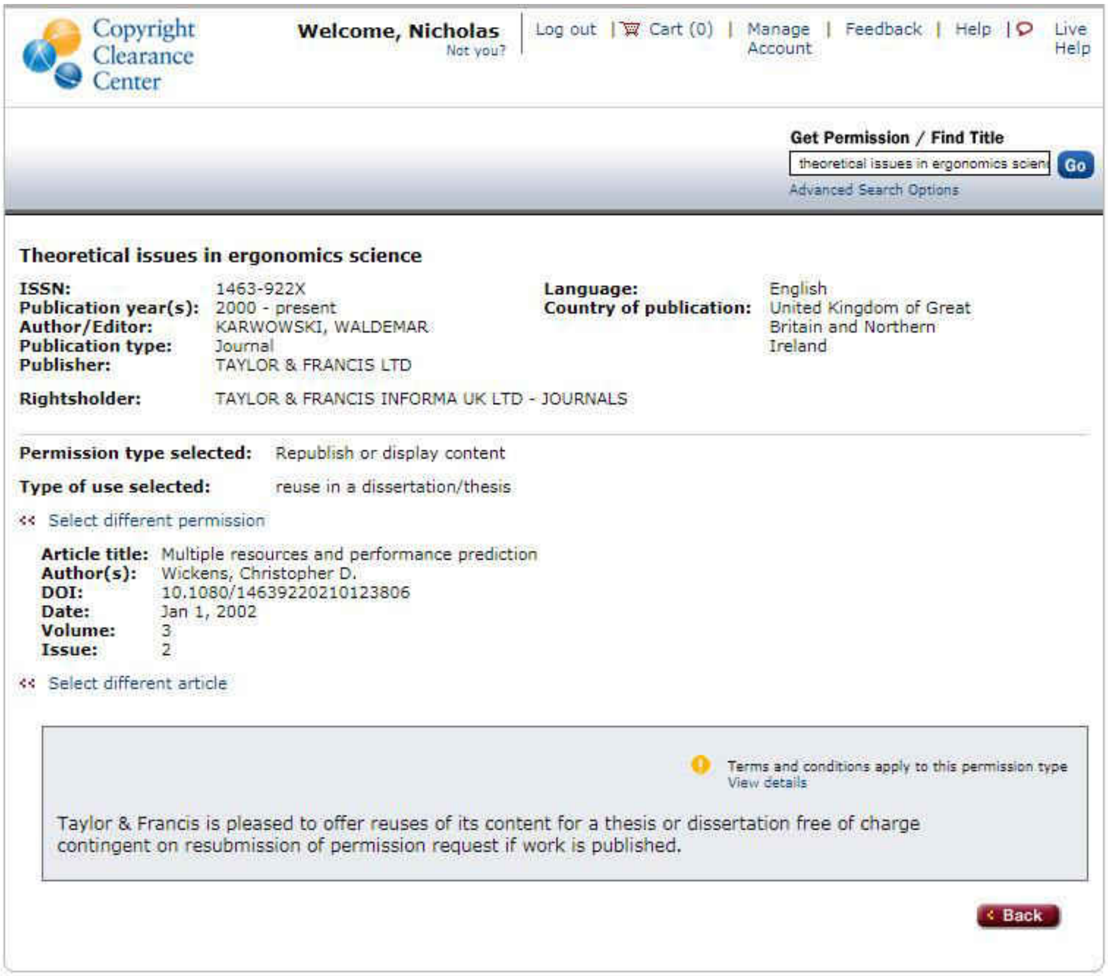
Kamille Chap

Signature applied by Kamille Chaparro on 07/10/2017 04:12:02 PM EDT

IRB Coordinator

APPENDIX B: FIGURE PERMISSIONS



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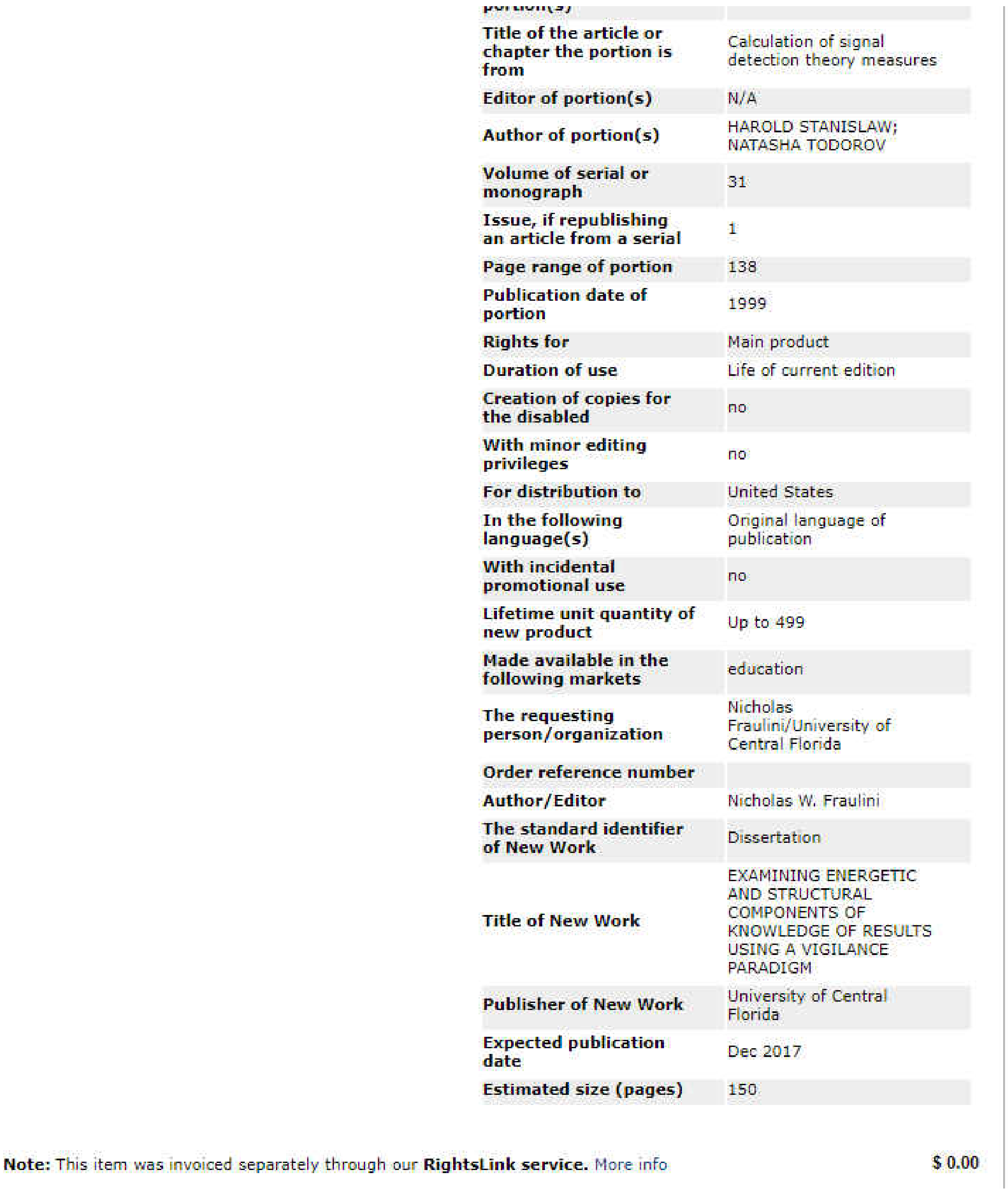

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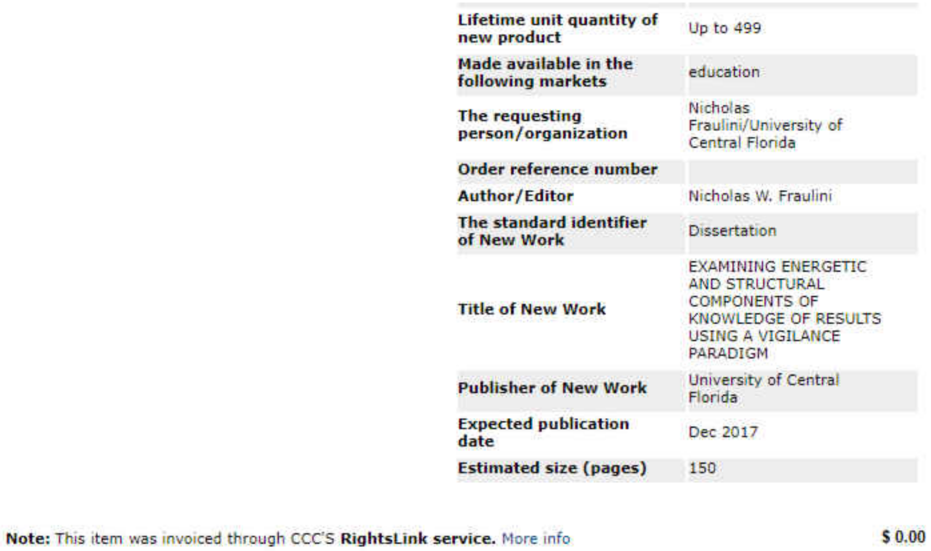

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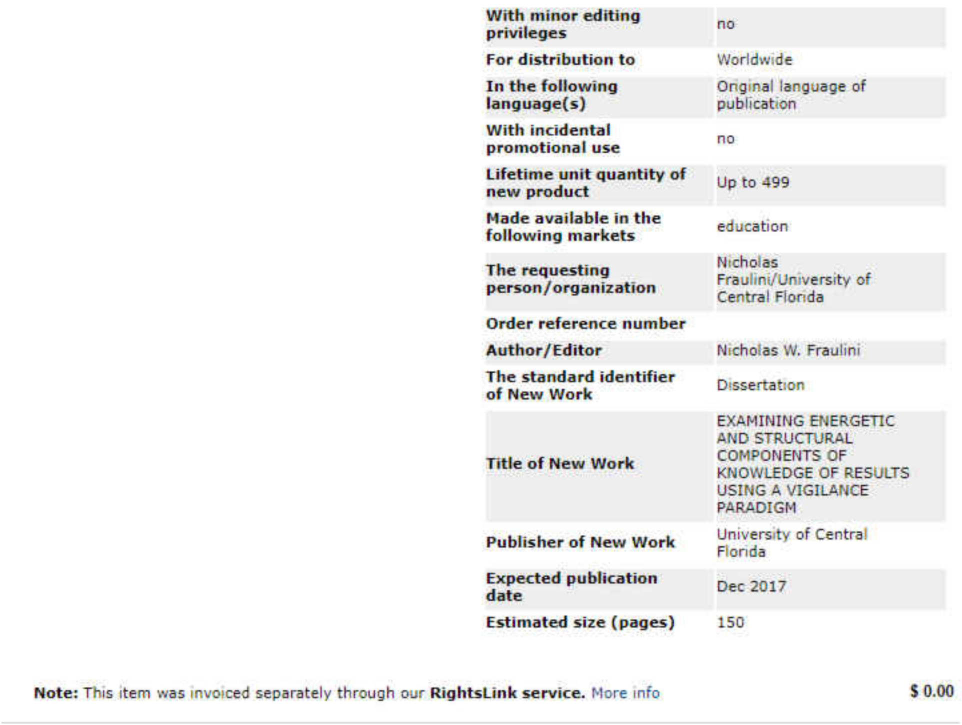

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James Szalma <James.Szalma@ucf.edu>
Yesterday, 11:51 AM

Nick,

Here is a copy of my MA thesis. You have my permission to use any of these figures in your dissertation. The one that might be most appropriate as Figure 6 in your dissertation is Figure 10 in my MA thesis.

James L. Szalma, Ph.D.
Associate Professor
Director, Human Factors and Cognitive Psychology Ph.D. Program
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Fax: 407-823-5862
e-mail: James.Szalma@ucf.edu
Lab website: perl.cos.ucf.edu

APPENDIX C: LEXICAL TASK CRITICAL SIGNALS

1	At
2	Be
3	So
4	To
5	Do
6	Me
7	He
8	Am
9	An
10	No
11	Of
12	If
13	We
14	Hi
15	Us
16	In
17	It

APPENDIX D: MEANS AND STANDARD DEVIATIONS FOR SHORT-FORM DSSQ ACROSS ALL STUDIES

Experiment 1			
	Pre-Training	Post-Training	Post-Transfer
Task Engagement	20.71 (3.59)	18.46 (4.94)	13.31 (6.57)
Distress	5.39 (4.02)	8.05 (5.88)	7.95 (5.67)
Worry	17.34 (4.58)	14.96 (5.86)	16.65 (6.34)

Experiment 2			
	Pre-Training	Post-Training	Post-Transfer
Task Engagement	20.10 (4.10)	17.15 (5.44)	12.78 (5.82)
Distress	5.41 (4.05)	6.65 (5.08)	7.66 (4.88)
Worry	16.01 (5.01)	14.89 (5.48)	15.88 (5.59)

Experiment 3			
	Pre-Training	Post-Training	Post-Transfer
Task Engagement	20.23 (4.01)	16.64 (5.88)	13.43 (5.89)
Distress	5.71 (3.50)	6.96 (5.50)	6.74 (5.77)
Worry	15.80 (4.65)	14.23 (5.45)	15.75 (6.14)

APPENDIX E: MEANS AND STANDARD DEVIATIONS FOR SHORT-FORM DSSQ ACROSS ALL STUDIES

Experiment 1		
	Post-Training	Post-Transfer
Mental Demand	42.78 (27.46)	42.25 (32.01)
Physical Demand	11.48 (16.64)	12.56 (19.28)
Temporal Demand	41.90 (27.14)	35.87 (27.07)
Performance	54.29 (32.03	54.64 (31.95)
Effort	38.34 (26.06)	39.20 (28.33)
Frustration	33.73 (28.59)	39.07 (30.20)
Global Workload	42.18 (19.65)	42.63 (21.07)

Experiment 2		
	Post-Training	Post-Transfer
Mental Demand	43.67 (28.60)	43.74 (27.43)
Physical Demand	11.42 (14.90)	13.33 (16.46)
Temporal Demand	37.36 (24.96)	36.19 (25.60)
Performance	52.56 (31.74)	52.58 (29.68)
Effort	38.51 (27.57)	41.36 (28.16)
Frustration	28.44 (23.41)	37.96 (28.39)
Global Workload	41.94 (18.84)	42.76 (17.98)

Experiment 3		
	Post-Training	Post-Transfer
Mental Demand	46.63 (26.98)	42.33 (30.01)
Physical Demand	10.93 (15.58)	16.04 (20.47)
Temporal Demand	37.62 (25.05)	32.66 (25.90)
Performance	51.65 (32.57)	54.29 (33.90)
Effort	40.48 (26.81)	39.05 (27.89)
Frustration	33.72 (28.36)	36.25 (27.66)
Global Workload	43.55 (17.77)	40.45 (19.55)

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