THE EFFECT OF DISRUPTIONS ON VIGILANCE

by

Hayden Aaron Ross

A thesis submitted in fulfilment of the requirements for the degree of

Master of Science in Psychology

Department of Psychology

University of Canterbury

2013

UNIVERSITY OF CANTERBURY

ABSTRACT

The Effect of Disruptions on Vigilance

by Hayden Aaron Ross

The goal habituation model of vigilance proposed by Ariga and Lleras (2011) posits that it is possible to attenuate the vigilance decrement (the decline in performance that occurs with time-on-task) through dis-habituation of a vigilance task's goal. The goal in a vigilance task is to detect critical signals. Hence, a switch away from this goal should dishabituate the task goal. When a person resumes the vigilance task, the person's performance should improve. Follow up studies to the Ariga and Lleras study have not found supporting evidence (Helton & Russell, 2011; 2012). The methods in these follow up studies differed from those of Ariga and Lleras in a number of ways. The present study attempts to replicate the original Ariga and Lleras (2011) work using methods that more closely follow the original study. The present research sought to uncover confounds in the original article through replicating the original task and manipulating variables in line with hypotheses made by attentional resource theory.

Overall, the results of this research present a challenge to the goal habituation model. Rest breaks, not goal switching; lessened the magnitude of the decline in sensitivity with time on task, while task switching resulted in a temporary re-correction of increasingly conservative responding that occurred with greater time on task. We also found support for the context dependent relationship of task-unrelated thought, (TUT) and task demand. Given that the vigil was determined to impose relatively low workload, pre-task TUT was associated with average

performance rather than post-task TUT. Finally, we discuss the dangers of over compliance with signal detection theory (SDT) measures. We explain that SDT sensitivity and bias measures are not independent given responding floor and ceiling effects during low demanding tasks such as the present. It is argued that this may have distorted the original conclusion arrived at by Ariga and Lleras (2011).

TABLE OF CONTENTS

LIST OF FIGURES & TABLES

ACKNOWLEDGMENTS

The primary author wishes to express sincere appreciation to Associate Professor Deak Helton and Mr. Paul Russell for their supervision and assistance in the preparation of this work. It is hoped that their stress levels did not reach clinical levels in the lead up to its conclusion. Thanks also to my parents, Brendan and Colleen Ross who have supported me throughout my studies.

GLOSSARY

SDT	Signal detection theory
FA	False alarm rate
A′	Non-parametric sensitivity index
B″D	Non-parametric response bias index
DSSQ	Dundee Stress State Questionnaire
NASA-TLX	North American Space Agency Task Load Index
CFQ	Cognitive Failures Questionnaire
TRT	Task related thought
TUT	Task unrelated thought
EA	Energetic arousal
TA	Tense Arousal

Chapter 1

INTRODUCTION

Vigilance and sustained attention are used interchangeably and refer to the ability of individuals to monitor a continuous stream of stimuli for rare critical targets. Understanding how the various characteristics of vigilance tasks affect performance is of both practical and theoretical importance. The major empirical finding from the study of vigilance is the vigilance decrement or a decline in performance over time. A major concern of pure vigilance research is discovering the basis of vigilance decrement phenomena, as well as developing strategies to inhibit, eliminate or predict the development of the vigilance decrement. These research themes have been common since World War II where they originally started as an applied problem arising in radar operators, but which also founded scientific theorising on the psychological basis of vigilance (Mackworth, 1948). From the outset definitions should be established, vigilance will be regarded as synonymous with sustained attention although there are minor differences. Attention has multiple definitions including a conscious experience; however vigilance need not be experienced consciously. Historically, vigilance has been described simply as a physiological and psychological readiness to react (Head, 1926). A more functional, operational definition has been developed more recently and describes vigilance as monitoring the environment for prolonged periods of time, in search of infrequently occurring critical events, while ignoring irrelevant stimuli (Nuechterlein, Parasuraman, & Jiang, 1983;

Warm, 1984). Vigilance research spans the field of psychology, for example in clinical psychology where different clinical conditions affect vigilance function, psychopharmacology, for example how differing drugs impact vigilance, neurophysiologists, for example investigate the effects of sleep deprivation and physical correlates, and of course cognitive neuroscience, just to name a few. This thesis approaches vigilance from a cognition and applied cognition/human factors perspective.

The vigilance decrement is characterised by three measure of performance in its most basic form, the hit (or correct detection) rate, the false alarm rate and response time. However, since the 1960's with the advent of signal detection theory (SDT), separate metrics of sensitivity and response bias have been widely accepted (Swets, Tanner, & Birdsall, 1964). SDT allows for a more in-depth analysis of constructs such as sensitivity (the average difference in sensory processes elicited by a target and distracter) and response bias (e.g. conservative; tendency to make fewer false alarms with a consequent loss in proportion of signals detected) in addition to the traditional metrics of raw hit and false alarm rates. SDT is held in high regard within the psychophysical field of research (Harvey, 1992). There are however risks in over using or misapplying SDT. There exist multiple corrections to data and alternate formula for sensitivity and bias when violation of assumptions such as statistical normality occur, each with their own supporting evidence which can produce in some cases large variations for subsequent inferential analysis (See, Warm, Dember, & Howe, 1997; Stanislaw & Todorov, 1999). SDT sensitivity and bias are assumed to be independent of one another. This independence however breaks down when hit and false alarm rates approach ceiling and floor levels (when hit or false alarm proportions approach 1 or 0) which occurs often in practice. To briefly illustrate this point, example calculations are shown below regarding the independence violation of sensitivity (*A′*) and bias (B′′D). Example two shows a valid change in sensitivity, example three a valid change in response bias and example four, a change in response bias contaminating sensitivity.

Table 1.
Example of sensitivty, response criterion and response criterion shift influencing sensitivity

#	SDT change	FA	Hits	Hits-FA	A'	B"D
(1)	Benchmark	40.00%	60.00%	20.00%	.67	.00
(2)	Sensitivity shift	25.00%	75.00%	50.00%	**.83**	.00
(3)	Response criterion shift	20.00%	40.00%	20.00%	.67	**.71**
(4)	Response criterion shift influencing sensitivity	.00%	10.00%	10.00%	**.77**	**1.00**

Equations for SDT transformations appear in appendix C

As can be seen above, example four shows a possible response bias shift however the false alarm (FA) rate cannot drop below 0%.This demonstrates the inability to decipher sensitivity from response bias fluctuation given floor effects. If there are no or extremely few false-alarms occurring, it becomes extremely difficult to determine whether a change in hits occurs because of a change in sensitivity or a change in response criteria, or both.

1.1 Theories of vigilance.

The vigilance decrement is affected by task taxonomy of various task characteristics; most commonly those task characteristics which vary the information processing demands and thus difficulty. Some examples of the taxonomy which affect the vigilance decrement are:

- The rate of appearance of stimuli that need to be scanned for the presence of critical signals or increased event rate; as event rate increases, sensitivity decreases, effects on bias are dependent on relative event rate (Joshi, Warm, & Dember, 1985).
- Spatial uncertainty in the location or appearance of critical signals; as spatial uncertainty increases, sensitivity decreases (Adams & Boulter, 1964).
- Multitasking; with more task load, sensitivity decreases (Caggiano & Parasuraman, 2004; Cosenzo, 2007).
- Simultaneous comparison vs. successive task discrimination; successive discriminations which place heavier burden on working memory generally results in decreased performance. (Parasuraman, Warm, & Dember, 1987; Warm & Dember, 1998).
- Sensory modality; visual signals are typically more difficult than auditory signals (Davies & Parasuraman, 1982).
- Sensory vs. cognitive discrimination; cognitive discriminations typically are not as subject to the vigilance decrement as sensory discriminations (Noonan, Karwoski, & Loeb, 1985).
- Pauses (rest breaks); rest breaks improve performance (Bergum & Lehr, 1962; Colquhoun, 1959; Davies & Tune, 1969; Ware & Baker, 1977).
- Event asynchrony or irregularities in the time when events occur; irregular temporal structure typically reduces performance (Scerbo, Warm, & Fisk, 1986).

Alternative theories or explanations of the vigilance decrement attempt to explain or take account of the various impacts of task characteristics on vigilance performance. Up until recently, the popular family of theories presented in the literature were (a) information-processing resource theory (also known as mental fatigue, or overload theory), (b) arousal theory (with variants such as mindlessness, boredom or under-load theory), and (c) expectancy theory, but recently Ariga & Lleras (2011) published unique results which they explained using a novel theory (d) a goal-habituation model.

1.1.a Arousal Theory and Habituation. Arousal has long been a topic of research in psychology. The Yerkes-Dodson Law dictates that performance varies with physiological or mental arousal in a quadratic inverted U shaped function (Yerkes & Dodsan, 1908). Too little arousal and performance suffers, but also if there is too much arousal performance suffers. From an arousal theory perspective, the vigilance decrement was thought to be caused by sensory habituation or underarousal resulting from the monotony of the vigilance task (Mackworth, 1968). Some theorist suggested vigilance was characterised by a lack of arousal elicited by the task from the outset (Eysenck, 1982). Operationally similar theories are known collectively as arousal theories (Frankmann & Adams, 1962; Welford, 1968). Essentially, poor vigilance performance is due to under arousal.

These theories were supported with physiologic measures of arousal which provided good construct and convergent validity. Such measures included electroencephalographic (Paus et al., 1997; Sharpless & Jasper, 1956) thalamic activity (Robbins, 1997), and galvanic skin conductance (Andreassi, 1966; Freeman, 1940; Sostek, 1978; Surwillo & Quilter, 1965). Neurotransmitters related to arousal have also been identified to vary during vigils. Levels of noradrenalin decline concomitantly with correct detection rates (O'Hanlon, 1965). The previously outlined results however are mostly correlational and causal direction is difficult to establish. Administering amphetamine (Elkes, 1961) and chlorpromazine (Loeb, Hawkes, Evans, & Alluisi, 1965) to participants has shown to increase and decrease participant's sensitivity, although not the rate of decline in vigil performance. Together, all of these findings are purported to relate the vigilance decrement to a down-regulation of the reticular formation, ascending reticular activating system, and finally, the diverse regions of the cortex attached to this system, particularly the frontal and pre-frontal cortex which are directly implicated in vigilance (Hitchcock et al., 2003; Lewin et al., 1996; Oken, Salinsky, & Elsas, 2006). Arousal theory suffers in its inability to account for the slope of detection metrics and its causal influence.

The latest arousal theory derivative was posited by Robertson and his colleagues in which they argue that failures in vigilance tasks to register critical signals is caused by "participant mindlessness" (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). This term refers to the assertion that during the inter-critical stimulus intervals, participants become habituated and bored, drifting off into daydreaming. Smallwood et al. (2004) built on this by proposing a mechanism which is ultimately responsible for slips in attention under the mindlessness approach, task-unrelated thoughts (TUT). Moreover, disruptions in vigilance are said to occur when the current task fails to maintain exogenous attentional control through the inability to reach and maintain adequate levels of arousal, which is governed by such factors as novelty and stimulus change. This lack of arousal forces the participant to rely on endogenous attentional control which induces automatic responding and is susceptible to interference from TUTs and other higher order thoughts (Giambra, 1995; Smallwood et al., 2004). Mindlessness proponents do however subscribe to the idea of attentional resources in that when a participant becomes aware of an error, they accept that attentional resources are subsequently redeployed towards the task. They reason however that this detracts from performance is due to meta-cognitive task-related interference, forming a vicious cycle (Manly, Robertson, Galloway, & Hawkins, 1999; Smallwood, et al., 2004).

Self-reported TUTs have, however, thus far failed to be reliably predictive of the size of the vigilance decrement, although there is evidence that greater reported incidence of TUTs is associated with lower average detection performance (Helton & Warm, 2008). Other challenges to the theory have also been made. For example, bolstering exogenous attention via extraneous stimulation should improve overall performance and reduce the vigilance decrement. This has been attempted by speeding event rate (Parasuraman & Davies, 1976), introducing undemanding extra auditory and visual stimuli (Helton, Matthews, & Warm, 2009; Smit, Eling, & Coenen, 2004), and spatial uncertainty in target presentation (Helton, Hayrynen, & Schaeffer, 2009). None of these however proved to boost performance, with some of these manipulations actually reducing performance, presumably by placing cognitive load on participants (Helton, Dorahy, & Russell, 2011; Helton, Kern, & Walker, 2009; Ossowski, Malinen, & Helton, 2011). Although the core tenants of mindlessness theories have been seriously challenged, it has placed a major research emphasis on TUTs and its role in vigilance. Indeed, TUTs and other higher order thoughts may play an important role in vigilance performance.

1.1.b Attentional Resource Theory. Resource theory argues that failures to register critical stimuli in vigilance tasks are caused by a depletion of relevant information processing ‘resources’.

This is caused by a task which demands available resources by placing a cognitive load on the participant to the extent that the system cannot replenish that which is lost. Rather than traditional vigilance tasks being considered underwhelming, boring and easy, resource theory would argue that resources must be used to keep competing auxiliary functions repressed (for example, suppressing other processing) and to keep attention focused upon the primary task. When participants respond to task load measures following a typical vigil, they report experiencing stress, high workload in particular, mental demand (Grier et al., 2003; Warm, Dember, & Hancock, 1996; Warm, Parasuraman, & Matthews, 2008). Furthermore, increasing task difficulty through reducing critical signal salience, increasing spatial uncertainty or increasing event rate results in increased self-reported task load, increased self-reported stress and an amplified vigilance decrement (Helton & Warm, 2008; Helton, Warm, Matthews, Corcoran, & Dember, 2002). The vigilance decrement has also been established to be associated with reduced self-reported energetic arousal (Helton, Matthews et al., 2009; Matthews & Davies, 2001) which is indicative of mental fatigue (Matthews, Davies, Westerman, & Stammers, 2000).

The underlying physiological basis of these resources remains unclear and is a major target of criticism of the theory, although there is a growing body of neuropsychological evidence which provides support for an embodiment of information-processing resources. Although resource theory is one of the most far-reaching theories, it is commonly criticised for using circular logic when inferring resources from performance results instead of directly, then in turn predicting performance results (Navon, 1984). This however can be overcome if resources can be directly measured through their embodiment and there is a growing body of evidence to support this approach. Evidence from positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) suggests that attention resources may be measured through cerebral blood flow in the frontal cortex and in particular the pre-frontal cortex (Parasuraman & Caggiano, 2005; Pardo, Fox, & Raichle, 1991). Additionally, a number of studies employing less invasive, practical measures of cerebral blood flow and oxygenation have shown good convergent validity with data obtained from PET and fMRI, for example near infra-red spectroscopy (Funke et al., 2010; Helton et al., 2010; Ossowski, Malinen, & Helton, 2011; Stevenson, Russell, & Helton, 2011), trans-cranial Doppler sonography (Helton et al., 2007; Tripp, Warm, Parasuraman, & Rizzo, 2007) and tympanic membrane temperature (Helton, Hayrynen et al., 2009). There appear to be metabolic changes in cerebral tissue which correspond to the vigilance decrement.

Attentional resource theory's strength is its ability to accurately and reliably describe the decline in performance measures during vigils (Parasuraman, 1979). TUTs have also been incorporated into resource theory. TUTs have been found to affect the overall rate of signal detections but have not been found to relate with the vigilance decrement per se (Helton & Warm, 2008). It has been established that tasks which are considered more cognitively demanding produce significantly fewer TUTs (Antrobus, 1968; Grodsky & Giambra, 1989; Grodsky & Giambra, 1990). Within a resource perspective, an individual could, however, allocate cognitive resources to TUTs and this misallocation could prove detrimental to performance. This by extension means that even single task vigils are in fact dual-tasks where the observer must allocate attentional resources to both current task-demands and TUTs. The response bias vigilance decrement is not a topic which is directly engaged by resource theory, although expectancy theory is generally seen as complimentary to resource theory (Parasuraman, 1985).

1.1.c Expectancy Theory. Expectancy theory was initially proposed by Deese in 1955. The expectancy theory of vigilance explains that participants interpret average RTs and target probabilities and thus develop expectancy about future task events. Further, signal expectancy is assumed to be low immediately following the arrival of a target, and increases as the mean inter-target interval approaches, and is exceeded. When these expectancies are violated, the individual alters their response criteria accordingly. Expectancy theory explains response bias shifts and the RT decrement well, and has also been related to other vigilance phenomena (Baker, 1959b). It is not known whether expectancy generation occurs consciously, unconsciously or contains elements of both.

Expectancy theory is supported by a solid empirical base. Increasing event rate resulting in increased target detection rates and faster RT has been well documented (Browne, 1949; Deese, 1955; Deese & Ormond, 1953; Pollock & Knaff, 1958). This is explained from the perspective that participants have a greater sample size on which to base their expectant predictions. In other words, if event rate is high, then variability in inter target intervals will be less and there is less uncertainty and better prediction and hence better detection and faster responses. Obviously this applies only to tasks where the increase in event rate does not in turn cause the cognitive demands to hit a ceiling, which would result in the opposite (Warm & Dember, 1998). Increasingly variable inter-target intervals result in increasingly more severe sensitivity decrements (Baker, 1959a; Lisper, Melin, Sjödén, & Fagerström, 1977) and speed decrement (Adams & Boulter, 1964). This may be due to a heavier cognitive load placed upon participants. Baker (1962) however eloquently demonstrated that when inserting probe trials with alternate inter-target intervals, the probe detection probability varies inversely with how extreme its inter-target interval is compared to the preceding trials. Irregular inter-target intervals also result in increased overall vigil RT compared regular inter-target intervals (Adams & Boulter, 1964).

The main strength of expectancy theory comes in explaining decision criterion shifts. Targets are rare in vigilance tasks, which participants subsequently develop low probability expectancy for the targets. Nearly all tasks present critical targets randomly. In terms of response bias, expectancy theory stipulates that when a participant misses a target, it forces a reduction in their estimation for subsequent target probability. This in turn results in the shifting of their threshold criterion upward, becoming more conservative in 'yes' responding and failing to register hits and false alarms. Identical events in turn reduce expectancy and the process evolves into a vicious cycle, continually increasing the decision criterion (Broadbent, 1971). This is supported by studies such as Colquhoun & Baddeley (1964) which demonstrated that alternating target probabilities between a training and test visual vigils alters response bias, for example going in this case from a lower to higher probability induces a conservative response style in the second half of the vigil. This result was supported using an identical method in the auditory modality (Colquhoun & Baddeley, 1967). These findings were supported by a number of subsequent studies (Halcomb, Barry, & Farl, 1970; Krulewitz & Warm, 1977; Wiener, 1963). Floyd, Griggs & Baker (1961) however demonstrated that participants who did not have altered target probabilities performed better overall and displayed reduced vigilance decrements.

There is however an obvious limitation in expectancy theory, in the situation where participants perform the same task repeatedly, practice effects should become evident as they develop keen expectancies of temporal events but typically there are no practice effects (Davies & Tune, 1969). Regardless, expectancy theory provides a plausible explanation for the speed with time on task, and is the best explanation regarding shifts in response bias.

1.1.d Goal Habituation Model. Recently a novel model emerged which suggested that micro task switches may alleviate the sensitivity decrement. Ariga and Lleras (2011) published results they claimed indicated that the vigilance decrement could be ameliorated if the primary vigilance task is interrupted by a secondary task that required participants to briefly change the task goal from target detection to a memory test. Although similar to mindlessness theory, the authors posited a 'goal-habituation' model which they argued was best able to explain their results. Its premise was that the ability of the secondary task to ameliorate the decrement was due the deactivation and reactivation of an internal goal-representation. This switching of goal they argued prevented habituation and did not include routinisation. At this point in the literature there is little evidence to support the model. Two publications have further investigated the model, but have not supported its predictions (Helton & Russell, 2011; 2012). In fact when the deactivating and reactivating cycles in the task are increased, these interruptions actually amplify the vigilance decrement (Helton & Russell, 2011). A possible explanation for this finding may be that there exists a ceiling effect where goal switching increases the vigilance decrement, and that the combined task load and switching frequency was too burdening (Loeb & Alluisi, 1977). There are however some limitations in generalizing between Ariga and Lleras (2011) and Helton and Russell (2011; 2012) such as the use of an abbreviated vigil and alpha-numeric stimuli, instead of the line-length employed by Ariga and Lleras.

1.1.e Multi-Component Theory. The existing theories prior to the goal habituation fit together under a multi-component theory which incorporated them all**.** Parasuraman (1985) first posited the idea of a multi-component theory to form a universally congruent model. The model dictates that alternative theories each account for specific forms of the vigilance decrement:

- Arousal controls the overall level of vigilance, but not the decrement
- The vigilance decrement can be due to either a sensitivity decrement (*d'* decrement) or a criterion shift (increasingly conservative responding) with sensitivity remaining stable.
- The Sensitivity decrement is due to depletion of attentional resources over time. The Sensitivity decrement is greater for:
    - high event rate (observation load)
    - successive discrimination (memory load)
    - low signal salience (greater perceptual load)
- The Criterion shift is due to expectancy

The central question asked then is if the goal-habituation model produces valid and reliable evidence for its assertions, how might it conform to the existing literature and multi-component theory perspective? Thus far it has directly challenged the ability of attentional resource theory to account for the sensitivity decrement.

1.2 Task Switching and Rest Breaks in Vigilance Tasks.

The question arising from the discussion of theories of the vigilance decrement is how does the goal-habituation model fare against attentional resource theory as an account for the sensitivity decrement? As previously established, attentional resource theory has a very solid empirical base for accounting for the sensitivity vigilance decrement. A possible explanation for the results found by Ariga and Lleras (2011) from the resource theory position could be that the task switches serve as rest breaks for vigilance systems to re-accumulate attentional resources resulting in the net gain in sensitivity. This is however unlikely due to the fact that the switch task periods only lasted for a two second period. An alternative account may be brought about from the expectancy theory position where the switch task serves to 'reset' the participant's temporal predictions, resulting in a reduction of response bias. As previously noted in SDT, the independence between measures of response bias and sensitivity can be violated.

1.2.a Task Switching in vigilance. Although there are no studies as yet supporting the notion of a goal habituation model apart from Ariga & Lleras (2011), there are a number of previous studies which appear to share similar conclusions that task and 'goal' switching can alleviate the vigilance decrement. Most of this evidence comes from studies from non-laboratory environments as practically speaking, organisations would rather workers switch tasks rather than take breaks in an attempt alleviate their lack of productivity. For example, in his review of field studies of human inspection occupations, Craig (1985) concluded that where boredom is a problem, the task can be made more interesting by breaking it up into segments and interpolating periods of activity of some other kind. For example, Fox (1977) found that batch inspection of coins, with interpolated periods of fetching and loading/unloading conveyor belts, resulted in significantly higher fault detections than was observed with continuous inspection. The same results were found by Saldhana (1957) when workers performing repetitive vernier gauge measurements separated their task with periods of other activity. Tertiary level lecturing is considered by some to be analogous to classical vigilance and evidence exists that interspersing mini novel tasks within a lecture can temporarily restore student attention levels (Young, Robinson, & Alberts, 2009). Although it is a straightforward notion, it is unclear as to how the specific effects(s) are brought about.

1.2.b Rest breaks in vigilance. Much evidence exists in the literature on the positive effects of napping to alleviate vigilance decrements, especially in the sleep deprivation literature. The effects of rest breaks or pauses are not so commonly investigated. This is likely due to it being viewed as similar to task switching and that it may appear obvious that rest breaks benefit vigilance. It is important however to build a body of literature to quantify exactly to what degree and with task specifics for its most efficient implementation. It is also important to establish to what extent it is advantageous when compared to other options such as switching the task at hand as the time can be use productively elsewhere. Bergum & Lehr (1962) positioned 10 minute rest breaks after 30 min periods over a 90 min vigil at two different event rates (low rate= ¼ high rate). They found that breaks significantly attenuated performance at both event rates compared to no break controls, however the degree of attenuation between the event rates were not analysed. An early study was also completed with Canadian soldiers who received no-break, 5min or 10min breaks following the 40th minute of a 50min vigil (McCormack, 1958). There was a significant improvement with rest, although the authors reported a sampling error was evident between participants.

1.3 TUTs

Self-report measures are commonly used in vigilance research. An example is the NASA task load index (NASA-TLX) which is used to demonstrate that participants find tasks challenging and demanding as characterised by increases in mental, physical and temporal demand, effort and frustration (Grier et al., 2003; Helton et al., 2005; Warm et al., 1996; Warm et al., 2008). The Dundee Stress State Questionnaire (DSSQ) which is also commonly used, measures energetic arousal, tension, and task related and unrelated thoughts (Matthews et al., 1999). Generally vigilance tasks are found to reduce energetic arousal and increase tension, task related and unrelated thoughts (Grier et al., 2003; Helton et al., 2002; Warm et al., 2008). TUTs in particular have been a source of much attention, especially over the last 10 years in terms of their role in vigilance performance, as previously discussed in the context of mindlessness theory. It has been established that TUTs are increased by factors such as a low event rate, low task load (Antrobus, 1968; Giambra, 1995; Grodsky & Giambra, 1990), low target rate (Giambra, 1995) and long task lengths (Antrobus, 1968; Giambra, 1995; Scerbo et al., 1986; Smallwood, Obonsawin, & Reid, 2002).

As previously mentioned, TUTs have been shown to be associated with the average performance, although not the rate in decline of performance (Helton & Warm, 2008). Causation within this relationship is not clear but easily investigated, i.e. is the pre-task TUT frequency a greater predictor of task performance, or does the rate of TUTs during the task (post-task TUT) better predict performance? Studies suggest that artificially inserting salient worries in participants before a task increases TUTs during the tasks (Antrobus, Singer, & Greenberg, 1966). Participant's dysphoria in particular has been implicated in causing a significant increase in the incidence of TUTs during tasks, while rumination has been implicated in task related thoughts (TRTs) and self-performance appraisal (Lyubomirsky, Kasri, & Zehm, 2003; Smallwood, Obsonsawin et al., 2002). Evidence suggests that pre-task TUTs and TUTs during tasks negatively affect task performance. Proponents of each view argue the importance of both on the vigilance decrement given that pre-task and post-task TUT are strongly related.

How does TUT propensity develop during the task and how are attentional resources implicated, i.e. once an individual has the antecedents for TUTs, what is the process in generating and/or inhibiting them? Specifically, are TUT 'fragments' elaborated by resource allocation into complete and consciously aware thoughts leaving fewer resources to attend to the primary task, or are TUTs persistent in the subconscious with resources consumed to inhibit them and prevent their interference with task processes and intrusion into awareness? Obviously both TUT elaboration or suppression at the cost of attentional resources should detract from vigilance performance as those resources cannot be utilised by the task.

Giambra (1989) concluded that TUTs enter consciousness when there are sufficient available resources to attend to them, and that high valence TUTs will occur when there are lower resources as opposed to lower valence TUTs. Most recently, working memory capacity (WMC) has been implicated in TUT research (Kane, Bleckley, Conway, & Engle, 2001). WMC is somewhat similar to attentional resources as it is argued to be a general controlled-attention capability (Conway, Tuholski, Shisler, & Engle, 1999), and here will be considered synonymous with attentional resources. McVay & Kane (2009) found that TUTs mediate the relationship between WMC and performance to a greater extent than the cognitive failure questionnaire scores (Kane & McVay, 2012). They concluded that individuals with higher WMC are more apt to block TUT intrusions interfering with proactive goal maintenance and conflict resolution (response inhibition). This view is known as the control-failure hypothesis. This perspective is congruent with studies that show salient pre-task worries in participants adversely affect task performance.

Alternatively, Smallwood et al. (2004) are proponents of the view that resources are allocated toward TUT elaboration which redirects attention and resources from the vigilance task. This perspective is supported by studies which show that manipulating task resource demand results in alterations to TUT occurrence, where increased resource cost results in reduced TUT frequency (Teasdale et al., 1995) and reduced demand in raised frequency (Mason et al., 2007; Teasdale, Proctor, Lloyd, & Baddeley, 1993). These conclusions assume that TUT during the task is more important to performance than TUT preceding the task.

Most recently, a compromise between the two positions has been proposed under a dual context dependent role of resources and TUTs, moderated by task demand (Levinson, Smallwood, & Davidson, 2012; McVay & Kane, 2012). In contexts that place few demands on resources and in which restricting attention to the task at hand is not prioritized, resources are free to be allocated to personal worries that facilitate TUTs. Moreover in resource-demanding contexts, if restricting attention to the task at hand is prioritized, resources can help maintain the goal to stay on task and inhibit TUT development. Such a dual role of resources can explain both the positive and negative correlations reported in the literature between workload and TUT. In terms of vigilance performance, this should mean that overall performance and/or the vigilance decrement is associated with pre-task TUT for less demanding tasks and post-task TUT for increasingly demanding tasks.

1.4 Present Study

As Helton and Russell (2012) suggested, they may have failed to replicate the goal switching advantage reported by Ariga and Lleras because their vigil was shorter, the line length vigil was replaced by a letter-detection task. The vigil used by Ariga and Lleras (2011) extended for a considerably longer period than most modern vigilance tasks (Helton & Warm, 2008; Lim et al., 2010; Robertson et al., 1997).

One explanation for the failure to replicate the finding that goal switching can ameliorate the vigilance decrement may lie in the differing characteristics of the vigils that have been employed. For example, for the effects of goal switching to occur, the vigil may have to be quite lengthy, involve variable inter-stimulus intervals or require a task that has low overall cognitive demand. In the case of Helton & Russell (2012), it is possible that habituation to the task switching may have occurred due to the higher frequency of the secondary tasks, and thus disinhibition of the goal representation may not have occurred. Alternatively even, the task switches might have served as minute rest periods where the participant had the opportunity to reconsolidate their resource reserves. Considering Ariga and Lleras (2011) did not report an analysis of response bias, it is possible that goal switching acted to 'reset' participant's expectancies if a criterion shift had contaminated their sensitivity decrement. Further research exploring the role of goal switching on vigilance decrement is required to isolate the conditions under which goal switching can be beneficial in ameliorating vigilance decrement.

The comparison between rest-breaks and goal switching also has practical applications. Goal switching can occur when the there is an interruption to the flow of the primary task. The participant may be required to shift to a new task completely, or to complete a secondary task concurrently with the primary task. While allowing a complete break from the primary vigilance task to switch to a different task may prove beneficial, switching tasks in a divided attention, dual task situation may not. Often during work tasks with vigilance properties, individuals will periodically switch duties or exchange a portion of duties to refresh performance but minimise lost efficiency. For example during long haul aircraft travel, pilots may temporarily exchange some of their task profile (attending to alternative instrumentation) with colleagues to improve performance. It is of interest to investigate if goal switching needs to be complete, or if partial goal switching still provides benefits to vigil performance.

Lastly it will be investigated how TUT variations affect vigil performance, given the workload imposed by the vigil. If the Ariga and Lleras (2011) task imposes a relatively low workload, pre-task TUT should be more strongly associated with vigil performance that post-task TUT.

1.4a Overview of experiments.

- We aim to successfully replicate the Ariga and Lleras (2011) vigilance task. To do so, we hope to produce a reliable vigilance decrement similar to that of Ariga and Lleras (2011)
- Given a successful replication of the Ariga and Lleras (2011) task, we plan to compare the effects of rest breaks and task switching on the vigilance decrement.
- Subjective reports of workload and TUT will be collected during vigils and examined for their relation to task-switching, rest breaks and the vigilance decrement.

Chapter 2

EXPERIMENT 1

Aim

The aim of experiment one was to establish that the line-length vigilance task employed by Ariga and Lleras (2011) reliably produces a decrement in vigilance performance with time on task so that it can be later used to test the effects of goal habituation vs. rest breaks on the vigilance decrement. In order to be deemed a suitable task for exploring the effects of goal switching and other variables on vigilance decrement the task needs to produce a significant decrement in hit rate, sensitivity and speed of response with time on task. Response bias will also be analysed although it was not reported by Ariga and Lleras (2011). In addition, self-report measures of stress state and workload will be administered and analysed. The task employed in Experiment 1 is identical to that of the control condition in Ariga and Lleras (2011) and it was hoped it would produce a similar and reliable vigilance decrement in hit rate, sensitivity and response time.

The reproduction of the task will also give an indication of the utility for inserting secondary tasks, rest breaks or both simultaneously into the vigil. During experiment 2, we hope to add an additional dimension to the secondary task employed by Ariga and Lleras (2011), by presenting it separately (during gaps in the vigil) as well as concurrently during the vigil. Ideally, the prospective secondary switch task would be presented visually, as it was in Ariga and Lleras

(2011). It was uncertain if the participant would be able to successfully attend to both tasks visually and simultaneously. If not feasible, an auditory or tactile task would be considered. The present study was designed to provide more information regarding the task employed by Ariga and Lleras (2011), as they did not include independent assessments of either workload or stress, a limitation they acknowledged in their study.

Method

Participants

Seven male (37%) and 12 female University of Canterbury undergraduate psychology students over the age of 18 years (mean age of 19.2 years) and with normal or corrected to normal vision served as participants in the study. They were actively recruited and received course credit.

Apparatus

The vigilance task was run on PC computers using SuperLab Pro 2.0 for Windows (Cedrus Corporation). The computer monitors used were 22”, 1680x1050 pixel liquid crystal displays running at 60Hz. Responses were made using the keyboard spacebar. Participants completed Paper-and-pencil versions of the DSSQ (Matthews et al., 2002) and the NASA-TLX (Wickens & Hollands, 2000). These questionnaires appear in Appendix B. The experimental sessions were held in computer laboratories where each participant sat in a separate cubicle work-station area Participants were run in groups of up to 6 participants simultaneously.

On each trial, one of two alternate line lengths was presented vertically orientated with a pseudo-random variability. The lines measured 5.94cm and 7.88cm in length. Line stimuli were presented for a 153ms duration inter-stimulus-interval (ISI), varied randomly between 1350ms, 1850ms and 2350ms (mean 1850ms). One of the three ISI lengths was pseudo-randomly selected per presentation. A central red-dot which acted as a fixation point was constant throughout the vigil. Participants responded toward the shorter line lengths (targets) by pressing the spacebar on the keyboard and withheld responding to the longer line lengths (distracters). Event probability for targets was .1. The total duration of the task was 40 minutes.

Procedure

Participants were given the opportunity to read the information sheet (see Appendix A.), and were instructed to sign an informed consent form (see Appendix A). They were then asked to complete the respective questionnaires. Participants were required to complete the pre-task component of the DSSQ before the commencement of the experiment and the post-component along with the NASA-TLX following the experiment. Participants were asked to surrender any watches and electronic devices such as mobile phones or media players. All participants were instructed to respond toward the shorted line and to ignore the longer line stimuli, to respond as quickly and accurately as possible, to focus as much attention on the task as possible and to refrain from other competing activities.

All participants were given a total of 2 minutes (60 stimulus presentations) of practice to familiarise them with the vigilance task. During practice, feedback was given instantly when the participant made a false alarm (responded to the longer line) or missed a target (failed to respond to a shorter line). Following practice and before the start of the vigil, participants were given the opportunity to ask the experimenter any questions relating to the experiment. Participants were not informed as to the length of the vigil, but did know that the entire experiment would not exceed 1 hour in duration. Participants completed the task in groups ranging 1 to 6 participants. Within group sessions, participants were positioned so that they were not in view of other participants and were run in synchrony so as not to disturb other participants. Participants were instructed to focus on the task and refrain from talking. Following the conclusion of the experiment, participants were asked to complete the post-DSSQ (task) and the NASA-TLX.

Ethics approval

Ethics approval was provided by the University of Canterbury Human Ethics committee under a low-risk classification.

Results

Vigilance Performance

Performance measures included hit rates, false alarm rates and reaction time (RT). From hit and false alarm rates, signal detection theory (SDT) metrics of non-parametric sensitivity (*A′*) and non-parametric response bias (B″D; b-prime-prime-d) were calculated. The response bias measure B″D (Donaldson, 1992) was specifically employed based on the recommendations of See, Warm, Dember & How (1997). *A′* scores vary between 0.5 and 1 with 1 corresponding to perfect target-distracter discrimination. Positive and negative B″D values indicate conservative and liberal response bias respectively. For purposes of analysis the 40 minute vigils was divided into 4 10-minute periods. Hit rate, sensitivity, RT and response bias are plotted across watch periods in Figure 1. One-way repeated measures ANOVAs revealed that there was a significant decline across periods of watch in hit rates, $F(3, 54) = 7.84$, $p < .01$, $\eta^2 = .30$ and sensitivity $F(3, 54) = 4.30$, $p < .01$, $\eta^2 = .19$, an increase in reaction time $F(3, 54) = 7.50$, $p < .01$, $\eta^2 = .29$ and increased conservative response bias $F(1, 18) = 5.32$, $p < .01$, $\eta^2 = .23$ across periods of watch. FA rates did not vary across periods of watch.

Tukey's honestly significance post-hoc analysis of period performance revealed that period 1 had higher mean hit rates and sensitivity ratings than period four ($p < .01$), and period one had quicker RTs than periods 2, 3 and 4 ($p < .02$). Linear trend characteristics were identified for the decline in hit rate $F(1, 18) = 20.01$, $p < .01$, $\eta^2 = .53$, sensitivity $F(1, 18) = 9.72$, $p < .01$, $\eta^2 = .35$, the incline of RT $F(1, 18) = 9.33$, $p < .01$, $\eta^2 = .34$ and the increasingly conservative response bias $F(1, 18) = 10.363$, $p < .01$, $\eta^2 = .36$.

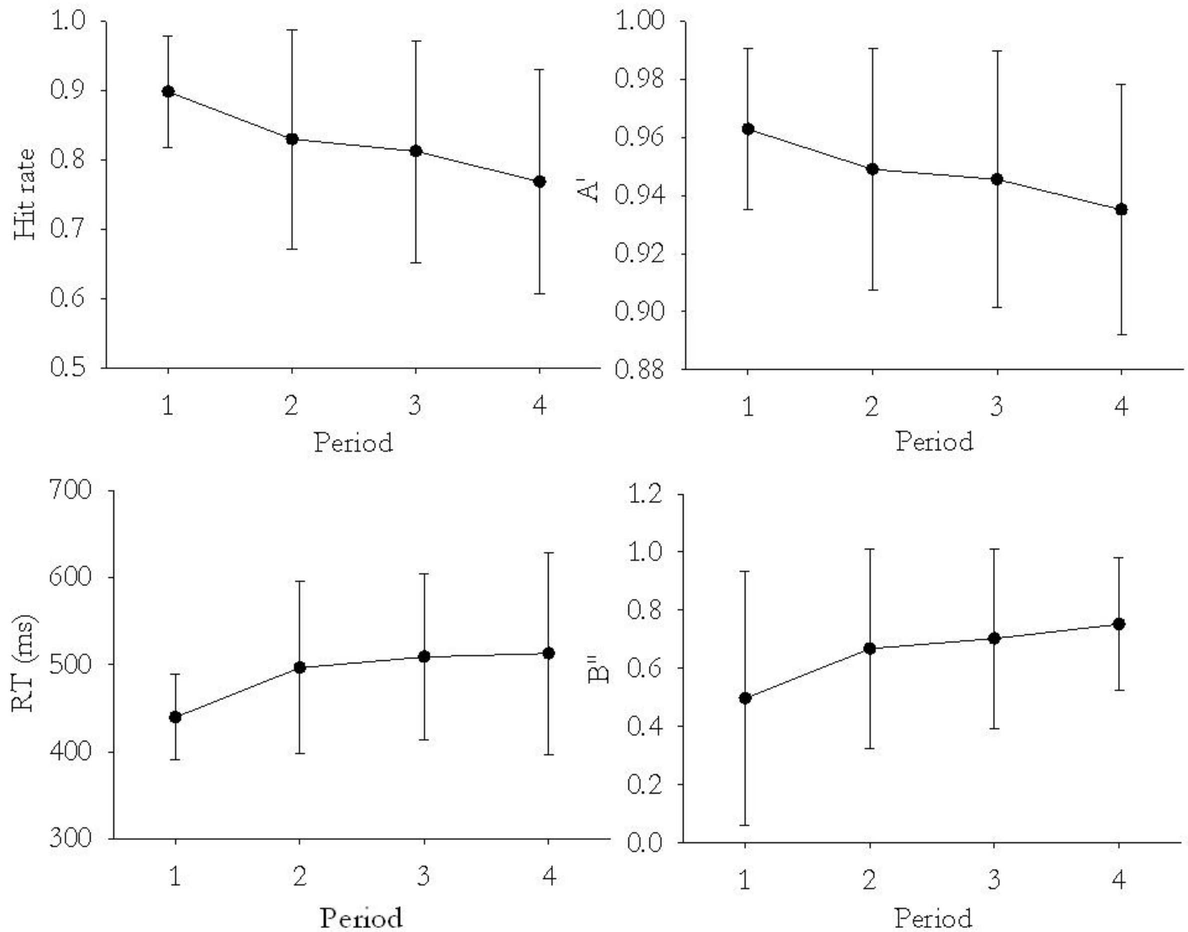

Figure 1. Mean hit rate (upper left) sensitivity (upper right) reaction time (lower left) and bias (lower right).
Note. Error bars indicate standard deviation.

Self-Report Measures

Figure 2 displays mean post vigil NASA-TLX and DSSQ change scores with their confidence intervals. Paired sample t-tests were used to examine the change in DSSQ scores pre-task and post-task. Energetic arousal (EA) decreased $t(18) = 3.94$, $p < .001$ and TRTs increased $t(18) = 4.03$, $p < .001$. Tense arousal (TA) and TUT did not change significantly. Compared to the scale midpoints NASA-TLX scores show a pattern of low physical demand, low temporal demand and a slightly high mental demand during the vigil. The various NASA-TLX scores were treated by repeated measures ANOVA to compare differences in scale scores. This analysis revealed that NASA-TLX scales varied significantly, $F(5, 85) = 11.53$, $p < .001$, $\eta^2 = .40$. Visual inspection of Figure 2 suggests the task imposed significant mental demand and low physical demand. Overall, the task demanded an average level of workload, $M = 51.48$, $SD = 13.57$.

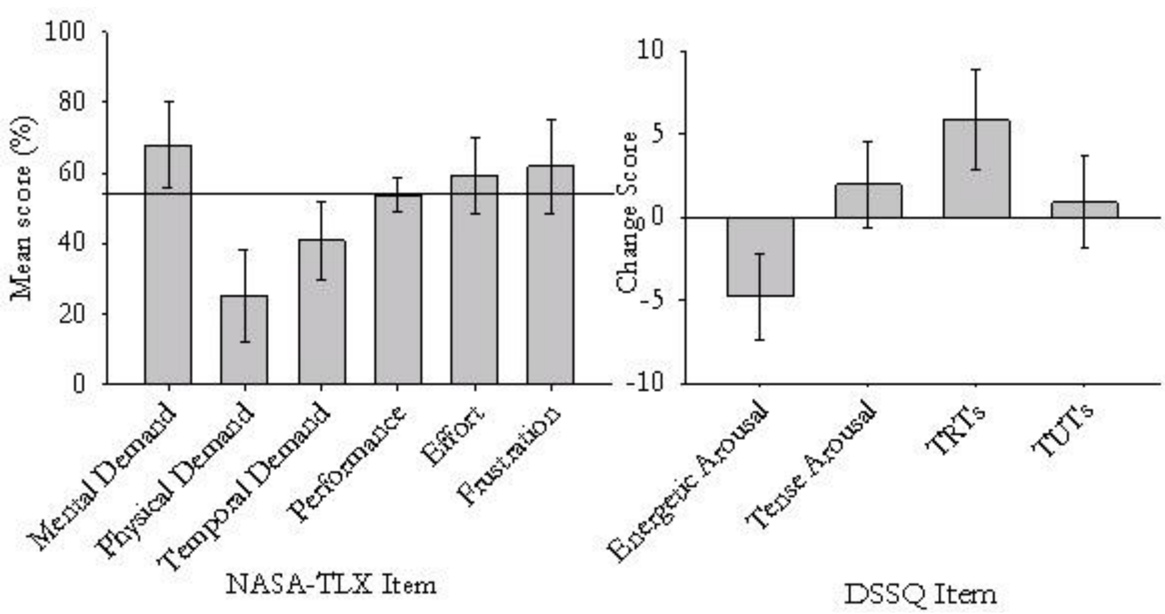

Figure 2. Mean DSSQ change scores and NASA-TLX scores.
Note. Error bars displayed on both graphs indicate 95% confidence intervals. The horizontal line through NASA-TLX Figure indicates the measures intermediate score (scores' confidence intervals not intersecting this line are indicative of statistical significance.

Discussion

From the control condition reported in Ariga and Lleras (2011) it was anticipated that the line-length vigilance task would produce decrement in detection performance with time on task. Results confirmed a significant decrement in hit rate, sensitivity and speed of response, similar to that of Ariga and Lleras (2011). Also identified was an increasingly conservative trend in response bias which cannot be concluded as unique to the present replication as Ariga and Lleras (2011) failed to report response bias analysis. In addition to the performance measures, our subjective measures also showed patterns characteristic of vigilance tasks with elevated TRTs, mental demand and reduced energetic arousal. The task was intermediately demanding with the average overall workload falling on the midpoint of the NASA-TLX. This is similar to other relatively 'easier' vigilance tasks (Dittmar, Warm, Dember, & Ricks, 1993; Grier et al., 2003; Temple et al., 2000). As previously mentioned, a significant change in bias towards increased conservative responding was found which was intriguing as response bias was not reported by Ariga and Lleras (2011). Participants became more cautious with their responses, making fewer FAs and hits. This is interesting as FA rates did not vary significantly although this may be due to a floor effect for FA rates. It is known that increasing signal irregularity (Deese & Ormond, 1953) and low task demand (Parasuraman, 1986) lead to more conservative responding. The pseudo-random signal presentation and variable ISI lengths in conjunction with the relatively low task difficulty may have been responsible for the observed bias shift.

We concluded that the task induced a low cognitive load through high signal salience. The only consideration that was given as an alteration to the original task for further use was to reduce the signal salience. This would be achieved by reducing difference in the length of target and distracter stimuli. It was decided not to alter relative line lengths because of the increased cognitive load this might induce which might interfere with a planned secondary task in Experiment 2. Further we wanted to retain similarity with Ariga & Lleras (2011) as much as possible to allow comparisons between experiments.

The task was concluded to be unsuitable for the imbedding of simultaneous secondary visual tasks. This was primarily due to the high event rate which required highly regular attention toward the vigil stimuli. An audible secondary task was concluded to be most suitable.

Chapter 3

EXPERIMENT 2

Aim

Because Experiment 1 demonstrated that a reliable and substantial vigilance decrement occurs with the task employed by Ariga and Lleras (2011), we can confidently use it to explore the effects of rest breaks and secondary task engagement. This allows us by extension to contrast attentional resource theory and the goal habituation model. Unlike Ariga and Lleras (2011), we employ longer secondary events (60 seconds vs. two seconds). This ensures that rest-breaks and secondary task engagements serve their intended function of giving participants sufficient opportunity to reconsolidate attentional resources and/or completely deactivate the primary task goal. The secondary switch task also differs in that it is an audible counting task rather than a visual memory task. This discrepancy is to ensure low cognitive loading.

In order to compare and contrast rest breaks and goal dishabituation four groups of participants were employed. One group (continuous vigil only; control) completed the line-length vigilance task alone and without interruption or rest for the entire 40 minutes of the vigil. Another vigil only group (broken vigil only) was given a one minute rest break from the vigilance task after 20 minutes and again after 30 minutes into the vigil. Since these groups perform only one task, they are also no-switch groups, although they do differ as to whether they have a break from the line-length vigilance task or perform it continuously without a break. The remaining two groups performed a second task during the one minute periods 20 and 30 minutes into the vigil. As these two groups must switch to a second task during the one minute periods, they are designated as switch groups. Like the continuous vigil only group, the continuous switch group was given no break from the primary vigilance task but while monitoring visual displays for target line lengths they had to simultaneously complete the switch task. The second switch group, like the vigil only break group was not required to perform the line-length vigil during the one minute periods, but during these times they had to complete the switch task. In this way Experiment 2 is able to compare vigilance decrement where the task is uninterrupted and where rest breaks are provided. Further it affords opportunity to compare break periods where the break provides opportunity for complete rest with those where the goal is switched to a different task and also where the primary task has to be maintained (divided or dual task situation) and where it may lapse during the 1-minute switch periods. .We hypothesised from the resource theory perspective that an attenuation of the vigilance decrement might be observed by interpolating rest breaks in the task. This follows the rationale that attentional resources are given the opportunity to replenish stores through the temporary lack of demand. Similarly it is hypothesised that the switch task will not remediate the vigilance decrement and will instead catalyse it by additionally loading resource demand. Alternatively from the goal habituation model perspective, we hypothesise that the secondary switch task will attenuate the vigilance decrement through the dishabituation (switch-break) or habituation interference (switch-continuous) of the vigil goal. Furthermore rest-breaks might attenuate the decrement by suspending the vigil's goal representation, but to a lesser extent due to the lack of an alternative suppressive goal.

Also of interest are the interrelations within subjective measures, and between performance measures. Helton & Warm (2008) found that post-task TUTs were related to the overall hit rate and sensitivity performance of participants during vigils. Workload has also been reported to predict overall vigil performance (Wiggins, 2011). As an aside, we will examine the different positions regarding attentional resources and TUTs by McVay & Kane (2009) and Smallwood (2010). These are associated with the role of resources and TUT development as opposed to TUT inhibition. If TUTs are suppressed at the cost of attentional resources, participants with more salient worries preceding the task should perform worse than other more carefree participants (McVay & Kane, 2009). Or alternatively, if subconscious TUT precursors are elaborated into TUT at the expense of attentional resources, participants with greater TUT progression over the task should perform worse (Smallwood et al., 2004). Also of interest is the compromise between these two views that there exists a context specific role of attentional resources and TUT (Levinson et al., 2012). This view stipulates that resources have a dual role in the development of conscious TUT depending on task context. During demanding tasks, resources are employed proactively to focus attention on the primary task and prevent TUT intrusions. Alternatively, during minimally demanding tasks, surplus resources are misallocated toward TUT generation. As such we will investigate the relationship between self report measures and vigil performance.

Method

Participants

Participants were 40 (15 male) University of Canterbury psychology students aged 18 to 51 years (mean 22.0 years) with normal or corrected to normal vision. They were actively recruited and received course credit or a shopping voucher in return for participation.

Design

As already explained, the experiment involves four groups. Two groups completed only the line-length vigilance task of Ariga and Lleras (2011). One of these groups performed the task for 40 minutes without a secondary task or rest (control) while the other group was given a complete rest from the vigilance task for one minute after 20 minutes and again after 30 minutes into the 40 minute vigil (broken vigil). The remaining two groups performed not only the vigil but also the switch task. One of these groups continued the vigilance task without a break while simultaneously performing the switch task after 20 minutes and again after 30 minutes into the 40 minute vigil (continuous switch). Finally the second group to perform the secondary task was given a minute break in the vigil after 20 minutes and again after 30 minutes into the 40 minute vigil, during which they completed the switch task (broken switch). These four groups can be conceived comprising a 2 x 2 factorial design in which the two levels of a task factor (vigil only or switch task) are crossed with two levels of a break (break and no break) as illustrated in Figure 3

		Vigil	
		Continuous vigil	***Broken vigil***
Task	***Vigil only***	Control	Broken vigil
	Vigil + switch	Switch, continuous vigil	Switch, broken vigil

Figure 3. Experimental design.
Design of four between subject conditions using two between subject factors with two levels each.

Apparatus

The vigilance and switch tasks were run on laboratory computers using SuperLab Pro for Windows 2.1(Cedrus Corporation). Stimuli were displayed on 22” LCD screens (1680x1050 pixels) with a 60Hz refresh rate. Pairs of Panasonic stereo headphones were used to transmit audible stimuli and serial response mice were used for responding to ensure ms timing accuracy. Participants completed paper-and-pencil versions of the DSSQ (Matthews et al., 2002) and the NASA-TLX (Wickens & Hollands, 2000).

The vigilance task was identical to that of experiment 1, except that during minutes 20 and 30, the first 9 stimulus presentations were all distracters so that those in the continuous dual task group did not have to respond to both vigilance and secondary task events during these periods.

Responding towards the switch task also used the right mouse button of the same serial mouse as that employed for the vigilance task. The audio for the secondary switch task was generated using sound editing software (Audacity 2.0.3). Audio sequences were primarily composed of a series of tones which were similar in nature to sonar beeps. The tone was 32-bit, mono channel, 1411 kbps and 1050ms in duration. The switch task comprised a series of either 10 or 11 tones which were played for 60 second durations at an even ISI (4750, 4318 msec respectively). The beginning and end of audible sequences were denoted by a computer generated vocalised 'start' and 'end' to orientate and prepare participants to respond (synthetic speech generated using: www.research.att.com/~ttsweb/tts/demo.php). Identical audio sequences were presented to all groups following the 19th and 29th minutes of the vigil.

Procedure

The procedure was the same for that of experiment 1 except that practice and instructions deviated depending on between subject groups. The control group underwent an identical procedure as that of experiment 1.

Broken vigil group. Following the standard two-minute vigil practice, participants were informed about the potential for intermittent random breaks in the vigil where the switch task audio would be transmitted as a substitute. They were then familiarised with the audio by the transmission of three 20 second duration sequences.

Switch, continuous vigil group. Participants underwent one minute of vigil only practice as opposed to two for the rest of the groups. Following this, participants were informed of the content and possibility of random intermittent switch tasks simultaneous to the vigil. Participants were instructed to respond on the right serial mouse button to the total number of tones being an even or odd number immediately after the conclusion of the audio sequence. An even number was to elicit two presses and an odd number, one press. They were then given three 20 second practice sessions during which they completed the vigil and switch task together, as it would occur during the experiment. Feedback was given on the switch task practice well as the vigil.

Switch, broken vigil group. Participants completed the standard two minutes of vigil practice and were then informed on the content and possibility of intermittent and random switch tasks presented during the vigil, during which the vigil would be temporarily suspended. Participants were instructed to respond on the right serial mouse button to the total number of tones being an even or odd number immediately after the conclusion of the audio sequence. An even number was to elicit two presses and an odd number, one press. They then completed three 20 second practice sessions and received feedback. During practice sessions, the ISI (persistent red dot) was visually displayed as it would occur during the experiment.

Ethics approval

Ethics approval was provided by the University of Canterbury Human Ethics committee under a low-risk classification.

RESULTS

The two 1min 18sec periods following the 19th and 29th minutes (where manipulations were performed and a series of 9 distracters were presented) were removed from analysis. Performance metrics used were identical to those of experiment 1. Performance metrics were also transformed into linear equations using a line of best fit approach with the horizontal axis units of measurement being coded as -1.5, -.5, .5 and 1.5. This meant that the intercept of the equation fell on the midpoint of the vigil giving an indication of the overall average level of performance. DSSQ scores were transformed into change scores by subtracting pre-task from post-task scores. Violations to sphericity assumptions were Greenhouse-Geisser corrected (Greenhouse & Geisser, 1959). For analysis of the vigilance task performance, we directly analysed the effects of the experimental manipulations by performing a two (rest-break vs. continuous vigil) x two (switch-task vs. no-switch) x two (period 2 vs. period 3; period 3 vs. period 4) split-plot analyses.

Table 3 shows the descriptive statistics of hit rate, sensitivity and response bias per experimental condition over watch periods two three and four.

Table 2.
Descriptive statistics for performance measures per condition over periods of watch

		Period 1		Period 2		Period 3		Period 4	
Measure	Condition	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hit Rate	Control	.927	.09	.887	.08	.815	.15	.819	.15
	Broken vigil	.953	.04	.860	.12	.870	.10	.870	.12
	Switch, continuous vigil	.963	.06	.927	.05	.919	.08	.911	.05
	Switch, broken vigil	.953	.04	.890	.13	.911	.12	.856	.15
A′	Control	.979	.02	.971	.02	.953	.04	.954	.04
	Broken vigil	.984	.01	.962	.03	.965	.02	.963	.03
	Switch, continuous vigil	.990	.01	.980	.02	.976	.02	.978	.02
	Switch, broken vigil	.983	.01	.970	.03	.976	.03	.960	.04
B′′D	Control	.717	.40	.889	.11	.930	.06	.925	.06
	Broken vigil	.587	.42	.705	.35	.728	.37	.758	.46
	Switch, continuous vigil	.764	.27	.927	.06	.875	.13	.837	.17
	Switch, broken vigil	.600	.47	.775	.23	.728	.33	.827	.19
RT	Control	455	67	496	73	534	83	514	71
	Broken vigil	448	59	504	64	512	64	541	97
	Switch, continuous vigil	439	65	484	79	485	61	507	67
	Switch, broken vigil	466	54	529	93	532	93	562	118

Vigilance Performance

Hit rate. Hit rates demonstrated a decrement over periods of watch (periods one through four), $F(3, 108) = 10.72$, $p < .01$, $\eta^2 = .23$. Two mixed ANOVAs of two (vigil) x two (task) x two (periods two and three; three and four) revealed a significant period x vigil interaction between periods two and three, $F(1, 36) = 4.53$, $p < .05$, $\eta^2 = .11$. No significant results were found between period three and four. Figure 4 shows the changes in hit rate per condition over periods two, three and four (left panel), as well as the vigil x period two to three interaction (right panel).

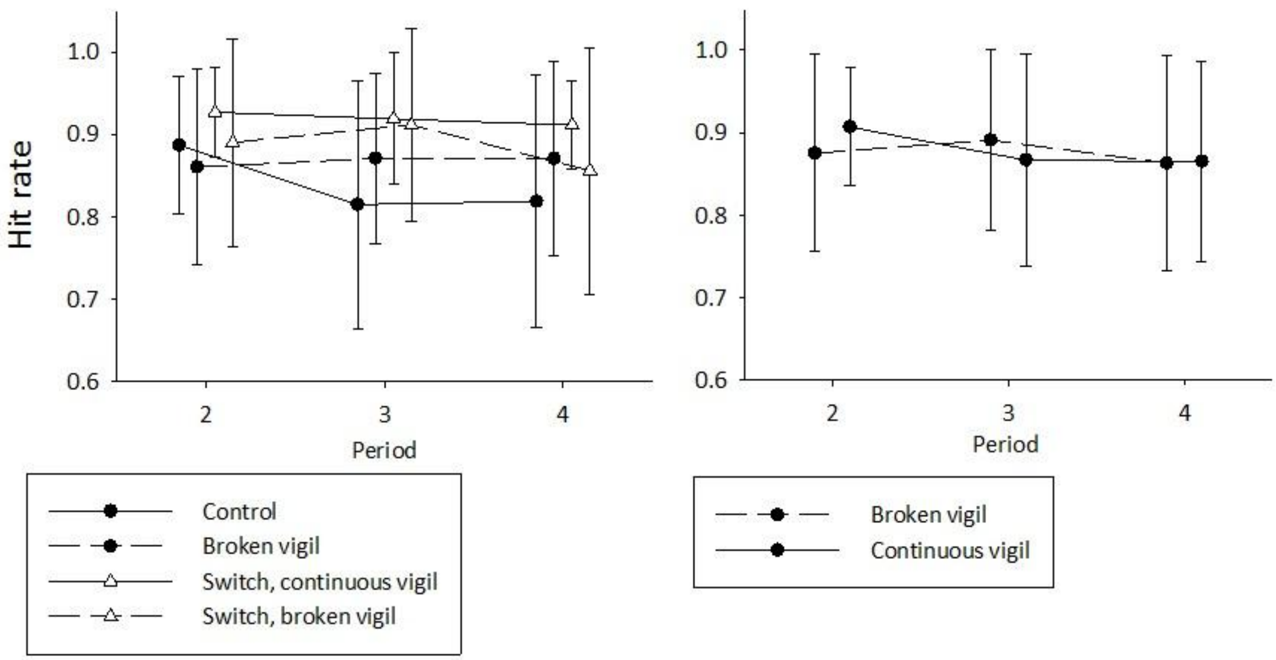

Figure 4. Mean hit rates per period by condition (left panel) and the continuous vigil vs. broken vigil interaction (right).
Note. Error bars represent standard deviation.

False Alarm (FA) Rate. False alarm rates did not follow a significant change over periods one through four. Further ANOVA analysis was therefore not completed. Participants in the control group exhibited markedly low FA rates with little variation. Overall, the average FA was .08% (or 2/270 responses per period), with a standard deviation of 1.8%. Comparison with a hypothetical distribution with an identical SD but cantered on mean of zero indicates that the observed FA rate can be interpreted as zero ($p > .6$). Regardless, FA rates still varied between participants and analysis of sensitivity and response bias was continued.

Sensitivity (*A′*). Sensitivity followed a decrement over periods of watch (periods one through four), $F(3, 108) = 9.26$, $p < .01$, $\eta^2 = .20$. *A′* was also analysed with two mixed ANOVAs of two (vigil) x two (task) x two (periods two and three; periods three and four). As with hit rate, there was a significant interaction for vigil over periods two to three $F(1, 36) = 5.5$, $p < .05$, $\eta^2 = .13$. No differences were observed between periods three and four. Figure 5 below shows the changes in sensitivity per group over periods two, three and four (left panel), as well as the vigil x period two to three interaction (right panel).

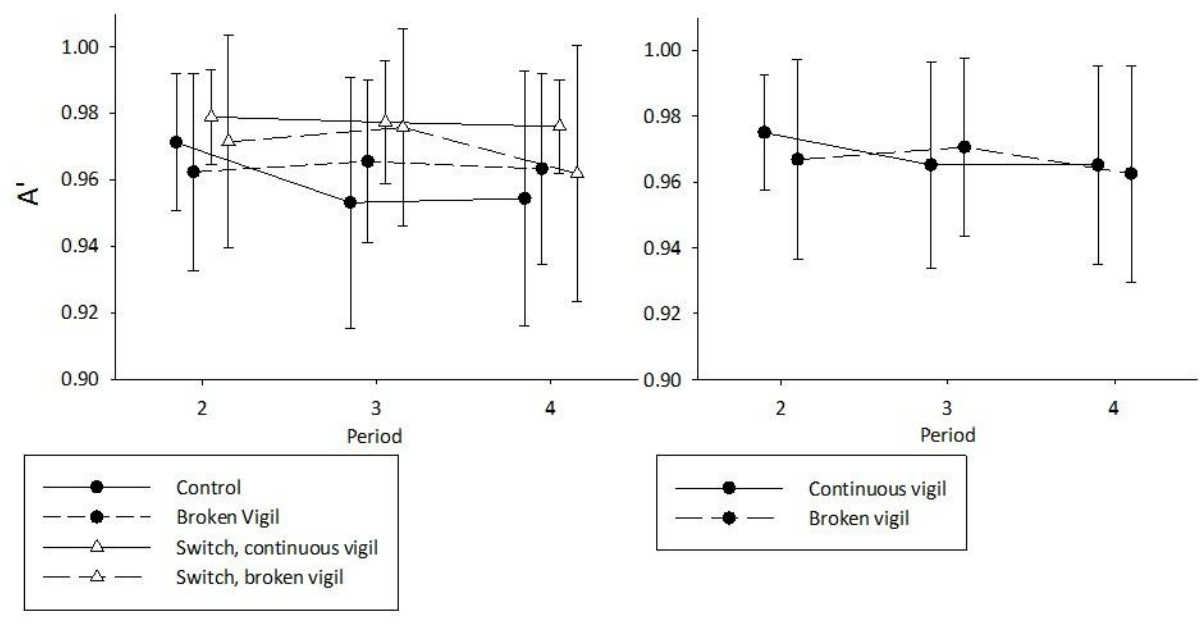

Figure 5. Mean sensitivity (*A′*) per period by condition (left panel) and the continuous vigil vs. broken vigil interaction (right).
Note. Error bars represent standard deviation.

Response Bias. Response bias became increasingly conservative over periods of watch (periods one through four), $F(1.44, 108) = 7.65$, $p < .01$, $\eta^2 = .23$, $\varepsilon = .48$. Two mixed ANOVAs of (vigil) x two (task) x two (periods two and three; periods three and four) determined an interaction for task over periods two and three, $F(1, 36) = 4.28$, $p < .05$, $\eta^2 = .11$, and also three and four, $F(1, 36) = 6.37$, $p < .05$, $\eta^2 = .15$. Figure 6 below shows the changes in response bias per condition over periods two, three and four (left panel) and the task x period two to three and period three to four interaction (right panel).

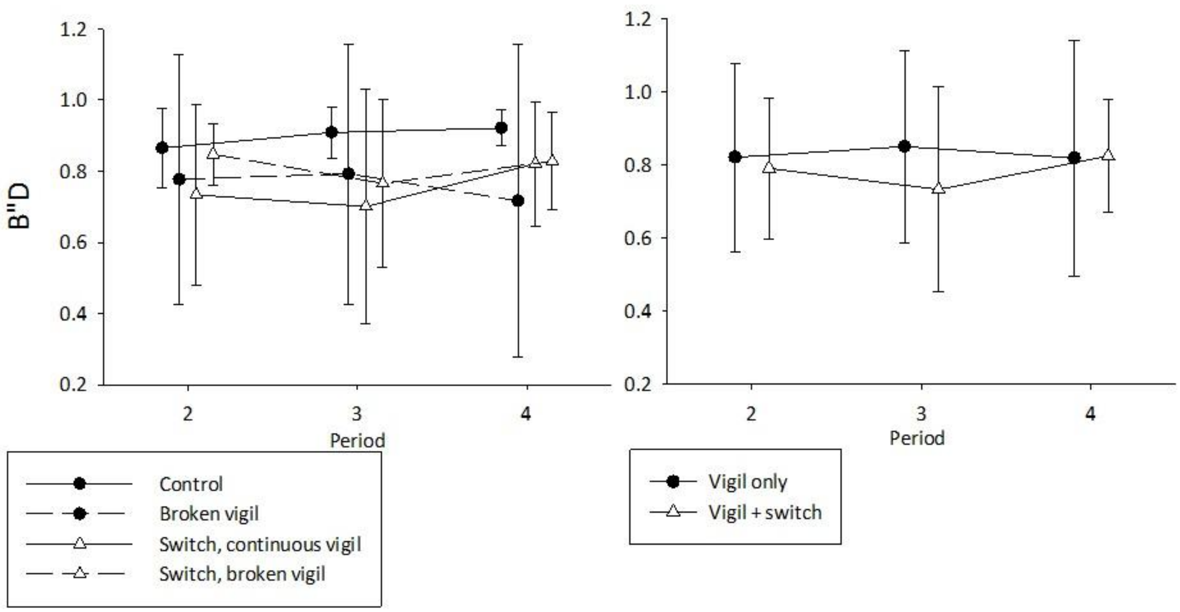

Figure 6. Mean response bias (B′′D) per period by condition (left panel) and the task interaction (right).
Note. Error bars denote standard deviation; Positive and negative B′′D values indicate conservative and liberal bias respectively.

Reaction time. A increment in RT was exhibited over periods one through four over all groups, $F(2.43, 108) = 24.65$, $p < .01$, $\eta^2 = .41$, $\varepsilon = .81$. Two mixed ANOVAs of (vigil) x two (task) x two (periods two and three; periods three and four) did not result in any significant results.

Switch task. From the switch conditions, the switch task data were divided into two overall sets, those who attempted the second task and those who didn't, and again for those who performed the switch task simultaneous with the vigil (switch/continuous) and those who received a reprieve in the vigil (switch/rest break). It was found that half of participants did not attempt to respond at all toward the switch task in the switch/rest break group (5/10) compared to those who were in the switch/continuous group (2/10). Chi-squared analysis revealed however that the difference in attempt rate was not significant, although this was probably due to a small sample size. Chi-squared analysis was also completed for correct responses overall although there were no significant differences between groups found. For those who did attempt the switch task, those in the switch/continuous group displayed better performance in the first switch task (7/8 vs. 3/5 correct), but those in the switch/rest break group improved during the second switch task (7/8 vs. 5/5 correct).

Subjective Measures.

DSSQ. DSSQ change scores (post-task – pre-task scores) per group are displayed in Figure 7 below. EA decreased while TA, TRT and TUT increased. Subscale scores of the DSSQ were treated by a mixed two (vigil) x two (task) x two (pre- and post-vigil) repeated measures ANOVA. Energetic arousal declined significantly over the course of the vigil, $F(1, 36) = 68.41$, $p < .001$, $\eta^2 = .65$, while tense arousal, $F(1, 36) = 29.70$, $p < .001$, $\eta^2 = .45$ and TRTs both increased, $F(1, 36) = 53.68$, $p < .01$, $\eta^2 = .60$. Participants who completed the switch task reported a larger decline in EA than those who only completed the vigil, $F(1, 36) = 8.87$, $p < .01$, $\eta^2 = .20$. There was also an interaction in EA as the switch, continuous group declined significantly more than those of the switch, broken vigil group, $F(1, 36) = 7.72$, $p < .01$, $\eta^2 = .18$. Analysis did not identify significant effects for TUT.

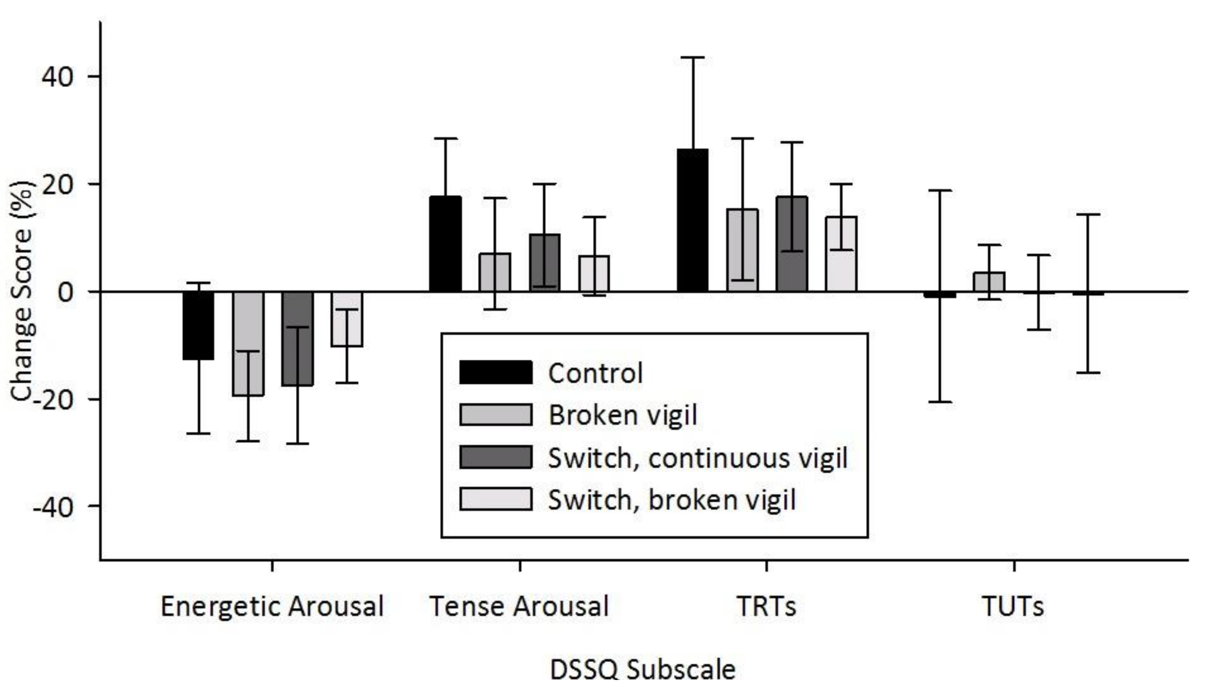

Figure 7. Mean DSSQ subscale change scores per condition.
Note. Error bars indicate 95% confidence intervals.

NASA-TLX. The mean NASA-TLX scale scores are shown in Figure 8. NASA-TLX data were entered into a two (vigil) x two (task) x six (subscales) mixed ANOVA which was not significant although did indicate a showed a trend towards broken vigils demanding lower workload.

Subscale scores were then subjected to a two (vigil rest breaks) x two (switch task) factorial ANOVA. Broken vigil participants reported significantly greater temporal demand than those who underwent the continuous vigil, $F(1, 33) = 4.92$, $p < .05$, $\eta^2 = .12$. Participants who performed the vigil only reported using more effort to complete the task $F(1, 33) = 4.18$, $p < .05$, $\eta^2 = .11$. No other subscale analyses were significant.

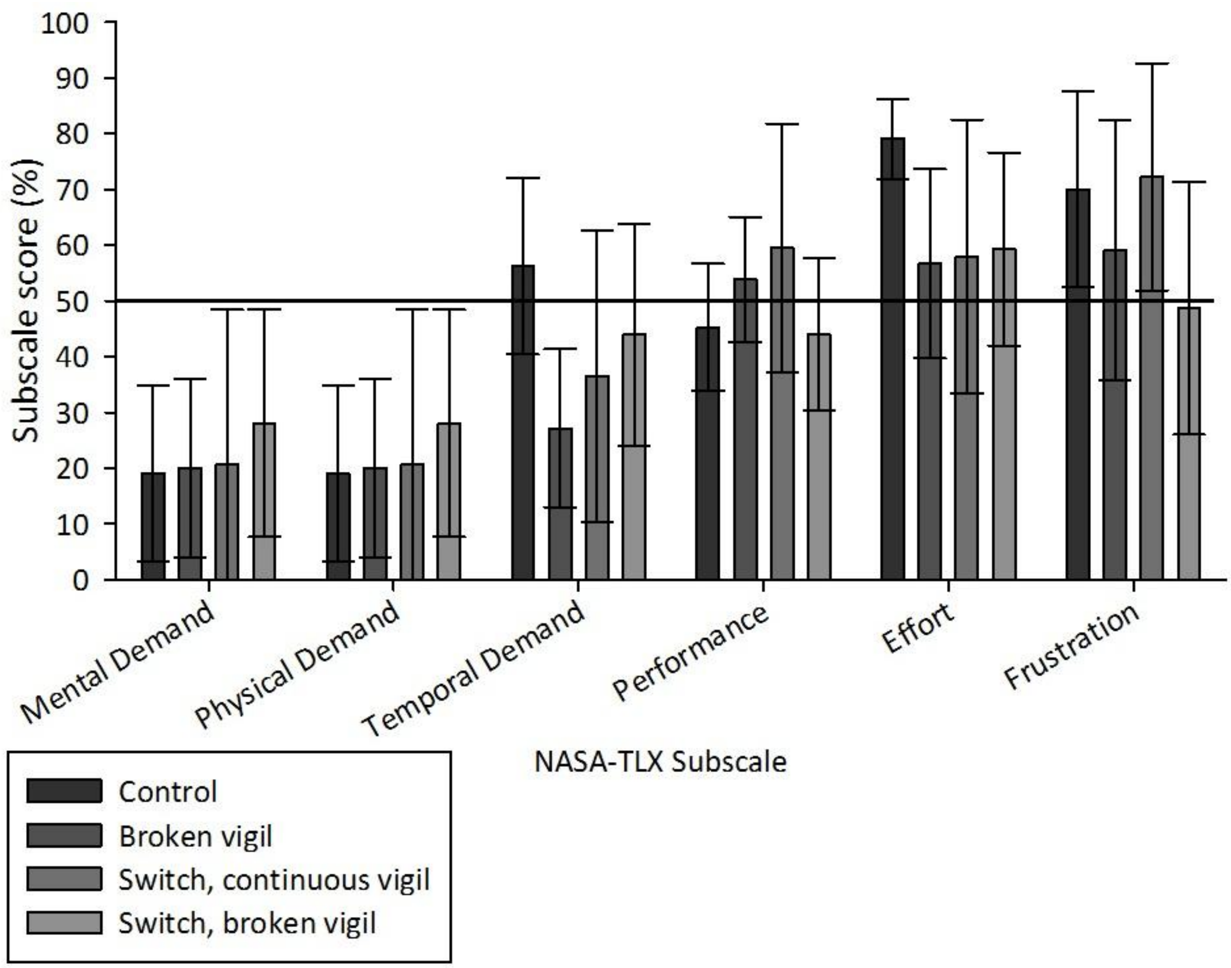

Figure 8. Mean NASA-TLX subscale scores per condition.
Note. Error bars denote 95% confidence intervals; The horizontal line refers to the midpoint of the scale (scores' confidence intervals not intersecting this line are indicative of statistical significance).

DSSQ vs. NASA-TLX and Vigil Performance.

NASA-TLX items were correlated with both pre-task and post-task DSSQ items. Higher pre-task TRT, $r(37) = .34$, $p = .03$ and post-task TRT $r(36) = .34$, $p = .02$ was associated with elevated scores on the NASA-TLX mental demand subscale. Higher pre-task EA was related to higher scores on the NASA-TLX performance subscale, $r(37) = .40$, $p = .01$. Higher scores on the NASA-TLX frustration, d $r(37) = .54$, $p < .01$, and performance subscales, $r(37) = .35$, $p = .03$, were associated with higher reports of TA.

Using the linear equations for performance metrics detailed earlier, comparison between the relationship of pre-task TUT and post- task TUT on average hit rate (intercept) was analysed using stepwise regression (entry = $p < .05$, exclusion = $p > .1$). Pre-task TUT was initially entered in the analysis and satisfied selection restrictions, $R^2 = .11$, $F(1, 35) = 5.71$, $p < .04$. Post-task TUT was not significant. Pre-task TUT was investigated for correlations per block and determined to be significant for the latter half of the vigil during periods three and four ($p < .05$).

Discussion

Overall, experiment two produced results which support resource theory and raise issues for the goal habituation model of vigilance. As hypothesised, rest breaks during the vigil produced the biggest benefits to performance, although only following the first break. Participants who were required to perform the switch task lost significantly more self-reported energy and in particular, those who performed it simultaneously with the vigil. The switch task also demanded more effort from participants and imposed a higher workload.

We unexpectedly found that the switch task produced significant shifts in response bias towards liberal responding. This effect, like rest breaks, also only occurred following the first switch task. This is curious, especially considering we consistently found a trend towards increasingly conservative responding in experiments one and two. This indicates that participants made increasingly fewer hits and FAs, although participants became more liberal making more hits and FAs following switch task.

Our results also supported at face value the central position of McVay & Kane (2012). They argue that attentional resources are used to suppress TUT as well as maintain vigilance performance. Pre-task TUTs should therefore have a greater association with vigil performance than post-task TUTs. Greater pre-task TUT were found to significantly predict poorer average vigil performance while post-task TUTs did not, when pre-task TUTs were accounted for. This provides some support for the idea proposed by McVay and Kane that those with pressing worries brought into the vigilance task may have difficulties suppressing them. It may be that it is not the TUTs that cause performance disruption, but the TUTs may be a sign of executive control exhaustion (the system is too fatigued to suppress the worries). Self-reported workload on the NASA-TLX did not differ substantially between experimental groups. Further investigation using the present task would be interesting through varying participant workload and examining if workload mediates the relationship between pre-task TUT, post-task TUT, and vigil performance.

Some limitations were identified during the study. Participants in the switch, broken vigil group commonly reported having difficulty responding toward the switch task as a result of the sudden reinstatement of the vigil. Future use of the current task may benefit by including the response period for the switch, broken vigil group, within the vigil break.

Chapter 5

GENERAL DISCUSSION

In summary, we were successfully able to reproduce the decrement obtained by the control condition of Ariga and Lleras (2011) in experiment one. During experiment two, we found results consistent with a resource theory account of vigilance. The results of experiment 2 pose challenges for the goal habituation model and provide support and new research questions for both expectancy and resource theories. The finding that breaks during the vigil reduced the hit rate and sensitivity decrement fall in line with the rationale that they give the opportunity for attentional resources to replenish. Alternatively it might be argued that the break in a vigil might suspend or arrest goal habituation or increase arousal. However, increases in arousal are unlikely because participants were required to remain at their station during breaks and simply view the central red fixation dot during the extent of the break. This is hardly an arousing situation. Also, participants who received breaks reported lower levels of expended effort and an overall trend to lower levels of workload, while participants who completed the secondary task reported larger declines in energetic arousal.

Our results also gave relevant information on the nature of subjective states and vigilance. Greater pre-task TUTs were associated with poorer hit rates during periods three and four. This would imply that participants who have a lot of concerns preceding the task were unable to prevent them from manifesting as TUT into consciousness at a cost of executive resources

(McVay & Kane, 2009). This is likely due to the relatively low workload induced by the task. As previously mentioned, further investigation using this task by varying signal salience is warranted to examine a moderating effect between TUT and performance by workload.

The criterion shift results were unexpected and intriguing as sensitivity is most commonly investigated and Ariga and Lleras (2011) failed to report any response bias data and/or analysis. The first experiment which aimed to replicate the Ariga and Lleras (2011) task produced a significant criterion shift towards conservative responding over the task. Secondly, during experiment two, task switching temporarily alleviated the response bias shift. This was evident through the interaction of task switching over periods two and three for bias, toward more liberal responding. This effect did not last however as there was a subsequent identical interaction over periods three and four where bias shifted back to more conservative responding. Together it would suggest that task switching may temporarily suspend Broadbent's (1971) vicious expectancy-criterion shift cycle, 'resetting' expectancy. To recap this, when a participant perceives missing a target or making a FA, they become more hesitant to respond. This in turn results in the shifting of their threshold criterion upward, becoming more conservative in 'yes' responding and failing to register hits and false alarms. Identical events in turn reduce expectancy and the process evolves into a vicious cycle, continually increasing the decision criterion (Broadbent, 1971).

The previously discussed result however brings up multiple considerations to the conclusions made by Ariga and Lleras (2011). Task switching may have the propensity to temporarily alleviate criterion shifts toward conservatism. This should not be problematic to their original findings although as task switches were shown to affect sensitivity which was previously explained to be independent of criterion shift. To recap, in principal sensitivity and bias are independent of one another in continuous hit and false alarm variables. This is not the case in practical settings however as one cannot exceed 100% or 0% of yes and no responses. When hit and/or false alarm rates reach ceiling of floor limitations, the assumptions of independence between sensitivity and bias is invalidated. As it was identified there was no difference between obtained FA rates and hypothetical zero FA during our study, we can assume that this independence does not hold. Ariga and Lleras (2011) report obtaining FA rates >1% during their study. In summary, this equates to the possibility that Ariga and Lleras' (2011) sensitivity finding may be invalid due to a response bias shift which their task is likely to produce, and which task switch has been found also impact. This would then leave only hit rate and RT as suitable variables for vigilance decrement analysis. Hit rate analysis was however absent and no significant RT results were found between conditions in Ariga and Lleras (2011). This is compounded by the findings of Helton & Russell (2011; 2012) which failed to find any support for task switching alleviating traditional hit/FA rate decrement or sensitivity.

Although the present study failed to find support the goal-habituation model of vigilance, it still provided support and novel findings to the other existing vigilance literature and practical considerations. The results of this experiment demonstrate the advantages and disadvantages of taking breaks during sustained attention demanding duties, as opposed to switching duties temporarily. Rest breaks during work should be more advantageous during strenuous tasks which contain great demands upon the individual. The effects of rest breaks are also longer lasting than task switching. Alternatively, task switching is more beneficial during minimally demanding tasks where participants merely fail to detect all stimuli. The effect of task switching is not as long lasting as taking rest breaks but may arguably be more effective than rest breaks as it may not reset an individual's criterion as they may continue thinking about the task and their expectancy. This study also points out the over compliance with SDT measures. Greater consideration and of the limitations and assumptions involved should help ensure that invalid conclusions are not drawn from results.

The limitations of the current experiment were mainly associated with the setting and responding toward the switch task. Ideally if the experiment were completed again, having individuals participate in stricter laboratory conditions and independently would be very advantageous. The temptation for off task-behaviour is increased in group and classroom settings and participant's data had to be replaced due to off-task behaviour in once instance. Unstructured feedback from participants suggests that their responding toward the switch task was greatly impaired by the concomitant reinstatement of the vigil. We reasoned that not placing targets within the first 18 seconds of periods three and four would allow for a sufficient period to respond, although this appears to have been insufficient time. In future, positioning the switch task response period within the vigil breaks should overcome this problem. Future directions for research would be to increase the difficulty of the task to further investigate task switching's effect on criterion shift and to remove the false alarm floor effect. Further investigating the effect of rest breaks would be advantageous such as varying lengths and task difficulty.

References

Adams, J. A., & Boulter, L. R. (1964). Spatial and temporal uncertainty as determinants of vigilance behavior. *Journal of Experimental Psychology, 67*(2), 127.

Andreassi, J. L. (1966). Skin-conductance and reaction-time in a continuous auditory monitoring task. *The American Journal of Psychology*, 470-474.

Antrobus, J. S. (1968). Information theory and stimulus-independent thought. *British Journal of Psychology, 59*(4), 423-430.

Antrobus, J. S., Singer, J. L., & Greenberg, S. (1966). Studies in the stream of consciousness: Experimental enhancement and suppression of spontaneous cognitive processes. *Perceptual and Motor Skills, 23*(2), 399-417.

Ariga, A., & Lleras, A. (2011). Brief and rare mental "breaks" keep you focused: Deactivation and reactivation of task goals preempt vigilance decrements. *Cognition, 118*(3), 439-443.

Ariga, A., & Lleras, A. (2011). Brief and rare mental "breaks" keep you focused: Deactivation and reactivation of task goals preempt vigilance decrements. *Cognition, 118*(3), 439.

Baker, C. H. (1959a). Attention to visual displays during a vigilance task. *British Journal of Psychology, 50*(1), 30-36.

Baker, C. H. (1959b). Towards a theory of vigilance. *Canadian Journal of Psychology/Revue canadienne de psychologie, 13*(1), 35.

Baker, C. H. (1962). Probability of Signal Detection in a Vigilance Task. *Science, 136*(3510), 46-47.

Bergum, B. O., & Lehr, D. J. (1962). Vigilance performance as a function of interpolated rest. *Journal of Applied Psychology, 46*(6), 425.

Broadbent, D. E. (1971). *Decision and stress*: Academic P.

Broadbent, D. E., Cooper, P., Fitzgerald, P., & Parks, K. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British journal of clinical psychology, 21*(1), 1-16. doi: 10.1111/j.2044-8260.1982.tb01421.x

Browne, R. C. (1949). The day and night performance of teleprint switchboard operators. *Occupational Psychology, 23*, 121-126.

Caggiano, D. M., & Parasuraman, R. (2004). The role of memory representation in the vigilance decrement. *Psychonomic bulletin & review, 11*(5), 932-937.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*: Lawrence Erlbaum.

Colquhoun, W. P. (1959). The effect of a short rest-pause on inspection efficiency. *Ergonomics, 2*(4), 367-372.

Colquhoun, W. P., & Baddeley, A. D. (1964). Role of pretest expectancy in vigilance decrement. *Journal of Experimental Psychology; Journal of Experimental Psychology, 68*(2), 156.

Colquhoun, W. P., & Baddeley, A. D. (1967). Influence of signal probability during pretraining on vigilance decrement. *Journal of Experimental Psychology; Journal of Experimental Psychology, 73*(1), 153.

Conway, A. R. A., Tuholski, S. W., Shisler, R. J., & Engle, R. W. (1999). The effect of memory load on negative priming: An individual differences investigation. *Memory & Cognition, 27*(6), 1042-1050.

Cosenzo, K. A. (2007). *The Effects of Multitasking on Cerebral Hemodynamics and Task Performance.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Craig, A. (1985). Field studies of human inspection: The application of vigilance research. *Hours of work: Temporal factors in work-scheduling*, 133-145.

Davies, D. R., & Parasuraman, R. (1982). *The psychology of vigilance*: Academic Press London.

Davies, D. R., & Tune, G. S. (1969). Human vigilance performance. New York: American Elsevier.

Deese, J. (1955). Some problems in the theory of vigilance. *Psychological Review, 62*(5), 359.

Deese, J., & Ormond, E. (1953). Studies of detectability during continuous visual search. *USAF, WADC Tech. Rep*(53-8).

Dittmar, M. L., Warm, J. S., Dember, W. N., & Ricks, D. F. (1993). Sex differences in vigilance performance and perceived workload. *Journal of General Psychology, 120*(3), 309-322.

Donaldson, W. (1992). Measuring recognition memory. *Journal of Experimental Psychology: General, 121*(3), 275.

Elkes, J. (1961). Drugs influencing affect and behavior: possible neural correlates in relation to mode of action. *The Physiology of Emotions. Springfield, Ill.: Charles C Thomas*, 95.

Eysenck, M. W. (1982). *Attention and arousal, cognition and performance*: Springer-Verlag Berlin.

Floyd, A. J. R., Griggs, G. D., & Baker, R. A. (1961). Role of expectancy in auditory vigilance. *Perceptual and Motor Skills, 13*(2), 131-134.

Fox, J. G. (1977). Quality control of coins. *Case Studies in Ergonomics Practice, London, Taylor & Francis, 1*.

Frankmann, J. P., & Adams, J. (1962). Theories of vigilance. *Psychological Bulletin; Psychological Bulletin, 59*(4), 257.

Freeman, G. L. (1940). The relationship between performance level and bodily activity level. *Journal of Experimental Psychology; Journal of Experimental Psychology, 26*(6), 602.

Funke, M. E., Warm, J. S., Matthews, G., Riley, M., Finomore, V., Funke, G. J. (2010). A Comparison of Cerebral Hemovelocity and Blood Oxygen Saturation Levels during Vigilance Performance. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 54*(18), 1345-1349. doi: 10.1177/154193121005401809

Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: A laboratory study. *Psychology and Aging, 4*(2), 136.

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and cognition, 4*(1), 1-21.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*(2), 95-112.

Grier, R. A., Warm, J. S., Dember, W. N., Matthews, G., Galinsky, T. L., Szalma, J. L. (2003). The vigilance decrement reflects limitations in effortful attention, not mindlessness. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 45*(3), 349-359.

Grodsky, A., & Giambra, L. (1989). Task unrelated images and thoughts whilst reading. *Imagery: Current Perspectives*.

Grodsky, A., & Giambra, L. M. (1990). The consistency across vigilance and reading tasks of individual differences in the occurrence of task-unrelated and task-related images and thoughts. *Imagination, Cognition and Personality*.

Halcomb, G., Barry, P., & Farl, M. C. (1970). Expectancy and stimulus generalization in vigilance. *Perceptual and Motor Skills, 30*(1), 147-151.

Harvey, L. O. (1992). The critical operating characteristic and the evaluation of expert judgment. *Organizational Behavior and Human Decision Processes, 53*(2), 229-251.

Head, H. (1926). *Aphasia and Kindred Disorders of Speech*. New York: MacMillan.

Helton, W., & Russell, P. (2012). Brief mental breaks and content-free cues may not keep you focused. *Experimental brain research, 219*(1), 37-46. doi: 10.1007/s00221-012-3065-0

Helton, W. S. (2009). Impulsive responding and the sustained attention to response task. *Journal of Clinical and Experimental Neuropsychology, 31*(1), 39-47.

Helton, W. S. (2011). Working memory load and the vigilance decrement. *Experimental brain research, 212*(3), 429-437. doi: 10.1007/s00221-011-2749-1

Helton, W. S., Hayrynen, L., & Schaeffer, D. (2009). Sustained attention to local and global target features is different: Performance and tympanic membrane temperature. *Brain and Cognition, 71*(1), 9-13. doi: 10.1016/j.bandc.2009.03.001

Helton, W. S., Head, J., & Russell, P. N. (2011). Reliable-and unreliable-warning cues in the Sustained Attention to Response Task. *Experimental brain research, 209*(3), 401-407.

Helton, W. S., Hollander, T. D., Warm, J. S., Matthews, G., Dember, W. N., Wallaart, M. (2005). Signal regularity and the mindlessness model of vigilance. *British Journal of Psychology, 96*(2), 249-261.

Helton, W. S., Hollander, T. D., Warm, J. S., Tripp, L. D., Parsons, K., Matthews, G. (2007). The abbreviated vigilance task and cerebral hemodynamics. *Journal of Clinical and Experimental Neuropsychology, 29*(5), 545-552.

Helton, W. S., Matthews, G., & Warm, J. S. (2009). Stress state mediation between environmental variables and performance: The case of noise and vigilance. *Acta psychologica, 130*(3), 204-213.

Helton, W. S., & Russell, P. N. (2012). Brief mental breaks and content-free cues may not keep you focused.

Experimental brain research, 219(1), 37-46. doi: 10.1007/s00221-012-3065-0

Helton, W. S., & Warm, J. S. (2008). Signal salience and the mindlessness theory of vigilance. *Acta Psychologica, 129*(1), 18-25. doi: 10.1016/j.actpsy.2008.04.002

Helton, W. S., Warm, J. S., Matthews, G., Corcoran, K. J., & Dember, W. N. (2002). Further Tests of an Abbreviated Vigilance Task: Effects of Signal Salience and Jet Aircraft Noise on Performance and Stress. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 46*(17), 1546-1550. doi: 10.1177/154193120204601704

Helton, W. S., Warm, J. S., Tripp, L. D., Matthews, G., Parasuraman, R., & Hancock, P. A. (2010). Cerebral lateralization of vigilance: A function of task difficulty. *Neuropsychologia, 48*(6), 1683-1688.

Hitchcock, E. M., Warm, J. S., Matthews, G., Dember, W. N., Shear, P. K., Tripp, L. D. (2003). Automation cueing modulates cerebral blood flow and vigilance in a simulated air traffic control task. *Theoretical Issues in Ergonomics Science, 4*(1-2), 89-112.

Joshi, A., Warm, J. S., & Dember, W. M. (1985). *Effects of event rate and spatial uncertainty on performance in simultaneous and successive vigilance tasks.* University of Cincinnati Cincinnati, OH.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*(2), 169-183.

Kane, M. J., & McVay, J. C. (2012). What Mind Wandering Reveals About Executive-Control Abilities and Failures. *Current Directions in Psychological Science, 21*(5), 348-354.

Kessler, R. C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E. (2005). The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. *Psychological medicine, 35*(2), 245-256.

Krulewitz, J. E., & Warm, J. S. (1977). The event rate context in vigilance: Relation to signal probability and expectancy. *Bulletin of the Psychonomic Society*.

Levinson, D. B., Smallwood, J., & Davidson, R. J. (2012). The Persistence of Thought Evidence for a Role of Working Memory in the Maintenance of Task-Unrelated Thinking. *Psychological Science, 23*(4), 375-380.

Lewin, J. S., Friedman, L., Wu, D., Miller, D. A., Thompson, L. A., Klein, S. K. (1996). Cortical localization of human sustained attention: detection with functional MR using a visual vigilance paradigm. *Journal of Computer Assisted Tomography, 20*(5), 695-701.

Lim, J., Wu, W., Wang, J., Detre, J. A., Dinges, D. F., & Rao, H. (2010). Imaging brain fatigue from sustained mental workload: an ASL perfusion study of the time-on-task effect. *Neuroimage, 49*(4), 3426-3435.

Lisper, H. O., Melin, L., Sjödén, P. O., & Fagerström, K. O. (1977). Temporal uncertainty of auditory signals in a monitoring task: Effects of inter-signal interval length and regularity on increase in reaction time. *Acta Psychologica, 41*(2), 183-190.

Loeb, M., & Alluisi, E. A. (1977). An update of findings regarding vigilance and a reconsideration of underlying mechanisms. *Vigilance: Theory, operational performance, and physiological correlates*, 719-814.

Loeb, M., Hawkes, G. R., Evans, W. O., & Alluisi, E. A. (1965). Influence of D-amphetamine, Benactyzine, and Chlorpromazine on Performance on an Auditory Vigilance Task. *The Journal of the Acoustical Society of America, 37*(6), 1194-1194.

Lyubomirsky, S., Kasri, F., & Zehm, K. (2003). Dysphoric rumination impairs concentration on academic tasks. *Cognitive Therapy and Research, 27*(3), 309-330.

Mackworth, J. F. (1968). Vigilance, arousal, and habituation. *Psychological Review; Psychological Review, 75*(4), 308.

Mackworth, N. H. (1948). The breakdown of vigilance durning prolonged visual search. *Quarterly Journal of Experimental Psychology, 1*(1), 6-21. doi: 10.1080/17470214808416738

Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. *Neuropsychologia, 37*(6), 661-670.

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: the default network and stimulus-independent thought. *Science, 315*(5810), 393-395.

Matthews, G., Campbell, S. E., Falconer, S., Joyner, L. A., Huggins, J., Gilliland, K. (2002). Fundamental dimensions of subjective state in performance settings: Task engagement, distress, and worry. *Emotion, 2*(4), 315.

Matthews, G., & Davies, D. R. (2001). Individual differences in energetic arousal and sustained attention: A dual-task study. *Personality and Individual Differences, 31*(4), 575-589.

Matthews, G., Davies, D. R., Westerman, S. J., & Stammers, R. B. (2000). *Human performance: Cognition, stress, and individual differences*. East Sussex, UK: Psychology Press.

Matthews, G., Joyner, L., Gilliland, K., Campbell, S. E., Falconer, S., & Huggins, J. (1999). Validation of a comprehensive stress state questionnaire: Towards a state "big three". *Personality psychology in Europe, 7*, 335-350.

McCormack, P. D. (1958). Performance in a vigilance task as a function of inter-stimulus interval and interpolated rest. *Canadian Journal of Psychology/Revue canadienne de psychologie, 12*(4), 242-246.

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(1), 196-204.

McVay, J. C., & Kane, M. J. (2012). Drifting from slow to "d'oh!": Working memory capacity and mind wandering predict extreme reaction times and executive control errors. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(3), 525.

Navon, D. (1984). Resources—a theoretical soup stone? *Psychological Review, 91*(2), 216.

Noonan, T. K., Karwoski, W., & Loeb, M. (1985). Perception of challenge and difficulty in a cognitive vigilance task. *Trends in ergonomics/human factors II, 2*, 189.

Nuechterlein, K. H., Parasuraman, R., & Jiang, Q. (1983). Visual Sustained Attention: Image Degradation Produces Rapid Sensitivity Decrement over Time. *Science, 220*(4594), 327-329.

O'Hanlon, J. F. (1965). Adrenaline and noradrenaline: Relation to performance in a visual vigilance task. *Science, 150*(3695), 507-509.

Oken, B. S., Salinsky, M. C., & Elsas, S. M. (2006). Vigilance, alertness, or sustained attention: physiological basis and measurement. *Clinical Neurophysiology, 117*(9), 1885-1901.

Ossowski, U., Malinen, S., & Helton, W. S. (2011). The effects of emotional stimuli on target detection: Indirect and direct resource costs. *Consciousness and Cognition, 20*(4), 1649-1658. doi: 10.1016/j.concog.2011.08.015

Parasuraman, R. (1979). Memory load and event rate control sensitivity decrements in sustained attention. *Science, 205*(4409), 924-927.

Parasuraman, R. (1985). Sustained attention: A multifactorial approach. *Attention and performance XI*, 493-511.

Parasuraman, R. (1986). Vigilance, monitoring, and search *Handbook of perception and human performance, Vol. 2: Cognitive processes and performance.* (pp. 1-39). Oxford England: John Wiley & Sons.

Parasuraman, R., & Caggiano, D. (2005). Neural and genetic assays of human mental workload. *Quantifying human information processing*, 123-149.

Parasuraman, R., & Davies, D. R. (1976). Decision theory analysis of response latencies in vigilance. *Journal of Experimental Psychology: Human Perception and Performance, 2*(4), 578.

Parasuraman, R., Warm, J. S., & Dember, W. N. (1987). Vigilance: Taxonomy and utility. *Ergonomics and human factors: Recent research*, 11-32.

Pardo, J. V., Fox, P. T., & Raichle, M. E. (1991). Localization of a human system for sustained attention by positron emission tomography. *Nature, 349*(6304), 61-64.

Paus, T., Zatorre, R. J., Hofle, N., Caramanos, Z., Gotman, J., Petrides, M. (1997). Time-related changes in neural systems underlying attention and arousal during the performance of an auditory vigilance task. *Journal of Cognitive Neuroscience, 9*(3), 392-408.

Pollock, I., & Knaff, P. R. (1958). Effect of rate of target presentation on target detection probability. *Amer. Psychol, 13*, 414.

Robbins, T. W. (1997). Arousal systems and attentional processes. *Biological psychology, 45*(1), 57-71.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). `Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia, 35*(6), 747-758. doi: 10.1016/s0028-3932(97)00015-8

Saldanha, E. (1957). Alternating an exacting visual task with either rest or similar work. *Applied Psychol. Unit Report*(289).

Scerbo, M. W., Warm, J. S., & Fisk, A. D. (1986). Event asynchrony and signal regularity in sustained attention. *Current Psychology, 5*(4), 335-343.

Schmertz, S. K., Anderson, P. L., & Robins, D. L. (2009). The relation between self-report mindfulness and performance on tasks of sustained attention. *Journal of Psychopathology and Behavioral Assessment, 31*(1), 60-66.

See, J. E. (1997). Vigilance and Signal Detection Theory: An Empirical Evaluation of Five Measures of Response Bias. *Human factors, 39*(1), 14-29. doi: 10.1518/001872097778940704

See, J. E., Warm, J. S., Dember, W. N., & Howe, S. R. (1997). Vigilance and signal detection theory: An empirical evaluation of five measures of response bias. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 39*(1), 14-29.

Sharpless, S., & Jasper, H. (1956). Habituation of the arousal reaction. *Brain, 79*(4), 655-680.

Smallwood, J. (2010). Why the global availability of mind wandering necessitates resource competition: Reply to McVay and Kane (2010). *Psychological bulletin, 136*(2), 202-207.

Smallwood, J., Davies, J. B., Heim, D., Finnigan, F., Sudberry, M., O'Connor, R. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness and cognition, 13*(4), 657-690.

Smallwood, J., Obonsawin, M., & Reid, H. (2002). The effects of block duration and task demands on the experience of task unrelated thought. *Imagination, Cognition and Personality, 22*(1), 13-13+.

Smallwood, J., Obsonsawin, M., Baracaia, S. F., Reid, H., O'Connor, R., & Heim, D. (2002). The relationship between rumination, dysphoria, and self-referent thinking: Some preliminary findings. *Imagination, Cognition and Personality, 22*(4), 317-342.

Smit, A. S., Eling, P. A. T. M., & Coenen, A. M. L. (2004). Mental effort causes vigilance decrease due to resource depletion. *Acta psychologica, 115*(1), 35-42. doi: 10.1016/j.actpsy.2003.11.001

Sostek, A. J. (1978). Effects of Electrodermal Lability and Payoff Instructions on Vigilance Performance. *Psychophysiology, 15*(6), 561-568. doi: 10.1111/j.1469-8986.1978.tb03110.x

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, 31*(1), 137-149.

Stevenson, H., Russell, P. N., & Helton, W. S. (2011). Search asymmetry, sustained attention, and response inhibition. *Brain and Cognition, 77*(2), 215-222. doi: 10.1016/j.bandc.2011.08.007

Surwillo, W. W., & Quilter, R. E. (1965). The Relation of Frequency of Spontaneous Skin Potential Responses to Vigilance and to Age. *Psychophysiology*.

Swets, J. A., Tanner, W. P., & Birdsall, T. G. (1964). Decision processes in perception. *Signal detection and recognition in human observers*, 3-57.

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I. (1995). Stimulus-independent thought depends on central executive resources. *Memory & Cognition, 23*(5), 551-559.

Teasdale, J. D., Proctor, L., Lloyd, C. A., & Baddeley, A. D. (1993). Working memory and stimulus-independent thought: Effects of memory load and presentation rate. *European Journal of Cognitive Psychology, 5*(4), 417-433.

Temple, J. G., Warm, J. S., Dember, W. N., Jones, K. S., LaGrange, C. M., & Matthews, G. (2000). The effects of signal salience and caffeine on performance, workload, and stress in an abbreviated vigilance task. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 42*(2), 183-194.

Tripp, L. D., Warm, J. S., Parasuraman, R., & Rizzo, M. (2007). Transcranial Doppler sonography. *Neuroergonomics: The brain at work*, 82-94.

Ware, R., & Baker, R. A. (1977). The effect of mental set and states of consciousness on vigilance decrement: a systematic exploration. *Vigilance: theory, operational performance, and physiological correlates. ed. by Mackie RR*, 603-616.

Warm, J. S. (1984). *Sustained attention in human performance*: John Wiley & Sons.

Warm, J. S., & Dember, W. N. (1998). Tests of vigilance taxonomy. In J. S. Warm (Ed.), *Viewing psychology as a whole: The integrative science of William N. Dember* (pp. 87-112). Washington, DC: American Psychological Association.

Warm, J. S., Dember, W. N., & Hancock, P. A. (1996). Vigilance and workload in automated systems *Automation and human performance: Theory and applications* (pp. 183-200). Mahwah, NJ: Erlbaum.

Warm, J. S., Matthews, G., & Parasuraman, R. (2009). Cerebral hemodynamics and vigilance performance. *Military psychology, 21*(S1), 75-100.

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 433-441.

Welford, A. T. (1968). Fundamentals of skill. London: Methuen.

Wickens, C. D., & Hollands, J. G. (2000). *Engineering Psychology and Human Performance* (3 ed.). Upper Sadle River, NJ: Prentice Hall.

Wiener, E. L. (1963). Knowledge of results and signal rate in monitoring: A transfer of training approach. *Journal of Applied Psychology, 47*(3), 214.

Wiggins, M. W. (2011). Vigilance decrement during a simulated general aviation flight. *Applied Cognitive Psychology, 25*(2), 229-235.

Yerkes, R. M., & Dodsan, J. D. (1908). Dodson. The relation of strength of stimulus to rapidity of habit formation, J. Com p. *Journal of Comparative Neurology and Psychology, 18*, 459-482.

Young, M. S., Robinson, S., & Alberts, P. (2009). Students pay attention! Combating the vigilance decrement to improve learning during lectures. *Active Learning in Higher Education, 10*(1), 41-55.

Telephone: +64 27 413 9688

Email: hayden.ross@pg.canterbury.ac.nz

deak.helton@canterbury.ac.nz

14th of May, 2012

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

The Impact of Disruptions on Vigilance

Information Sheet for Participants

My name is Hayden Ross and I am a Masters student in the Psychology Department at the University of Canterbury. My study involves investigating the nature of vigilance, i.e. sustained attention. In the investigation of vigilance, participants are asked to perform vigilance tasks and performance on these tasks is subsequently analysed.

I invite you to participate in my research which involves 20-40 minutes of completing a vigilance task and approximately 10 minutes to complete associated questionnaires. The vigilance task itself will be presented on a computer and responding will be required on response pad or keyboard.

Please note that if you are a STAR programme student at the university, you are not eligible to participate in this experiment. If this is the case, please notify the experimenter.

Your participation in the research is completely voluntary and you have the right to withdraw at anytime without penalty. If you withdraw, I will do my best to remove any information relating to you, provided this is practically achievable.

Access to the data will be limited to me, Associate Professor Deak Helton and Mr Paul Russell within the University of Canterbury Psychology Department. The data will be adequately, physically stored and will be destroyed after a significant period following the conclusion of the research. Your anonymity will be ensured by converting your data to a numerical string.

After approximately 60 years of research in the vigilance field, the known risks for participants are not significant. Some mild mental fatigue may be induced however although this is a vital component of the research. If at any time this becomes too much to handle please notify the experimenter and efforts will be made to address this.

If you would like a report on the research I can provide you with this by emailing me at the address provided on the letterhead.

If you have questions at anytime about the research, please do not hesitate to contact me or my academic supervisor with the contact details provided on the letterhead.

This research has received ethical approval from the University of Canterbury Educational Research Human Ethics Committee, and you can address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

I invite you now then to please sign the informed consent form if you understand and are willing to participate in the research. This can be returned to me immediately following its completion.

Hayden Ross

Telephone: +64 27 413 9688

Email: hayden.ross@pg.canterbury.ac.nz

deak.helton@canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

14th of May, 2012

The Impact of Disruptions on Vigilance

Informed Consent for Participants

I have read and I understand the attached Research Statement.

I freely agree to participate in this project according to the conditions in the Research Statement.
I have been given a copy of the Research Statement and Consent Form to keep.

The researcher has agreed not to reveal my identity and personal details, including where information about this project is published, or presented in any public form.

This proposal has been reviewed and approved by the Department of Psychology, University of Canterbury and the University of Canterbury Human Ethics Committee Low Risk process.

Participant’s name (printed): ……………………………………………………………………

Signature: …………………………………………………… Date: …………………………

APPENDIX B - QUESTIONNAIRES

DSSQ

PRE- QUESTIONNAIRE

General Instructions. This questionnaire is concerned with your feelings and thoughts at the moment. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Your answers will be kept entirely confidential. You should try and work quite quickly. The first answer you think of is usually the best.

Age............ (years) Sex. M F (Circle one)

Please indicate how well each word describes how you feel **AT THE MOMENT** (circle the answer from 1 to 5).

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

1. Energetic	1	2	3	4	5
2. Relaxed	1	2	3	4	5
3. Alert	1	2	3	4	5
4. Nervous	1	2	3	4	5
5. Passive	1	2	3	4	5
6. Tense	1	2	3	4	5
7. Jittery	1	2	3	4	5
8. Sluggish	1	2	3	4	5
9. Composed	1	2	3	4	5
10. Restful	1	2	3	4	5
11. Vigorous	1	2	3	4	5
12. Anxious	1	2	3	4	5
13. Unenterprising	1	2	3	4	5
14. Calm	1	2	3	4	5
15. Active	1	2	3	4	5
16. Tired	1	2	3	4	5

Please indicate roughly how often you had each thought **DURING THE LAST TEN MINUTES.**

Never = 1 Once = 2 A few times = 3 Often = 4 Very often = 5

17. I thought about how I should work more carefully.	1	2	3	4	5
18. I thought about how much time I had left.	1	2	3	4	5
19. I thought about how others have done on this task.	1	2	3	4	5
20. I thought about the difficulty of the problems.	1	2	3	4	5
21. I thought about my level of ability.	1	2	3	4	5
22. I thought about the purpose of the experiment.	1	2	3	4	5
23. I thought about how I would feel if I were told how I performed.	1	2	3	4	5
24. I thought about how often I get confused.	1	2	3	4	5
25. I thought about members of my family.	1	2	3	4	5
26. I thought about something that made me feel guilty.	1	2	3	4	5
27. I thought about personal worries.	1	2	3	4	5
28. I thought about something that made me feel angry.	1	2	3	4	5
29. I thought about something that happened earlier today.	1	2	3	4	5
30. I thought about something that happened in the recent past	1	2	3	4	5
31. I thought about something that happened in the distant past	1	2	3	4	5
32. I thought about something that might happen in the future.	1	2	3	4	5

POST-QUESTIONNAIRE

General Instructions. This questionnaire is concerned with your feelings and thoughts during the task. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Your answers will be kept entirely confidential. You should try and work quite quickly. The first answer you think of is usually the best.

Please indicate how well each word describes how you felt **DURING THE TASK** (circle the answer from 1 to 5).

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

1. Energetic	1	2	3	4	5
2. Relaxed	1	2	3	4	5
3. Alert	1	2	3	4	5

4. Nervous	1	2	3	4	5
5. Passive	1	2	3	4	5
6. Tense	1	2	3	4	5
7. Jittery	1	2	3	4	5
8. Sluggish	1	2	3	4	5
9. Composed	1	2	3	4	5
10. Restful	1	2	3	4	5
11. Vigorous	1	2	3	4	5
12. Anxious	1	2	3	4	5
13. Unenterprising	1	2	3	4	5
14. Calm	1	2	3	4	5
15. Active	1	2	3	4	5
16. Tired	1	2	3	4	5

Please indicate roughly how often you had each thought **DURING THE LAST TEN MINUTES.**

Never = 1 Once = 2 A few times = 3 Often = 4 Very often = 5

17. I thought about how I should work more carefully.	1	2	3	4	5
18. I thought about how much time I had left.	1	2	3	4	5
19. I thought about how others have done on this task.	1	2	3	4	5
20. I thought about the difficulty of the problems.	1	2	3	4	5
21. I thought about my level of ability.	1	2	3	4	5
22. I thought about the purpose of the experiment.	1	2	3	4	5
23. I thought about how I would feel if I were told how I performed.	1	2	3	4	5
24. I thought about how often I get confused.	1	2	3	4	5
25. I thought about members of my family.	1	2	3	4	5
26. I thought about something that made me feel guilty.	1	2	3	4	5
27. I thought about personal worries.	1	2	3	4	5
28. I thought about something that made me feel angry.	1	2	3	4	5
29. I thought about something that happened earlier today.	1	2	3	4	5
30. I thought about something that happened in the recent past	1	2	3	4	5
31. I thought about something that happened in the	1	2	3	4	5

distant past					
32. I thought about something that might happen in the future.	1	2	3	4	5

NASA-TLX

Figure 8.6

NASA Task Load Index

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

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

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

Very Low — Very High

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

Perfect — Failure

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

Very Low — Very High

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

Very Low — Very High