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# The effects of emotional stimuli on target detection: Indirect and direct resource costs

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ABSTRACT

The present study was designed to explore the performance costs of negative emotional stimuli in a vigilance task. Forty participants (20 women) performed a vigilance task in two conditions: one with task-irrelevant negative-arousing pictures and one with task-irrelevant neutral pictures. In addition to performance, we measured subjective state (energetic arousal, tense arousal, task-related and task-unrelated thoughts) and frontal cerebral activity with near infrared spectroscopy. Overall performance in the negative picture condition was lower than in the neutral picture condition and the negative picture condition had elevated levels of energetic arousal, tense arousal and task-related thoughts. Moreover, there was a significant relationship between the impact of the negative pictures on tense arousal and task-related thoughts and the impact of the negative pictures on performance (in comparison to the neutral picture stimuli task). These results provide support for indirect cost models of negative emotional stimuli on target detection performance.



## 1. Introduction

People often need to sustain their attention, or remain vigilant, to streams of sensory information for prolonged periods of time and to detect the occurrence of rarely occurring critical stimuli in those streams (Davies & Parasuraman, 1982; Warm, 1984; Warm & Jerison, 1984). This ability to remain vigilant plays a role in many occupational and real-world settings, such as medical monitoring, military operations, surveillance, and transportation (Hancock & Hart, 2002; Warm, Parasuraman, & Matthews, 2008; Wickens & Hollands, 2000). Despite extensive research on sustained attention and vigilance (cf., Ballard, 1996; Davies & Parasuraman, 1982; Parasuraman, 1986; Proctor & Kim-Phuong, 2010; Warm et al., 2008), there has been little research on the impact that the emotional valence of stimuli present during the task may have on vigilance performance. In recent studies, Helton and colleagues (Helton, Dorahy, & Russell, 2011; Helton & Russell, 2011a) found that participants' target detection performance during vigilance tasks interrupted by negative arousing task-irrelevant picture stimuli was worse than during a vigil interrupted by neutral non-arousing task irrelevant picture stimuli. In the present study, we further explored the impact negative pictures have on vigilance by adding self-report measures of mood and thoughts occurring during the task and the monitoring of frontal cerebral activity with functional near infrared spectroscopy (fNIRS) during the task to the experimental protocol developed by Helton and colleagues.

The finding that negative emotional task-irrelevant stimuli had a detrimental impact on vigilance performance in comparison with neutral task-irrelevant stimuli raises questions regarding the underlying cause of attention lapses. Some vigilance researchers have suggested that poor vigilance is due to either under-arousal or boredom induced by task monotony (Manly, Robertson, Galloway, & Hawkins, 1999; Pattyn, Neyt, Henderickx, & Soetens, 2008; Robertson, Manly, Andrade,

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Baddeley, & Yiend, 1997). In vigilance tasks, the critical signals for detection occur infrequently. During the relative inactivity between critical signals, observers become increasingly bored which leads them to treat their assignment in a thoughtless manner. Participants disengage due to the non-stimulating nature of the task and this conscious disengagement results in lapses. Helton and colleagues' findings, however, prove vexing for this perspective, as the negative picture stimuli utilized in these studies have been found in other studies to be arousing (Helton, Kern, & Walker, 2009; Kern, Libkuman, & Otani, 2002; Kern, Libkuman, Otani, & Holmes, 2005; Lang, Greenwald, Bradley, & Hamm, 1993). Indeed, the stimuli were chosen from the International Affective Picture System (IAPS; Lang et al., 2001), because they were rated as being both high in negative valence and high in arousal. Nevertheless, Helton and colleagues' studies did not include measures of arousal, and while unlikely, there is the possibility that in combination with a vigil, the negative pictures produced no greater arousal in participants then the neutral pictures. Therefore, in the present experiment we have included self-report measures of both energetic and tense arousal (Matthews et al., 2002).

The alternative perspective of the cause of attention lapses during vigilance tasks is the resource depletion or mental fatigue theory (Helton & Warm, 2008; Matthews, Davies, Westerman, & Stammers, 2000; Parasuraman & Davies, 1977; Parasuraman, Warm, & Dember, 1987; Warm et al., 2008). Information-processing requires resources dedicated to task performance (Hirst & Kalmar, 1987) and these resources are not unlimited (Kahneman, 1973; Matthews et al., 2000). In carrying out vigilance tasks, observers must make continuous target/no-target discriminations under conditions of uncertainty without rest. The continuous nature of the information processing in vigilance does not allow for replenishment of these resources. Hence, the resource pool depletes over time, which is reflected in attention lapses (see Hitchcock et al., 2003; Shaw et al., 2009). This resource theory is the perspective advocated by Helton and Russell (2011a), as it appears more consistent with their findings. From this perspective the presence of task irrelevant negative emotional stimuli consumed additional attention resources and thus, resulted in lower performance. Nevertheless, there are two, not necessarily mutually exclusive, means by which the emotional stimuli may have consumed cognitive resources: directly and indirectly.

In regards to direct resource costs, in previous studies task-related emotional stimuli have been identified with higher accuracy than neutral stimuli in a variety of research paradigms, including attentional-blink, choice-reaction time, and visual search tasks (Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ohman, Flykt, & Esteves, 2001; Zeelenberg, Wagenmakers, & Rotteveel, 2006). Task-unrelated emotional stimuli have also been found to disrupt or interfere with on-task processing when presented concurrently with or just prior to task-related stimuli by spatially capturing and holding attention (Fox, Russo, Bowles, & Dutton, 2001). While the sustained impact of emotional stimuli on attention and task-relevant processing has been relatively unexplored, emotional stimuli, whether task-relevant or irrelevant, appear to directly consume processing resources (Ihssen & Keil, 2009). Emotional stimuli attract and hold attention in-of-themselves.

While direct resource costs may occur, emotional stimuli may also result in indirect resource costs by increasing the occurrence of conscious thoughts. The threatening nature of negative emotional stimuli may alter the subjective-state of the participant and encourage more elaborate conscious thought processing. Smallwood and colleagues (2009) have reported elevated levels of conscious thoughts after negative mood inductions. If these conscious thoughts compete for processing resources with task processing, then negative emotional stimuli may indirectly incur a resource cost via their impact on mood and thought occurrence (see McVay and Kane (2010) and Smallwood (2010) for alternative perspectives regarding resource costs of conscious thoughts). The present study explores the issue of indirect costs by including self-report measures of both task-related and task-unrelated thoughts occurring during the task (Matthews et al., 2002).

In order to further examine resource costs, we also employed a measure of cerebral activity, functional near-infrared spectroscopy (fNIRS). fNIRS measures hemodynamic changes within the brain, in particular regional oxygen saturation ($rSO_2$) in the cerebral cortex (Toronov et al., 2001). Research has demonstrated its potential in experimental settings and expanded the use of fNIRS to non-clinical samples (Helton et al., 2007, 2010). Previous research has confirmed that fNIRS is a valid and reliable technology comparable to neuroimaging techniques such as functional magnetic resonance imaging for measuring cerebral activation (Toronov et al., 2001).

In the present experiment, observers performed two vigilance tasks in a counterbalanced order: a negative emotion picture task and a neutral picture task. In these conditions, the vigil included the random presentation of brief task-irrelevant picture stimuli. In line with Helton and Russell's (2011a) findings, we expected that target detection performance would be worse in the negative picture stimuli task than in the neutral picture stimuli task. The emotional picture stimuli employed have been found to increase both self-reported energetic and tense arousal (Helton et al., 2009b; Kern et al., 2005; Lang et al., 1993). Therefore, we expected that self-reports of arousal, both energetic and tense, would be elevated more after the negative picture stimuli condition than the neutral picture stimuli condition. If there are indirect resource costs of negative picture stimuli, we would expect that reports of task-unrelated and task-related thoughts would be higher after the negative picture stimuli condition than the neutral picture stimuli condition. More specifically, if state induced increases in conscious thoughts consume attention resources, we would expect a significant relationship between negative stimuli induced task thoughts (e.g., relative to the neutral stimuli task thoughts) and the performance cost of negative stimuli (e.g., in comparison with performance on the task performance without negative stimuli). In addition, we hoped the inclusion of fNIRS, would provide further elaboration on the resource cost issue. Vigilance, for example, has been previously found to be right-hemisphere dominant (Berman & Weinberger, 1990; Cohen et al., 1988; Deutsch, Papanicolaou, Bourbon, & Eisenberg, 1987; Duschek & Schandry, 2003; Helton et al., 2007; Hitchcock et al., 2003; Parasuraman, Warm, & See, 1998; Pardo, Fox, & Raichle, 1991; Shaw et al., 2009). The processing of negative emotional stimuli has also been found to be right-hemisphere dominant (Balconi & Lucchiari, 2008; Foster et al., 2008). Helton et al. (2011) have suggested this may result in increased