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Reducing the vigilance decrement: The effects of perceptual variability

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ABSTRACT

The longer we are required to monitor for rare but critical events, the accuracy and speed with which we detect such events tend to suffer (the 'vigilance decrement') with more difficult tasks yielding larger decrements. Here, we present a striking example of a situation in which increasing the difficulty and complexity of a novel vigilance task actually decreases the vigilance decrement. In a 'Stable' condition participants monitored for the same critical target throughout the task, whereas in a 'Variable' condition, participants monitored for many possible instantiations of the critical target. Despite the fact that the Variable condition was objectively more difficult, the vigilance decrement was significantly reduced in response times relative to the Stable condition. We discuss these findings in light of 'overload' and 'underload' theories of the vigilance decrement and suggest that perceptual variability may provide bottom-up support for the maintenance of attentional resource allocation to an external task.

1. Introduction

Improving the capacity for observers to successfully monitor for rare, but critical, events has long plagued human factors researchers and cognitive psychologists alike. Consider for a moment, the case of a security screener at an airport, who must visually scan thousands of items contained within hundreds of bags in the course of a given day. It is easy to imagine that with such a constant, high-rate of perceptual input, and with dangerous items such as weapons being encountered so rarely, it may become rather difficult to remain vigilant over the course of a typical work shift. Given that the potential costs of failing to detect a deadly weapon concealed within a piece of luggage are significant, understanding the psychology of attention over time-on-task holds not only theoretical interest, but is also of practical importance.

The so-called 'vigilance decrement' was first demonstrated experimentally by Mackworth (1948), who was tasked with finding ways to mitigate the apparent drop-off in detection accuracy of British naval radar operators as their watch periods progressed. Using a simple task designed to parallel the job of a radar operator, Mackworth found that the ability of observers to respond to rare, but critical target events declined significantly over time. Since then, researchers have delineated the factors that lead to the vigilance decrement, allowing them to develop abbreviated vigilance tasks in which performance decrements can be observed after only a few minutes. Specifically, it has been found that robust decrements will be observed as long as: (1) the event rate is relatively high, (2) the target rate is relatively low, (3) stimuli are presented successively as

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opposed to simultaneously, and (4) signal salience is moderate to low (Parasuraman, 1979; Parasuraman & Davies, 1977; Parasuraman & Mouloua, 1987).

Currently, the leading theoretical account of the vigilance decrement is known as the 'resource depletion' account (Grier et al., 2003; Helton & Warm, 2008; Warm & Dember, 1998; Warm, Parasuraman, & Matthews, 2008). This theory holds that observers have a limited pool of information processing resources, and that as a vigil unfolds, those resources become depleted due to mental overload. As a consequence, the attentional focus required to maintain a high level of performance outweighs the available resources and so performance decrements are observed. While some researchers have described time-on-task effects as reflecting more than just resource depletion (e.g. motivation/effort and arousal, in addition to information processing limitations; Sanders, 1983, 1998), current theorizing with respect to the vigilance decrement still centers around resource depletion as the primary factor. For example, Helton and Russell (2012) state that: "Advocates of resource theory argue that the information processing resources required for vigilance are limited…The continuous information processing demands of vigilance tasks deplete the necessary cognitive resources, hence, a decline in performance efficiency over the watch-keeping session" (pp. 37–38). Likewise, Grier et al. (2003) posit that: "…performance failures in vigilance tasks result from a decline in information-processing resources rather than from a diminution of arousal" (p. 350). A key tenet of the resource depletion account is that vigilance decrements should be more pronounced in more demanding tasks, since the available resources will be depleted at a faster rate.

Empirical support for the resource depletion hypothesis stems from a host of studies in which increasing the demands on information processing resources has resulted in larger vigilance decrements. For instance, Smit, Eling, and Coenen (2004) had participants perform an abbreviated vigilance task in which they were required to respond to the rare occurrence of an 'a' following an 'x' in a sequence of letters. In a 'high' demand condition, participants performed the task concurrently with a secondary task in which they had to look for and respond to dark gray squares amongst light gray squares that were presented simultaneously with the letter stimuli for the primary vigilance task. Crucially, the vigilance decrement was larger for the high demand condition. Similarly, Helton and Warm (2008) varied the nominal demands on information processing resources by varying stimulus salience (the contrast of the stimuli with respect to the background). The vigilance decrement was found to be much steeper for the low-salience (harder) condition, relative to the high-salience (easier) condition (see also, Parasuraman et al., 2009 for a similar result). It has also been shown that the addition of a working memory load to a standard vigilance task magnifies performance decrements (Helton & Russell, 2011). And finally, vigilance decrements are more pronounced when observers must simultaneously monitor several displays for multiple critical events relative to when they only have to monitor one or two displays (Grubb, Warm, Dember, & Berch, 1995). Taken together, manipulations of task difficulty consistently result in steeper performance decrements, thus providing strong support for the idea that the vigilance decrement arises because of the depletion of information processing resources over time-on-task.

Nevertheless, there is some (albeit indirect) evidence that not all manipulations of task difficulty, or 'complexity' result in larger vigilance decrements. For example, it has been shown that when observers monitor for a *single* critical event in the context of a perceptually complex flight simulation task, the probability of detection does not depend on when the signal is presented during the vigil. In contrast, probability of detection of a single critical event during a perceptually 'simple' (i.e. 'standard') vigilance task, is much higher when the signal is presented within the first ten minutes of the vigil (Molloy & Parasuraman, 1996). Similarly, in a simulated air traffic control task, the vigilance decrement is abolished (with practice) when observers perform a secondary task that is tied to the task-relevant stimuli (i.e. click on incoming air craft) relative to when they passively monitor for critical events (i.e. possible collisions; Pop, Stearman, Kazi, & Durso, 2012). These findings suggest that the vigilance decrement may not stem from mental overload that depletes attentional resources, but rather from under-stimulation due to the monotony of vigilance tasks (see Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997).

It may be the case that whenever manipulations of task complexity/difficulty increase 'engagement' with the task-relevant stimuli (and decrease the monotony of the task), vigilance decrements may be alleviated. Importantly, this may be true even when such manipulations result in an objective increase in task difficulty. Indeed, perhaps the main reason why findings such as those reported by Pop et al. (2012) have not been considered overly problematic for the resource depletion hypothesis is that the conditions shown to exhibit the smallest decrements could in fact be the easier conditions (and thus *should* exhibit smaller decrements by a resource depletion account). What is needed is a manipulation of task complexity that *objectively* increases the difficulty of the vigilance task, while at the same time increasing observers' engagement with the task-relevant stimuli. If performance decrements are less pronounced in such a condition, this would be difficult to reconcile with the resource depletion hypothesis. Likewise, if the magnitude of the vigilance decrement is similar across conditions that vary in difficulty, this would, at the very least, demonstrate that task difficulty is not the *primary* determinant of the vigilance decrement, but simply one of many influences. Again, while several researchers (both recently and historically) have acknowledged that vigilance decrements likely owe to many factors, task difficulty (leading to resource depletion) is largely agreed upon to be the key factor.

How then, does one go about increasing both the objective complexity and difficulty of a sustained attention task in a way that will 'hold' the attention of the observer for longer periods of time? The answer may lie in research into motivation theory and aesthetics conducted by D.E. Berlyne, which has thus far been overlooked by vigilance researchers. For example, it has been shown that the complexity (i.e. the density of information content) of visual patterns is strongly related to subjective ratings of 'interestingness' and 'pleasingness' (Berlyne, Ogilvie, & Parham, 1968). Similarly, and perhaps more relevant for the present work, *perceptual variability* results in ratings of 'pleasantness' that remain fairly high over successive