

2011

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DOI: [10.4225/75/57a01810ac5c6](https://doi.org/10.4225/75/57a01810ac5c6)

Originally published in the Proceedings of the 4th Australian Security and Intelligence Conference, Edith Cowan University, Perth Western Australia, 5th -7th December, 2011

This Conference Proceeding is posted at Research Online.

<http://ro.ecu.edu.au/asi/17>

INDIVIDUALISED RESPONSES TO VIGILANCE DEMANDS AND THEIR MANAGEMENT

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Abstract

This research uses a task disengagement framework to examine how CCTV surveillance operators and novices respond to the vigilance demands of the detection process. Vigilance tasks are acknowledged as being high in mental workload, yet little is known about how operators deal with these demands in jobs where successful performance is reliant upon sustaining attention on a daily basis. Much vigilance research makes an implicit assumption that people perform tasks that require sustained attention in a passive manner. By contrast, this study examines how operators manage their levels of task engagement and attention resources. The sample consisted of 73 participants (42 CCTV operators and 31 novices) who performed a 90-minute CCTV video surveillance task. Individualised responses to vigilance demands were identified. Alternating fluctuations in task engagement were found for the majority of participants, indicating efforts to manage attention resources and cope with vigilance demands. Differences in subjective responses to the vigilance task were identified. Implications for the management of vigilance performance are discussed.

Keywords

Vigilance; closed circuit television (CCTV); operator performance; task engagement; coping

BACKGROUND

It is well established that vigilance tasks are high in mental workload (Temple, Warm, Dember, Jones, LaGrange & Matthews, 2000; Warm et al., 2008), tiring (Wickens & McCarley, 2008), are often stressful (Sawin & Scerbo, 1995; Szalma, Warm, Matthews, Dember, Weiler, Meier, & Eggemeier, 2004), and tend to drain attention resources (Parasuraman and Mouloua, 1996). This suggests that people who face vigilance demands in their jobs on a daily basis are likely to develop ways of coping with these demands so that they can continue to perform these jobs over extended periods. Coping strategies are likely to include ways of managing attention resources, concentration spans and levels of task engagement in order to prevent excessive fatigue. Closed circuit television (CCTV) surveillance represents a vigilance intensive job where operators are frequently required to monitor cameras for extended periods of time and are therefore likely to develop coping strategies. A large proportion of vigilance research has focused on the vigilance decrement as a response to vigilance demands (Parasuraman, 1984). Relatively few studies have examined changes in vigilance performance on a moment-by-moment basis (Gilden & Hancock, 2007) and how operators in vigilance intensive jobs cope with the demands made by their work in terms of management of attention resources and detection rates. A few studies have examined how CCTV operators break the monotony of their work by introducing activities that are not task related, such as talking to colleagues, taking toilet breaks and moving around (Smith, 2004). However, the links with moment-by-moment attention processes and job performance in real-world vigilance intensive work have been neglected by researchers. This research examines how CCTV operators and novices with no previous CCTV surveillance experience respond to and manage the vigilance demands of the detection process. It uses a task disengagement framework (Cheyne, Solman, Carrière, & Smilek, 2009) to examine moment-by-moment changes in attention deployed to tasks.

Relatively little research attention has been paid to operators' deliberate attempts to manage their attention resources. These attempts represent the endogenous modulation of alertness, and contrast with exogenous attention control which is brought about by characteristics of the display, such as novelty and visual conspicuity (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Theories regarding vigilance, and in particular the vigilance decrement, attribute performance to factors that are largely beyond the control of observers, such as habituation (Broadbent, 1953), arousal (Koelega, 1996), and changes in visual sensitivity and the response criterion (Balakrishnan, 1998). This suggests that observers adopt a passive approach to the monitoring process, rather than attempting to manage their attention processes and vigilance levels.

This passive approach to vigilance tasks is encapsulated in the mindlessness theory of vigilance (Robertson et al., 1997) whereby the vigilance decrement is attributed to the redirection of conscious attention away from the task (Helton, Weil, Middlemiss, & Sawers, 2010). Proponents of the mindlessness theory attribute mindlessness to boredom (Robertson et al., 1997). Contrasting with the mindlessness theory are the multiple attention resource theories which explain vigilance decrements in terms of the depletion of cognitive resources (Grier, Warm, Dember, Matthews, Galinsky, Szalma, & Parasuraman, 2003; Helton, Hollander, Warm, & Matthews, Dember, Wallart, et al., 2005; Johnson & Proctor, 2004; Matthews, Davies, Westerman, & Stammers, 2000). Multiple attention resource theorists acknowledge that vigilance tasks are frequently perceived as being boring, but attribute performance decrements to the need to continuously monitor the environment (Hitchcock, Dember, Warm, Maroney, & See, 1999).

Task engagement has recently been used to examine moment-by-moment attention lapses and variations in task engagement in vigilance tasks (Smallwood, Davies, Heim, Finnigan, Sudberry, O'Connor, et al., 2004). Task engagement is defined as 'A state of reduced allocation of attentional resources to environmental task-related stimuli' (Cheyne et al., 2009, p. 98). This is similar to mindlessness, but is applied to a variety of tasks including those that do not require vigilance. During task disengagement, attention resources are transferred to stimuli and cognitions that are unrelated to the immediate task, or off-line processing. Task disengagement and mind-wandering are associated with attention failures and errors (Grier et al. 2003; He et al., 2011; Manly, Robertson, Galloway, & Hawkins, 1999; McVay, Kane, & Kwapil, 2009), some of which have serious consequences (Dockree, Kelly, Robertson, Reilly, & Foxe, 2005). Disengagement results in lapses in the maintenance of task goals and even momentary lapses can be highly problematic. Cheyne et al. (2009) found that task disengagement is most likely to occur when there are long, inactive periods between significant events. They also suggest that engagement is unstable and constantly fluctuates. Fluctuations in task engagement have not been examined in CCTV operators despite the potential impact on detection rates.

Cheyne et al. (2009) propose a three-state model of attention disengagement. The first state involves 'tuning out' (p. 99) and decreased awareness of moment-to-moment changes in environmental stimuli. However, the person remains aware of the general task environment, divides attention between the task and cognitions that are not related to the immediate task, and still devotes sufficient resources to the task to prevent major errors. The second state of disengagement involves mind-wandering in a less conscious manner. There is decreased awareness of generic task-relevant stimuli in the environment, and a more automated manner of responding. Responses to near misses decrease, but blatant errors are likely to re-deploy attention to the task. The third and deepest level of disengagement involves little awareness of task demands and the person only responds to highly intrusive task events. This state is accompanied by behavioural indicators of mind-wandering. Motor restlessness is associated with fatigue and has been found to increase significantly over a 50-minute watch (Galinsky, Rosa, Warm, & Dember, 1993). The current research focuses on the third state of disengagement as this could be observed by the researchers and did not require intrusive bio-neurological measures.

Most of the research on task disengagement with vigilance tasks has used the Sustained Attention to Response Task (SART, Robertson et al., 1997) (e.g., Smallwood et al., 2004). The SART uses simple visual stimuli and participants are required to respond to all stimuli except for significant events (Robertson et al., 1997). This task has been criticised for evaluating response strategy and impulsivity rather than sustained attention (Helton, Weil, Middlemiss, & Sawers, 2010). The need to respond to non-significant stimuli creates a need for almost continual responses. This contrasts with vigilance intensive work in the real world, where significant events and responses occur less frequently. The SART and other vigilance tasks that are typically used in laboratory research are significantly less complex than jobs requiring sustained attention and make different information processing demands on people performing them (Donald, 2001). Unlike vigilance intensive jobs in the real world, the tasks typically used in vigilance research have little inherent meaning for participants (Craig, 1984). This also applies to the SART. In addition, whether participants in laboratory research perform well or poorly does not have same consequences as they would for job incumbents in operational contexts (e.g., career advancement). This is likely to affect the motivation of participants (Wickens & McCarley, 2008) and the approach they adopt to the monitoring task. Similarly, previous work exposure is likely to affect the ways in which participants manage their attention resources and approach the detection task in real-world jobs. This is consistent with research on expertise in other jobs (He, Becic, Lee, Jason, & McCarley, 2011; Jarodzka, Scheiter, Gerjets, & von Gog, 2010). The current research examines task engagement in operators who work in CCTV surveillance and novices with no prior CCTV surveillance experience.

METHOD

Sample

The total sample of 73 participants consisted of 42 (32 male, 10 female) operators employed full-time in CCTV surveillance and 31 university students (9 male, 22 female) with no prior experience with CCTV surveillance. Operators had a mean age of 36.48 years and a standard deviation = 8.2 years. The students' mean age was 21.55 years with a standard deviation of 1.48 years. All participants had normal or corrected to normal vision. Operators were drawn from six organisations in the hospitality and gaming, town centre surveillance, academic, mining, and processing sectors in South Africa.

Non-probability purposive sampling was used and participation in the research was voluntary. The setting for the task was a diamond processing plant. As no participants had worked in such a processing plant previously, no participants had an advantage in terms of situation awareness specific to the context of the video used in the study.

Materials

The task consisted of watching a 90-minute video and verbally reporting the detection of four target behaviours performed on objects that were too small to be observed on camera. The behaviours were, however, all visible and included picking up a small object, kicking the object to another location, flicking the object to another location with a broom, and swiveling the ankle with the intention of grinding the object into the underside of a boot in order to walk away with the object. The video consisted of a mixture of clips with target behaviours and others with no target behaviours. All clips were situated in diamond processing plants and represented realistic work activities, although some were real clips and others were simulations by professional actors in a diamond processing plant. The video was developed through two pilot studies aimed at selecting clips with a suitable range of difficulty levels, removing clips where high numbers of false alarms occurred, and ensuring that the thirty-minute phases were equivalent in terms of detection difficulty levels. For the purpose of analysis, the video was divided into thirty-minute phases, with each containing six target behaviours, and a total of eighteen target behaviours. Each phase included a mixture of target behaviours that were easy and difficult to detect.

Procedure

Instructions included explanations and demonstrations of the target behaviours and were followed by short practice sessions. For ethical and practical reasons, participants were told how long the video would last. Trained research assistants logged responses and their time of occurrence on a log sheet, recording hits, misses and false alarms. Periods of time when no responses were recorded and certain non-verbal behaviours were present, were interpreted as indicating task disengagement. This was based on Cheyne et al.'s (2009) third state of task disengagement. The first two states of disengagement were not measured, and this is likely to have led to an underestimate of task disengagement. The behaviours included, for example, looking around the room, having a glazed expression, and eyes closing frequently but briefly. A short semi-structured interview was conducted after watching the video to identify participants' subjective experiences of the task, how they coped with it and their search strategy.

RESULTS

The mean number of target behaviours detected was 8.99 (50%), with novices detecting 7.68 (42.67%) and operators 9.95 (55.28%) of target behaviours (Table 1). Specialists detected significantly more target behaviours than novices ($t=-3.75$, $p<.01$) and generalists ($t=-2.72$, $p<.01$), but the means for novices and generalists were similar ($t=-0.11$, $p>.05$).

Table 1. Target behaviours detected by novices and operators

Variable	Novice		Operator		All participants	
	Mean	SD	Mean	SD	Mean	SD
Total TBs	7.68	3.47	9.95	3.23	8.99	3.50

The number of participants who showed at least one period of task disengagement in each time phase is provided in Table 2.

Table 2. Disengagement by phase

	Disengagement						No disengagement	
	Phase A		Phase B		Phase C		All phases	
	n	Row %	n	Row %	n	Row %	N	Row %
Novice	12	38.71	21	67.74	20	64.52	7	22.58
Operator	5	11.9	14	33.33	16	38.1	17	40.48
Total	17	23.29	45	61.64	36	49.32	24	32.88

Almost a quarter (23.29%) of the sample lost concentration in the first thirty minutes, almost two thirds (61.64%) in the second thirty minutes, and about half (49.32%) in the last thirty minutes. In addition, novices (38.71%) tended to lose concentration sooner than operators. About a third of the whole sample (32.88%) showed no signs of disengaging during the video.

The patterns of hits and misses were examined and examples of these are illustrated in Table 3 where ‘X’ indicates a correct detection for each participant.

Table 3. Examples of target behaviours detected over the ninety-minute task

Obs	Target behaviour																	
	Phase A						Phase B						Phase C					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	X	X				X	X	X	X	X							X	
2	X	X	X		X	X		X	X		X		X	X	X	X	X	X
7		X	X					X										X
9	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
17		X			X	X			X		X		X		X			
20	X			X	X	X	X	X	X			X	X		X			X
25	X		X	X		X		X	X			X	X	X	X	X	X	X

Although some target behaviours were detected or missed by many participants, detection patterns varied considerably between participants. Two of these are illustrated with examples. Participant 1 detected the first two target behaviours, missed the next four, then detected four consecutively, missed six, detected one and then missed the last two. He presents a pattern with relatively long periods where no target behaviours are detected. This contrasts with participant 17 who missed the first but detected the second target behaviour, then only detected target behaviours five, six, eight, nine, ten, fifteen and sixteen. This person appears to have frequent but relatively short periods where no target behaviours were detected. Participant 25 missed a number of target behaviours in the first two phases, and then detected all target behaviours in the last phase. This could represent

a learning curve and/or the amount of effort invested towards the end of the video when she knew the trial was coming to an end.

Based on interview responses, all novices and some operators reacted negatively to the observation task. Negative comments regarding the detection task focused on the boring, tedious, frustrating, tiring and repetitive nature of the task. These were aggravated by the need to sustain concentration over a long period of time. Comments included 'You lose focus and become brain dead' and 'My concentration went on and off.' These comments were often associated with a passive and disengaged approach. As one novice said, 'I was not engaging with the video, I was just staring.' Other participants, however, attempted to manage the deployment of attention resources: 'You try to concentrate but you feel tired, then you try to bring your mind back.'

Positive responses to the video focused on perceptions of the task as being interesting and challenging. As one person said, it was 'Interesting because I don't know that type of environment. I looked at body language and other cues, then you can pick up the target behaviours.' Top performing operators emphasised the need for active analysis and interrogation of the display as part of their search strategy. As one person said, 'You look more intensely because you think you are not getting enough.'

DISCUSSION

Individualised responses were evident in patterns of disengagement, hits and misses. Task engagement emerged as a key process associated with performance fluctuations. This is based on the finding that misses were often accompanied by task disengagement. It is supported by studies reporting a relationship between task disengagement, attention failures, and decreased performance (Cheyne et al., 2009; Dockree et al., 2005; Gilden & Hancock, 2007; Grier et al. 2003; He et al., 2011; Manly et al., 1999; McVay et al., 2009). (Task disengagement was not the only reason for poor or decreased performance, but discussion of this is beyond the scope of this paper). Periods of task disengagement varied considerably between individuals in terms of onset time, duration and frequency (Table 2). Most (67.17%) participants disengaged from the video at various times, suggesting that task disengagement was highly pervasive. The starting time of the first disengagement period varied considerably between individuals, with some disengaging within the first thirty minutes but most during the second thirty minutes (Table 2). In addition, most participants demonstrated alternating periods of engagement and disengagement, with the length and frequency of disengagement periods varying between individuals. This alternating pattern is consistent with that reported by Cheyne et al. (2009) in a study on task disengagement. The alternation of periods of task engagement with attention 'time outs' assists the preservation of attention resources over time (MacLean, Aichele, Bridwell, Mangun, Wojciulik, & Saron, 2009, p. 23). The need to take 'time outs' indicates that most participants in the current research experienced difficulty in sustaining attention which impacted on their ability to maintain concentration and task goals.

Patterns regarding disengagement also show varying trends for sub-samples with different work exposure (Table 2). Novices tended to visibly disengage from the task sooner than operators. A corresponding result is that novices reported boredom most frequently. It is possible that one of the skills associated with different types of surveillance background is the ability to self-regulate attention, and that this reduces the vigilance decrement. However, it is not known whether operators were initially selected for their jobs because of their superior abilities to regulate and sustain attention and detect significant events, or whether they had developed this over time with work experience and training. The real-world task used in the research would have had more inherent meaning for operators than novices with no prior surveillance experience, and influenced the sub-samples' approaches to the tasks. This is consistent with existing expertise research demonstrating that more experienced personnel adopt different approaches to various tasks (He et al., 2011; Jarodzka, Scheiter, Gerjets, & von Gog, 2010).

Previous research links boredom and disengagement (Donald, 2001) but has not examined the link between boredom and work exposure. Boredom was highly pervasive in the novice sub-sample. In the current research it is unclear whether a mindless approach resulted in disengagement and boredom, or whether the depletion of attention resources caused difficulties in sustaining attention and boredom. Previous research has linked novice status to higher resource depletion (Kanfer & Ackerman, 1996), suggesting that in the current research the attention resources of novices were likely to be depleted more quickly than those of operators. This requires further research in the CCTV context.

Evidence emerged demonstrating that participants attempted to regulate their attention during the video. First, some participants reported efforts to maintain concentration. Second, the alternating periods of engagement and disengagement suggest a degree of attention management in that attention is re-engaged and does not remain disengaged. These suggest that a mindful approach and subsequent resource depletion as the underlying mechanism for disengagement in contrast to theories on mindlessness. This tends to support the mindful (Grier

at al., 2003) rather than the mindlessness theory of vigilance (Robertson et al., 1997). However, further research is required to identify ways of renewing motivation and interest in the task and enhancing the self-regulation of task engagement.

CONCLUSION

By focusing on task engagement in a real-world task, this research adopted a different approach from most vigilance research that examines the vigilance decrement. It is possible that fluctuations in task engagement influence the detection of significant events whether a vigilance decrement is present or not, but their role within steady vigilance decrements requires further research. The finding that work exposure influences task engagement and subjective experiences of the vigilance task suggest that work exposure should be considered in vigilance research on real-world tasks and that different results are likely to be obtained for novices and job incumbents with varying degrees of relevant work exposure. The nature of samples chosen for vigilance research requires careful consideration. Implications for operational contexts focus on selection and training. The ability to maintain and self-regulate task engagement for extended periods of time should possibly be considered as a selection criterion. The development of instruments that assess this would be useful. The differences between generalists and specialists suggest that a component of training should be aimed at developing an active approach to monitoring. This would include an understanding of what typically occurs in CCTV footage in relevant contexts, and how significant events play themselves out.

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