Consciousness and Cognition 45 (2016) 174–183

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Attention lapses and behavioural microsleeps during tracking, psychomotor vigilance, and dual tasks

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ARTICLE INFO

Article history:
Received 8 February 2016
Revised 15 July 2016
Accepted 3 September 2016
Available online 14 September 2016

Keywords:
Arousal
Attention lapse
Behavioural microsleep
Psychomotor vigilance task
Resource depletion
Task complexity
Tracking

ABSTRACT

This study examined the incidence of attention lapses and microsleeps under contrasting levels of task complexity during three tasks: PVT, 2-D tracking and a dual task combining the two. More attention lapses per participant (median 15 vs. 3; range 1–74 vs. 0–76, $p = 0.001$), with the greatest increase with time spent-on-task ($p = 0.002$), were evident on the more cognitively-demanding dual task than on the PVT. Conversely, fewer microsleeps (median 0 vs. 0; range 0–1 vs. 0–18, $p = 0.022$) occurred during the more complex task compared to the tracking task. An increase in microsleep rate with time spent-on-task ($p = 0.035$) was evident during the tracking task but not the dual task. These results indicate that the higher cognitive load, associated with an increase in task complexity, increased the likelihood of attention lapses, while a reduction in task complexity increased the likelihood of microsleeps.

1. Introduction

Momentary lapses of responsiveness are disruptions in performance that typically last between 0.5–15 s and frequently impair sustained goal-directed behaviour (Peiris, Davidson, Bones, & Jones, 2011). Understanding the cause and impact of these lapses is important, particularly in the transport sector, such as air traffic control, and high speed train operations, where response failures can lead to fatal accidents. Such lapses are also relevant to other sectors, such as pathology laboratories, food industries, and defence. Moreover, the impact of lapses extends into everyday tasks that affect us all (Cheyne, Carriere, & Smilek, 2006).

The literature underpinning research into lapses of responsiveness has focused on attention lapses, which Mackworth (1948) originally referred to as the vigilance decrement. Attention lapses are explained by two competing theories. One

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http://dx.doi.org/10.1016/j.concog.2016.09.002
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theory is often called the mindlessness/mind-wandering hypothesis and depicts cognitive underload (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Thomson, Besner, & Smilek, 2015). The alternate, overload theory, suggests that lapses occur due to resource-depletion (Helton & Warm, 2008; Parasuraman, Warm, & Dember, 1987; Warm & Dember, 1998). Both accounts link the prevalence of attention lapses to task factors, albeit differentially. The underload theory holds that respondents have difficulty maintaining endogenous stimulation in the absence of exogenous support because tasks requiring attention can be monotonous and under-stimulating (Manly et al., 1999; Robertson et al., 1997). This idea proposes that participants take an automatic or "mindless" approach to the task. Conversely, the overload account holds that attention tasks are taxing and effortful, so that information processing resources become suboptimal over time due either to high demand or reduced resource allocation (Epling, Russell, & Helton, 2016; Helton & Russell, 2011, 2012; Matthews, Warm, Reinerman-Jones, et al., 2010).

The two accounts predict different outcomes with respect to task factors. For the underload theory, higher workload or more stimuli-rich tasks couple attention to the task, which results in fewer attention lapses. Conversely, the overload theory posits that high task demand and workload negatively influence attention and increases lapses. For the overload theory, then, attention lapses will increase when the task is objectively more challenging, for example, when there are multiple demands on attention or when the task is psychophysically difficult (Helton & Russell, 2011, 2012).

A facet of this debate is that there are types of performance lapses, beyond the standard attention lapse, which the literature has seldom addressed (Anderson, Wales, & Horne, 2010). One alternative lapse is the behavioural microsleep (*microsleep*) (Peiris, Jones, Davidson, Carroll, & Bones, 2006). Microsleeps are defined as brief periods of non-responsiveness (0.5–15 s), defined by transient full or partial eye closure and overt signs of drowsiness that are thought to emanate from the homeostatic drive for sleep and a complex interaction between the brain's arousal and attention systems. Microsleeps are frequently found in people who are not necessarily sleep deprived, albeit sleep restriction increases microsleep propensity (Innes, Poudel, & Jones, 2013). For example, studies have found that 53–80% of non-sleep-deprived adults experience microsleeps when undertaking a monotonous task that takes up to an hour (mean 29–79 per hour; range 0–190) (Peiris et al., 2006; Poudel, Innes, Bones, Watts, & Jones, 2014). Clearly, under certain circumstances, microsleeps make a substantial contribution to task lapses.

Another facet of the debate of underload and overload contributions to lapsing is whether task factors, such as complexity, influence the propensity for microsleeps. Altering a task to reduce vigilance decrement might reduce both attention lapses and microsleeps and we do not know whether changes in one lapse measure will come at the expense of the other. More specifically, the inter-relationship between attention lapses and microsleeps, as contextualized by task demand, is not known. Towards this, Innes et al. (2013) compared attention lapses during a psychomotor vigilance task (PVT) against microsleeps during a subsequent extended tracking task. They found no statistically significant correlation between either PVT lapses or reaction times with microsleeps. This is in itself an important result, as it indicates that attention lapses and microsleeps are separate constructs and that a single intervention is unlikely to prevent both types of lapses.

The goal of this study was to clarify the relationship between attention lapses, microsleeps, and task demands. To do this, three 30-min tasks were used: a tracking-only task, a PVT-only task, and a dual task in which the tracking task and the PVT were concurrent. Tracking allowed the measurement of instances of microsleep lapses (Poudel, Jones, & Innes, 2008), whereas the PVT provided a classic measure of attention lapses (Dinges & Powell, 1985). Of interest was the change in each of these two measures during the dual task.

Increasing task demands should increase levels of arousal and therefore reduce propensity to microsleep (Poudel et al., 2014; Smallwood & Schooler, 2006). If true, we would expect that tasks that are more demanding or more objectively challenging should result in fewer microsleeps than would less-demanding tasks. Moreover, tasks that are more demanding should, according to the underload theory of vigilance (Manly et al., 1999; Robertson et al., 1997), result in fewer attention lapses because of stronger coupling. In contrast, the overload theory would predict an increase in attention lapses because of the increase in cognitive demand mediated by the increased task complexity.

2. Methods

2.1. Participants

Twenty-three healthy non-sleep deprived participants – 12 females and 11 males – with an average age of 26.3 years (range 21–40 years) and an average Epworth Sleepiness Score of 5.1 (range 0–10) voluntarily participated in this study. Participants, recruited from the general population, reported a usual time to bed between 22:00 and 24:00, a usual time in bed of 7.0–8.5 h, and had all recorded an Epworth Sleepiness Score $\leqslant 10$ from the week immediately prior to the study. No participants met the exclusion criteria, which were: a history of neurological disorders (other than headache or mild traumatic head injury), a history of psychiatric disorders (other than mild depression), sleep disorders, or the taking of any sedating or stimulating medications, or consumption of more than four cups of coffee or tea per day. Ethical approval for this study was provided by the Upper South A Ethics Committee (URA/09/11/079).

2.2. Apparatus

2.2.1. SMCTests

The three tasks were generated by *SMCTests* run on a Microsoft Windows platform (Poudel et al., 2008). The *SMCTests* program generated the target track, sampled the participants' joystick responses, generated the PVT, and calculated the reaction times to each trial. Stimuli and responses were displayed on a 17-inch LCD flat screen colour monitor (Viewsonic, Walnut, California, USA) with a screen resolution set at 1024 × 768 pixels and a refresh rate of 60 Hz.

2.2.2. Eye-video recording

A video recording of the participant's face was taken during each task using a Sony Handy Cam (Model HDR XR200E, Tokyo, Japan) mounted on a tripod placed immediately behind the stimulus display at the minimum height that would provide an unobstructed view of the participants' face.

2.2.3. Floor-mounted joystick

A locally manufactured floor-mounted joystick was used for tracking responses. It could be adjusted in height to suit each participant. Its lateral movement corresponded to a hand movement with a radius of 225 mm.

2.3. Tasks

2.3.1. Tracking task

The tracking task and floor-mounted joystick were the same as that developed by Poudel et al. (2008) to detect microsleeps. In brief, the participant was required to track a yellow disk (visual target) that was constantly moving in a pseudo-random 2-D manner (Fig. 1). Any lapse of responsiveness would be evident either due to a stationary response disk or an active tracking error (failure to follow the yellow disk with the red response disk).

2.3.2. Psychomotor vigilance task

The PVT was similar to that described by Dinges and Powell (1985) and was selected because of its widespread use in attention studies. In brief, the PVT required the participant to respond as quickly as possible to a randomly presented stimulus. The stimulus was the sudden appearance of a numeric counter in the middle of the visual display unit that showed the time in ms since it was displayed (Fig. 1). This numeric counter would change at every screen refresh (60 Hz) until deactivated by depressing a push-switch on top of the joystick. The numeric counter then remained visible for a further 500 ms to provide feedback to the participant.

2.3.3. Dual task

The dual task was a combination of the PVT and the tracking task run concurrently. During the dual task, the participant was required to continue tracking the target disk while at the same time respond as quickly as possible to the PVT stimulus by pressing the switch on top of the joystick. Combining the two tasks to form the dual task increased the complexity over either of the two standalone tasks, thus providing a contrast in task demands.

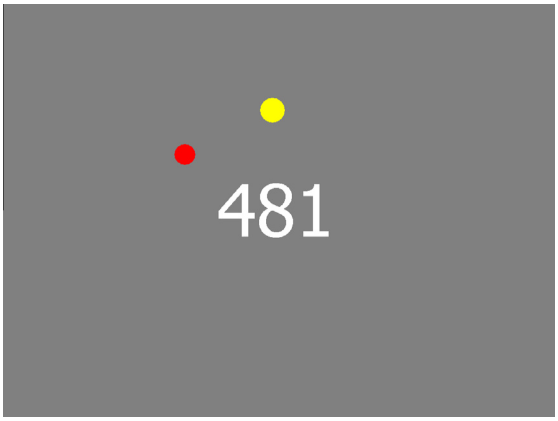

Fig. 1. A screen shot of the dual task as it appears on the stimulus screen. The yellow disk is the target and the red disk the tracking response. The white number is the stimulus for the PVT. It first appears as a zero and then counts upwards in milliseconds until the push-switch button on top of the joystick has been pressed. The stimulus during the PVT alone is the same but without the two moving disks being present, while during the tracking task only the red and yellow discs are shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.4. Procedure and design

All three tasks were completed during a single session and were interspersed with a 15-min rest period during which the participant was free to move around but not lie down or nap. The order of the three tasks was counterbalanced across subjects. The session occurred during the early afternoon commencing between 1.00–1.30 pm following a light lunch. The participant was seated with an eye-screen distance of 700–800 mm. The floor-mounted joystick was placed in front of the dominant arm and the height of the joystick was adjusted so that the forearm was horizontal with feet placed flat on the floor. A collar on the joystick provided a hand rest, which was adjusted so the thumb could comfortably reach and depress the button on top of the joystick. The stimulus screen was set with the top of the screen horizontal with most participants' eyes. The video camera was located behind the stimulus screen and high enough to allow the participant's eyes to be recorded unrestricted by the screen.

Each task began by stamping both the video and the *SMCTests* response recordings at the beginning and end of each trial. This was achieved by activating an LED that created a light flash visible on the video recording and simultaneously created an electrical impulse that stamped the time log used by *SMCTests*. Matching the video frame that first showed each light flash with its corresponding time stamp on the separate tracking stimulus and response file allowed millisecond synchronization accuracy.

2.5. Analysis

2.5.1. Event classification

Based on a visual rating protocol developed by Peiris et al. (2006) and Poudel et al. (2008), a microsleep was identified when flat or incoherent tracking was present for more than 500 ms but less than 15 s, coincident with full or partial eye closure (phasic/transition) greater than 80%, with behavioural indications of drowsiness (see Fig. 2).

These behavioural indications of drowsiness, based on those proposed by Wierwille and Ellsworth (1994), may include: a loss of eye focus or proper eye vergence, eye rolling upwards or outwards, loss of eye movement, partial eye closure, slow eyelid closure, episodes of head nodding, and loss of facial tone. Otherwise, epochs of poor, but not absent, tracking coincident with behavioural indications of drowsiness were classified as drowsiness-related impaired responsiveness events, but not lapses and, thus, not counted. Epochs of voluntary eye closure (e.g., temporary relief from fatigue) lasting more than 500 ms or epochs of partially or fully diverted attention, i.e., eyes diverted, were recorded but not counted as microsleeps.

Identification of eye closure involved recording the video frame numbers where the eyes were most open before starting to close, where 50% of total eye closure had occurred, the start of full eye closure, the end of full eye closure and the start of eye opening, and lastly the frame where eyes were fully open.

Attention lapses from the PVT and the dual task were identified from system recorded onset and offset times for each PVT trial. In addition, these events were confirmed using the face video recording. Those that coincided with either a normal eye-blink that would delay recognition of the PVT stimulus, or where the gaze was not on the screen at the time of stimulus onset, were discounted.

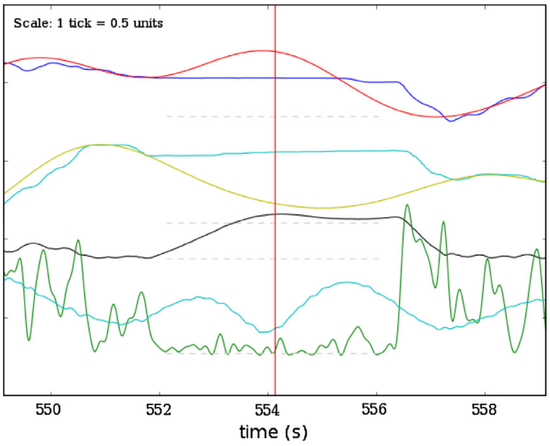

Fig. 2. Example of flat tracking (approximately zero speed) as displayed by SyncPlayer. The top two lines show the x-axes of the target track (red) and response (blue). The next two lines are the y-axes of the target track (yellow) and the response (light blue). The black line shows tracking error and is the Euclidian distance between the response and target. The bottom two lines indicate joystick speed, with the dark green showing actual speed and the light blue theoretical speed. Partial eye closure occurred at 551.7 s coincidental with the beginning of a flat response. Full eye closure occurred at 552.7 s. Eyes began to open at 555.6 s and were fully open 300 ms later at 555.9 s. This was immediately followed by a saccade to the target. Motor response was resumed at 556.4 s. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

We used the standard 500 ms reaction time to the PVT stimulus as the threshold to determine an attention lapse (Lim & Dinges, 2008). However, this threshold is specific to the standard PVT. Where tasks differ from the PVT, as it does in the dual task, then the required response, and therefore the time to respond must be assumed to differ regardless of any differences due to attention. This is particularly so when reaction times from a single task are to be compared to a dual task where allowances must be made for any psychological refractory period (Laguë-Beauvais et al., 2015). Accordingly, we applied a correction calculated as the difference in core times between the PVT and dual tasks. Reaction times can be partitioned into a core time that is task specific, to which a delay because of attention is added. Thus the best estimate of the task specific core portion of a reaction time will be provided by the fastest times. Using the fastest 10% of reaction times we calculated a conservative, task specific difference of 34 ms that was deducted from the dual task reaction time before applying the standard 500 ms threshold.

2.6. Statistical analysis

Much of the data were distributed non-normally. Accordingly, where this occurred, non-parametric tests were used. Specifically, the Wilcoxon paired-sample signed rank test was used to investigate task differences on microsleep and attention lapse rates. Friedman's ANOVA was used to investigate the effect of time-on-task on microsleep and attention lapse rates, whereas an aligned-rank transform test was used to investigate time and task interaction on attention lapses. To determine the effect of task and time on tracking errors and reaction times, a matched-pairs *t*-test and a MANOVA were used. Finally, both Spearman's ranked order correlation and Pearson's product-moment correlation tests were used to determine what correlations existed between tasks. False discovery rate correction was used to correct for multiple comparisons.

3. Results

3.1. Microsleeps

Participants showed a greater propensity to microsleep in the simpler tracking task than the more complex dual task. Of the 23 participants included in the analyses, 11 did not microsleep on either task. Of those that did, 8 participants had more microsleeps during the tracking task, 2 participants had more during the dual task, and 2 participants had one microsleep in each task. There were 51 instances of microsleeps in the less complex tracking task while only 5 occurred in the dual task (Fig. 3). This difference was partially due to two participants who between them had 32 microsleeps in the tracking task and none in the dual task. More descriptively, the median number of microsleeps was zero for both tasks, the tracking task had a range of 0–18, which was different to the range of 0–1 for the dual task (Wilcoxon $Z = 2.3$, $p = 0.022$ two-tailed, $r = 0.48$). Overall, the total number of microsleeps observed was 57 which was considerably less than the 714 attention lapses

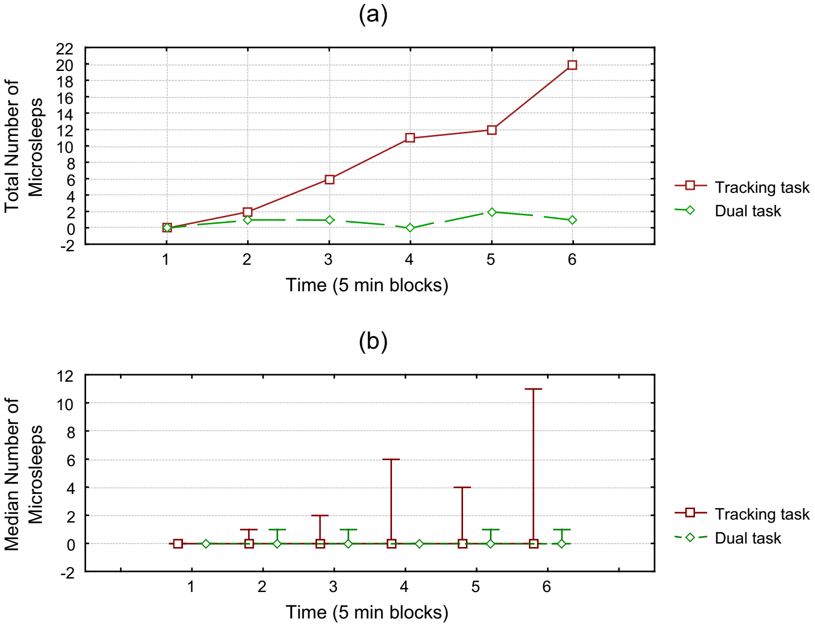

Fig. 3. Graph (a) shows the total number of microsleeps across all participants in each 5-min period during the tracking and dual tasks. Graph (b) shows the medians while the whiskers indicate the minimum and maximum counts for each 5-min period. Although the median for both tasks does not change over time, the plots show an effect of time on the tracking task but not the dual task in which there were fewer lapses (5 compared to 52).

observed ($t_{22} = -4.132$, $p < 0.001$, $d = -1.23$). There was also a time-on-task effect for microsleeps evident in the tracking task with rates increasing over time ($\chi^2_{2,N=23} = 6.72$, $p = 0.035$ one-tailed) that was not present in the complex dual task.

3.2. Attention lapses

3.2.1. Attention reaction time criteria

A correction of 34 ms was required to account for core task differences in reaction times between the PVT and dual task (see Section 2.5.1). It was validated by comparing corrected reaction times from the dual task against original reaction times from the PVT. To reduce any time-on-task effect we only used reaction times from the first 300 s of each trial. When corrected, the mean dual task reaction time (310.6 ms, SD = 42.5) did not differ significantly from the mean PVT reaction time (297.3 ms, SD = 47.6) ($t_{22} = 1.4$, $p = 0.18$), whereas, uncorrected, the two original means (i.e., 344.6 ms vs 297.3 ms) were different ($t_{22} = 4.6$, $p < 0.001$, $d = 1.05$).

3.2.2. Counts

Using corrected times, 21 participants had more attention lapses in the dual task than in the PVT, one participant had more lapses in the PVT, and one participant lapsed once in each of the two comparative tasks. More attention lapses occurred during the dual task (Median = 15) than the PVT (Median = 3), ($Z = 3.7$, $p < 0.001$ two-tailed, $r = 0.77$) (Fig. 4).

A time-on-task effect for attention lapses occurred on both tasks (Fig. 4). A non-parametric Friedman test of differences among repeated measures provided a Chi square value of 16.3 that was significant for the PVT ($p = 0.006$), and a value of 48.7 that was significant for the dual task ($p < 0.001$). For the first three 5-min periods, the rate of increase for both tasks was comparable. However, in the last three 5-min periods the time-on-task effect for the PVT waned (Fig. 4). This observation was confirmed by post hoc comparisons of the six 5-min periods, tested against false-discovery-rate corrected p-values that found an effect in the dual task across all 5-min periods while in the PVT only differences between period 1 versus periods 3, 4 and 5; and period 2 versus periods 3 and 4 were confirmed. An aligned rank transform test confirmed the observation that overall, the number of attention lapses that occurred during the dual task increased more rapidly over time than those that occurred during the PVT ($F_{5,264} = 4.02$, $p = 0.002$, $d = 0.60$).

3.2.3. Reaction times

Both time and task had a main effect on reaction times with corrected reaction times from the more complex dual task being on average 65.2 ms or 19% longer than reaction times from the simpler PVT ($F_{1,21} = 98.63$, $p < 0.0001$, $\eta^2_p = 0.82$), while overall, average reaction times were 18% slower at the end of the task than at the beginning ($F_{5,17} = 11.69$, $p < 0.0001$, $\eta^2_p = 0.77$). There was a trend for reaction times on the dual task to increase at a greater rate over time than on the PVT (Fig. 5), but the interaction between time and task was not significant ($p = 0.064$).

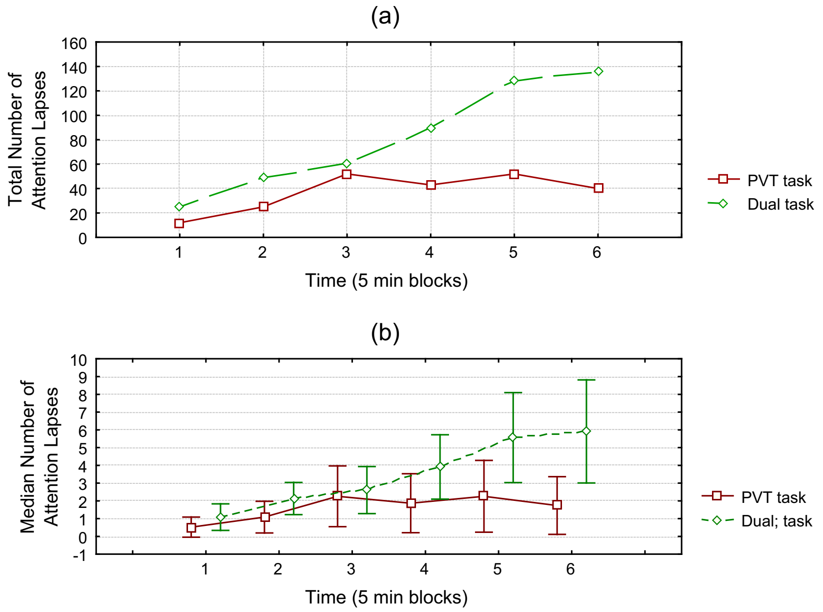

Fig. 4. The top graph (a) shows the total number of attention lapses in each 5-min period during the psychomotor vigilance task and dual tasks using reaction times corrected by subtracting 34 ms to account for differences between tasks due to tasks demands. Graph (b) shows the medians while the whiskers indicate the minimum and maximum counts for each 5 min block. Evident is the effect of time on both tasks, which manifests as an increase in counts.

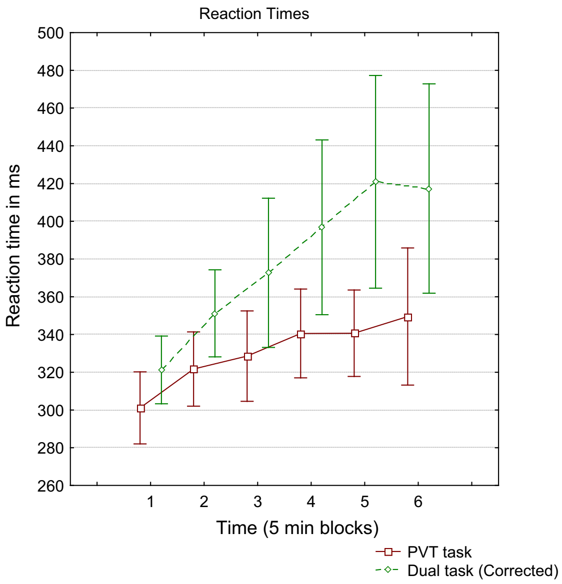

Fig. 5. Plot showing effect of time-on-task on reaction times. On average, reaction times were 18% slower at the end of the task than at the beginning.

3.3. Tracking accuracy

Tracking accuracy deteriorated similarly over time in both the tracking task and dual task (main effect of time, $F_{5,17} = 18.6$, $p < 0.0001$, $\eta^2_p = 0.85$) (Fig. 6). There was no task-by-time interaction ($F < 1.0$, $p > 0.5$).

3.4. Correlations between tasks

There were three significant correlations between measures on different tasks: numbers of attention lapses on the PVT and the dual task ($r_{s\,22} = 0.81$, $p < 0.001$), mean reaction times on the PVT and the dual task ($r_{22} = 0.77$, $p < 0.001$), and mean tracking errors on the tracking task and on the dual task ($r_{22} = 0.66$, $p < 0.001$). There were no other significant inter-task correlations.

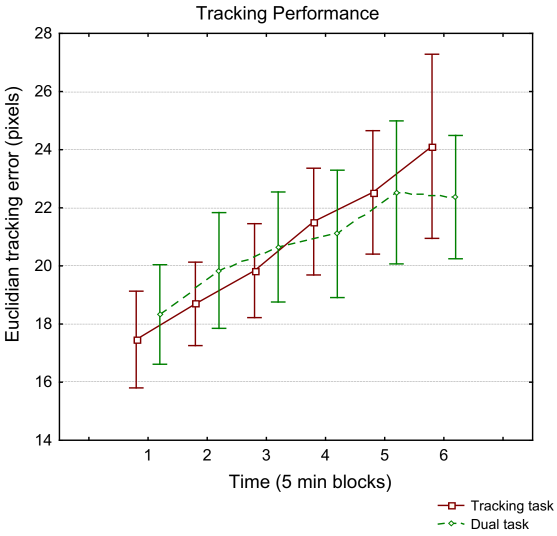

Fig. 6. Graph showing an increasing tracking error with time spent on both tasks. Tracking error in each block is the Euclidian distance between target and response stimulus (measured in pixels) averaged over each 5-min period.

4. Discussion

This is the first study to have investigated the relationship between attention lapses and microsleeps and to have done so within the context of task complexity. We found that an increase in task complexity increases a person's propensity for attention lapses. Conversely, most people have more microsleeps during less cognitively-demanding tasks. Moreover, a person's propensity to microsleep is less than their propensity for attention lapses. We also found that a person's propensity for microsleeps is not related to their propensity for attention lapses which suggests that the two constructs are, at least for the most part, behaviourally and physiologically independent.

We attributed these results to differences in task complexity, because other variables – task assignments, task order and inter-subject differences, including sleep propensity factors – were either balanced or remained unchanged. Accordingly, we conclude that task complexity is a factor that inversely influences risk of attention lapses from risk of microsleeps. We also found that susceptibility to both microsleeps and attention lapses increases with time on task. Although a time-on-task effect for attention lapses is well established (Helton & Russell, 2012; Langner & Eickhoff, 2013), the finding that microsleeps are also influenced by time-on-task is novel, albeit not surprising.

4.1. Microsleeps

Microsleeps during the dual task were almost eliminated, whereas there was a substantially higher number during the tracking task. We attribute this to changes in task complexity differentiating levels of arousal. Specifically, the primary difference between the dual and tracking tasks was the additional need to be vigilant for a randomly-presented stimulus with a sudden onset, a requirement of the PVT component of the dual task, which may have increased arousal. That microsleeps are a manifestation of reduced arousal levels is not surprising. Recent research by Poudel et al. (2014) reported that microsleeps are associated with decreased neural activity in the arousal-related brain regions, including the thalamus, midbrain, and posterior cingulate cortex, but with increased activity in the frontoparietal, insular, parahippocampal, and temporo-occipital cortices. Furthermore, microsleep propensity has been shown to increase following sleep deprivation (Innes et al., 2013) and that EEG-defined microsleeps have been widely linked to sleep and hence to arousal (Chee et al., 2008; Harrison & Horne, 1996).

Our participants had a usual bedtime between 22:00 and 24:00, a 7.0–8.5 h time in bed in the lead up to and including the night prior to experimental trials, and a mean Epworth Sleepiness score of 5.1. Similarly, the participants in earlier studies by Peiris et al. (2006) and Poudel et al. (2014) were not sleep deprived and had normal sleep and bed times. Findings that non-sleep-deprived participants with normal circadian and homeostatic sleep drives involuntarily experience microsleeps, together with microsleeps almost being almost eliminated in the more cognitively-demanding dual task indicate that it is not just tiredness or fatigue that causes microsleeps. Accordingly, in line with Poudel et al. (2014), who considered that microsleeps are the result of a complex interaction between arousal and attention systems, we found that a combination of reduced task-demand levels during the tracking task increased microsleep propensity.

4.2. Attention lapses

That this study has demonstrated a positive relationship between task complexity and attention lapses will come as no surprise to proponents of the overload theory. According to this theory, people's attentional performance is generally indexed to measures of task demands that are, in turn, indexed to task characteristics such as cognitive demand and time pressure (Helton & Warm, 2008; Randall, Oswald, & Beier, 2014). As task complexity increases, so does demand on limited resources and, eventually, the point is reached where demands exceed depleted resources.

Our results support a resource-based component in attention lapses. First, the more demanding task was associated with more attention lapses. Combining the PVT with the tracking task increased resource demands over the stand-alone PVT, because both subtasks placed demands on visual attention. Second, the finding that tracking performance in the dual task did not change from the standalone tracking task, but that PVT performance in the dual task was different to that in the stand-alone PVT, suggests that when performing both subtasks simultaneously, as in the dual task, an allocation of resources in favour of the tracking component was made at the expense of the PVT component. Thirdly, the requirement that similar priority be given to both simultaneous sub-tasks in the dual task would add an additional executive control component to that task over the stand-alone PVT (Laguë-Beauvais et al., 2015). Together, these factors suggest fewer resources would be available to sustain attention during the dual task compared to the stand-alone PVT.

Moreover, three other aspects of the study gave us confidence that the attention lapses were not primarily a result of tiredness. Firstly, facial video confirmed that many attention lapses were not concomitant with overt indications of drowsiness. Secondly, participants had to report normal sleep in the week prior to the study. Thirdly, task order was balanced.

We reject an underload or mindlessness explanation as the results were inconsistent with the expectations of that theory. The mindlessness theory posits that attention is withdrawn from the vigilance task and held by other stimuli or task-unrelated thoughts due to the absence of exogenous stimulation provided during the vigil assignment (Thomson et al., 2015). Moreover, Robertson & O'Connell (2010, p. 85) stated in support of this theory that "... performance could be significantly improved, at least temporarily, by increasing arousal through exogenous mechanisms." Yet we found that,

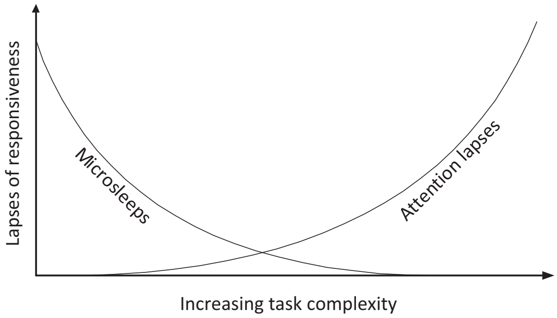

Fig. 7. Conceptual schematic showing (i) how an increase in task demand reduces microsleep propensity but increases attention lapse propensity and (ii) how a combination of these results in an inverted U curve for incidence of lapses of responsiveness.

contrary to this, the increased exogenous support and hence arousal, provided in the dual task, was not able to prevent an increase in attention lapses.

In summary, the positive association between the more demanding/stimulating task and high attention lapse rate, together with increase in such over time, provides substantive support for the resource-depletion theory in relation to attention lapses

4.3. General discussion

This study has demonstrated that task complexity, likely through its mediation of task demand, arousal, and engagement, differentially impacts rates of attention lapses and microsleeps, with more complex tasks leading to more attention lapses while simpler/less demanding tasks result in more microsleeps. These findings provide a possible explanation for popular inverted U-shaped models of performance. Typical of these is the Yerkes-Dodson Law that dictates that performance increases with physiological or mental arousal up to a point but beyond that point, when levels of arousal become too high, performance begins to degrade (McGinley, David, & McCormick, 2015; Neiss, 1988; Yerkes & Dodson, 1908).

However, both Hancock and Ganey (2003) and Matthews, Warm, Reinerman, Langheim, and Saxby (2010) caution against using the Yerkes-Dodson curve as a general explanation of the arousal/attention relationship. Notwithstanding, we are not proposing a unitary arousal construct to explain the performance curve, which was the focus of their criticism. Rather we observe that, from a performance perspective, both microsleeps and attention lapses result in errors (missed signals or long response latencies) but their underlying mechanism are substantially different. When both mechanisms are combined, the performance curve takes on a U shape as in Fig. 7. In this, there is an optimal level of task complexity where both types of lapses are minimized and for which task-demands and engagement are neither under-arousing (i.e., microsleep-inducing) nor overloading (i.e., attention-lapse-inducing).

5. Conclusion

This study had four main goals: clarify the relationship between microsleeps and attention lapses, clarify the impact of task complexity on that relationship (if any), clarify the impact of task complexity on a person's propensity for microsleeps, and clarify the impact of task complexity on a person's propensity to attention lapses.

We conclude that microsleeps and attention lapses are behaviourally separate constructs. This is evidenced by propensity for microsleeps being unrelated to propensity for attention lapses. Change in task complexity also affects propensity for the two types of lapses differently. When task complexity and, hence, workload are relatively high, we have a higher propensity for attention lapses. Conversely, when the workload is lower, the task less complex, and the task less stimulating; we have a higher propensity for microsleeps. A higher propensity for attention lapses during the more complex dual task compared to the simpler discrete PVT supports the overload theory for a cause of attention-mediated lapses of responsiveness. Furthermore, a substantial time-on-task effect on the number of attention lapses on the dual task, but not the PVT, provides clear support for the causal role of resource depletion in attention lapses.

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