The Impact of Sustained Wakefulness and Time-of-day on OSPAT Performance

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Abstract: Fatigue associated with shiftwork is a key contributor to human error in the workplace. One way to prevent fatigue-related errors from occurring is to identify fatigue in employees using fitness-for-duty measures. The Occupational Safety Performance Assessment Test (OSPAT), an unpredictable tracking task that measures hand-eye coordination, is currently being used as a fitness-for-duty measure in a variety of industries, but has not yet been validated as a test sensitive to the effects of fatigue. Consequently, the aim of this study was to systematically examine the impact of sustained wakefulness and time-of-day on OSPAT performance. Twenty individuals (10 male, 10 female), aged between 18–25 yr (M=20.90, SD=2.29) participated in the study, which was conducted in Australia. The study had a repeated measures design, whereby participants completed the OSPAT and measures of sustained attention (i.e., the psychomotor vigilance task: PVT), and subjective alertness (i.e., the Visual Analog Scale: VAS) every 2 h during 24 h of sustained wakefulness, beginning at 07:00h. Results revealed that VAS ratings of alertness, PVT performance, and OSPAT performance declined significantly as hours of wakefulness increased during the night-time (all p<.01). Furthermore, a positive correlation between OSPAT and PVT performance was observed (r=0.40, p<.01). Overall, these findings suggest that OSPAT is sensitive to sustained wakefulness during the night-time, and builds the case for OSPAT being a suitable measure for determining fitness-for-duty in workplace environments.

Key words: Fatigue, Shiftwork, Fitness-for-duty, Performance, OSPAT

Introduction

Fatigue is increasingly being recognized as a causal factor of incidents and accidents, particularly in industries involving shiftwork1). Shiftworkers are likely to experience the problems associated with fatigue such as difficulties in maintaining alertness, performance, and wakefulness while working at night. This is mainly due to the restriction and disruption associated with sleeping during the daytime, being awake during their normal sleep period, and working through the circadian nadir2, 3). Research has found that the consequences of fatigue include the impairment of several cognitive and sensorimotor skills including hand-eye coordination, vigilance, decision-making, visual search, memory, and logical reasoning1, 4). Furthermore, fatigue can have an adverse influence on affective states such as motivation and mood5, 6).

Because shiftworkers are more susceptible to high levels of fatigue than non-shiftworkers, they are more likely to make errors that result in incidents and accidents1, 7). Indeed, fatigue has been identified as a key contributing factor in several major industrial accidents including the Exxon Valdez oil tanker spill and the Chernobyl nuclear meltdown8, 9). The consequences of fatigue-related accidents substantiate the need to develop suitable preventative and protective measures that mitigate errors caused by fatigue10). One way to do this is to assess fitness-for-duty prior to the commencement of shifts11).

Fitness-for-duty measures assess performance capacity
and are sensitive to performance impairment induced by conditions such as fatigue. Consequently, it may be possible to determine how fit an employee is before they operate equipment that requires high levels of alertness. The Occupational Safety Performance Assessment Test (OSPAT) has been used as a fitness-for-duty measure in a variety of industries (in Australia, Brazil, New Zealand, and Malaysia), including mining, transport, and metal processing, and in the near future will be installed in steel production and brick-making organizations. OSPAT is an unpredictable tracking task that predominantly assesses hand-eye coordination, a skill considered a prerequisite for proficient performance, particularly during object manipulation. Specifically, during hand-eye co-ordination, visual information is spatially updated across eye movements, which are then transformed into commands appropriate for arm motion. Similar to other tracking tasks, OSPAT also assesses sustained attention and reaction time.

Whilst OSPAT is implemented in several industries as a fitness-for-duty measure, as yet, it has not been validated as a test sensitive to the effects of fatigue. In order to determine OSPAT’s sensitivity to fatigue, it is important to compare it to already well-established fatigue measures, such as subjective ratings of alertness and the psychomotor vigilance task (PVT).

Several studies have considered the effects of fatigue on subjective alertness. Without exception, these studies indicate that subjective alertness declines as hours of wakefulness increase, particularly during the night-time. However, self-ratings of alertness can be unreliable as they may be influenced by factors such as participants’ expectations, mood, and possibly malingering or faking. Consequently, subjective measures of fatigue are often supplemented with objective measures, such as the PVT.

The PVT is a measure of sustained attention that requires an individual to respond repeatedly to a visual stimulus over a period of time. Numerous studies have established that the PVT is sensitive to the effects of fatigue, particularly during the night-time. Notably however, the PVT is typically long in duration (i.e., approximately 10 min or longer). This questions the suitability of the PVT as a fitness-for-duty measure as this duration may be impractical in most workplace environments. Indeed, this limitation suggests that other tasks may be worth exploring, such as OSPAT. OSPAT has a relatively short duration (i.e., typically 90s or shorter), making it more practical for workplaces. Furthermore, the task’s short duration may make it less tedious for employees to complete, thus potentially removing modifier variables such as boredom that may confound the effects of fatigue.

Butler and Tranter (1994) proposed that fitness-for-duty measures should meet the following criteria: (1) be well validated and reliable, (2) be sensitive to small changes in performance that occur after the presence of conditions such as drugs or fatigue, (3) be simple to administer, (4) adjust to learning effects (i.e., practice trials reach asymptote), and (5) measure cognitive skills that are relevant to the workplace. A previous study has provided evidence that OSPAT is reliable, sensitive to small changes in performance following the presence of some condition, and adjustable to learning effects. Furthermore, the cognitive skills underlying OSPAT are important for proficient performance in the workplace, particularly in activities involving object manipulation. What remains therefore, is for OSPAT to be validated as a test sensitive to a source of impairment such as fatigue. Consequently, the current study sought to examine the impact of sustained wakefulness and time-of-day on OSPAT performance. The PVT and a visual analog scale (VAS) were used to measure participants’ sustained attention and subjective alertness, respectively.

**Method**

**Participants**

Twenty individuals (10 male, 10 female), aged between 18–25 yr (M=20.90, SD=2.29) participated in the study. To be included in the study, volunteers had to be (i) aged between 18–30 yr, (ii) self-reported good sleepers, (iii) medication-free, and (iv) in good physical and psychological health. Information regarding these inclusion and exclusion criteria was ascertained from volunteers’ responses to questions in a telephone interview and a health questionnaire.

Prior to commencing the study, participants were provided with an information sheet that contained details about the experiment and also outlined their rights, including their rights to confidentiality and anonymity, and their freedom to withdraw from the study at any stage without explanation or obligation. Informed written consent was obtained from each participant. At the completion of the study, participants received a payment of $350 (AUS) to compensate them for any inconvenience.

Ethics approval for the study was granted by The Queen Elizabeth Hospital Research Foundation Ethics Committee and the University of Adelaide Department of Psychology Human Research Ethics Subcommittee.

**Materials**

**Visual analogue scale**

Subjective ratings of alertness were obtained using a linear
bipolar visual analogue scale (VAS). Participants were required to respond to the question ‘How alert do you feel?’ by placing a single stroke through a 100 mm line, with the anchors ‘struggling to remain awake’ at the left-hand end and ‘extremely alert and wide awake’ at the right-hand end.

The dependent measure, subjective alertness, was the distance (in millimetres) that the stroke was placed from the left-hand end of the scale (i.e., score of 0–100). Higher scores indicated a greater level of alertness.

**Psychomotor vigilance task**

The psychomotor vigilance task (PVT, Ambulatory Monitoring Inc., Ardsley, NY) is a hand-held device that contains a 4-digit red light emitting diode (LED) display and two push-button response keys. Participants attended to the LED display for the duration of the test (10 min) using their dominant hand, and pressed the left or right response key as quickly as possible after the appearance of a visual timer stimulus (i.e., a number counting up from zero, in increments of 1 every millisecond). The participant’s response stopped the timer stimulus, and the response speed was displayed for a period of 500 ms. The interval between stimuli presentations varied randomly from 2,000–10,000 ms.

The dependent measure derived from the PVT was response speed, expressed as the mean reciprocal response time multiplied by 1000, as per standard methodology. Higher scores indicated a greater level of performance.

**Occupational safety performance assessment test**

The Occupational Safety Performance Assessment Test (OSPAT: OSPAT Pty Ltd, Western Australia) workstations consisted of a test unit, monitor and trackball placed on a desk or table in front of a chair. Participants were seated so that their eyes were approximately 75 cm from the monitor screen. OSPAT required participants to continually return an unpredictable moving cursor to the centre of a circular target presented on the monitor. Participants used a trackball with their dominant hand to manoeuvre the cursor. Whilst Dawson and Reid (1997) used a 90-s OSPAT, a 60-s OSPAT was used in the current study because this duration appeared more practical for workplace settings.

The algorithm used to determine the dependent measure derived from OSPAT cannot be disclosed as it is subject to commercial confidence. However, it is a global construct based on measures of hand-eye coordination, sustained attention, and reaction time. Higher OSPAT scores indicate a greater level of performance.

**Procedure**

**Experimental design and rationale**

The study employed a repeated measures design involving one within subjects factor ‘time-of-day’. Participants were required to remain awake for 24 h, beginning at 07:00h on one day (day 1) and ending at 07:00h the next (day 2) (see Fig. 1). During this period, participants were required to complete the OSPAT, PVT and VAS every 2 h (12 in total). Participants completed the study in groups of four. To ensure that participants were not sleep deprived at the start of day 1, they were (1) requested to obtain at least 8 hours of sleep per night for one week prior to beginning the study, and (2) required to sleep in the laboratory from 23:00–07:00h prior to the start of the sustained wakefulness period.

The study was designed to approximate the situation that many shiftworkers experience when changing from day shift to night shift. Specifically, if they do not have an opportunity to nap prior to their first night shift, shiftworkers may have to remain awake for approximately 24 h from the time they wake in the morning before the night shift, until when they sleep the following morning after the night shift. It was assumed participants’ sleepiness would progressively increase throughout the condition as a result of sustained wakefulness.

**Fig. 1.** Study protocol showing pre-condition night (training, sleep) and daytime/night experimental phase during the period of sustained wakefulness (2-hourly testing sessions in black).
wakefulness and time of day. It was expected that fatigue levels would be relatively low in the early sessions because they occurred during the day, after participants had slept for up to 8 h, and when they had been awake for a short period of time. In contrast, it was expected that fatigue levels would be relatively high in the late sessions of the condition because they had been awake for an extended period of time and were consequently more sleepier, and because they occurred during the night-time and early morning, when participants’ circadian rhythms of alertness and performance were at a nadir.

Protocol

The study was conducted at the Centre for Sleep Research sleep laboratory, The Queen Elizabeth Hospital, Woodville, South Australia. On the evening prior to the first testing day, participants arrived at the sleep laboratory at 20:00h. During this evening, participants completed a training session to familiarize them with the performance tasks and to extinguish any learning effects. During this training session, participants completed 3 PVTs and 20 OSPATs. Notably, in workplace situations, a mean for each employee is calculated, and the deviation from this “profile” mean during tests is calculated as the actual OSPAT performance. As this profile is continually updated and based on the most 20 recent tasks, it is assumed that OSPAT learning effects in the ‘real-world’ are much smaller then those observed in the laboratory.

At 23:00h, participants went to bed for 8 h. Participants were woken at 07:00h on day 1, ate breakfast and showered before commencing the first test session at 08:00h. The test session consisted of 1 PVT, 1 OSPAT, and 1 VAS. Subsequently, participants completed a testing session every 2 h, until 06:00h on day 2. The order of the tasks was randomly assigned to prevent order effects. Participants did not receive feedback regarding their overall performance at the conclusion of any of the tasks, as feedback may increase motivation and influence subsequent effort5, 19). However, due to the design of the task, immediate response feedback was provided to participants during the PVT. To keep participants free from distraction, each task was located in a separate room.

Participants were not permitted to eat or drink during the test session hours (i.e., 08:00–09:00h, 10:00–11:00h, 12:00–13:00h, etc) but were free to consume snacks and beverages between test sessions. Main meals were served at 13:00h and 19:00h. Given that consumption of glucose and fats may affect alertness and performance5, participants consumed only low-glucose, low-fat foods and beverages.

To minimize factors that may confound the effects of fatigue, participants were not permitted to exercise, listen to loud music, shower, or leave the sleep laboratory at any time. Between test sessions, participants undertook quiet activities, such as reading, watching television and videos, and conversing with others. To ensure wakefulness during the experimental period, all participants were monitored by a researcher. Ambient temperature (24°C) and artificial lighting (300 lux) were kept constant, as temperature and light conditions may influence alertness and performance5).

Statistical analyses

Separate repeated measures analyses of variance (ANOVA) with one within-subjects factor were conducted to determine the effects of ‘time-of-day’ on each of the dependent variables. If an ANOVA indicated a significant effect of ‘time-of-day’, contrasts were conducted for that dependent variable to compare the mean of each of the last seven test sessions (i.e., 18:00h, 20:00h, 22:00h, 00:00h, 02:00h, 04:00h, and 06:00h) with the daytime baseline, calculated as the grand mean of the first five test sessions (i.e., 08:00–16:00h).

Further bivariate correlation analyses using Pearson’s coefficient were conducted between mean scores for each of the measures across all time points. A separate repeated measures ANOVA with one within-subjects factor ‘task’ was also conducted to determine the within-subjects association between dependent measures.

Results

Data from two male participants were excluded from all analyses as they withdrew from the study for personal reasons after completing only one condition. Consequently, all analyses were conducted using data from the remaining 18 participants. There were no missing data for these 18 participants.

Mauchly’s statistic was calculated for each ANOVA to test for violations of the assumption of sphericity30). Mauchly’s statistic was significant for all ANOVAs, so all p-values were corrected using Greenhouse-Geisser epsilon.

Repeated measures ANOVA indicated that ‘time-of-day’ had a significant effect on mean subjective alertness (F(11,187)=16.50, p<.001) (Fig. 2). Post-hoc comparisons revealed that mean subjective alertness was significantly lower at 00:00h, 02:00h, 04:00h, and 06:00h than during the daytime baseline period (i.e., 08:00–16:00h) (all p<.05).

As shown in Fig. 2, repeated measures ANOVA indicated that ‘time-of-day’ had a significant effect on mean response
speed (F_{11,187}=15.49, p<.001). Post-hoc comparisons revealed that mean response speed was significantly lower at 02:00h, 04:00h, and 06:00h than during the daytime baseline period (i.e., 08:00–16:00h) (all p<.05).

Significant positive correlations were found between PVT and VAS data (r=0.37, p<.01), as well as PVT and OSPAT data (r=0.40, p<.01). However, no significant correlation was found between OSPAT and VAS data. These correlations were supported by the repeated measures ANOVA that indicated no significant effect of the within-subjects factor, ‘task’ (F_{2,34}=0.51, p=.57), but indicated a significant interaction between ‘time-of-day’ and ‘task’ (F_{22,374}=2.39, p<.05).

**Discussion**

The aim of this study was to determine the effects of fatigue on OSPAT performance. In order to ensure that these effects were achieved, measures of sustained attention (i.e., the psychomotor vigilance task: PVT), and subjective alertness (i.e., the Visual Analog Scale: VAS) were used to confirm that the experimental conditions produced low levels of fatigue during the daytime and high levels of fatigue during the night-time.

Analyses indicate that VAS alertness ratings decreased as hours of wakefulness increased. Specifically, alertness ratings were lower between 00:00–06:00h than during the daytime baseline period (i.e., 08:00–16:00h). These results are consistent with previous studies that have shown that subjective alertness is lower during the night-time after a period of sustained wakefulness, than it is during the daytime after a night of sleep^{16–18}. Furthermore, these results indicate that participants experienced higher levels of fatigue (and sleepiness) in the latter stages of the condition than they did in the early stages of the condition, as was intended when the protocol was designed. However, subjective measures of alertness cannot be relied upon alone as they may be affected by participants’ general expectations and other modifier variables^{20}. Consequently, participants’ performance on the PVT, a measure of sustained attention, was also examined.

Results of this study show that PVT response speed decreased, as hours of wakefulness increased. Response speed was slower between 02:00–06:00h than during the daytime baseline period (i.e., 08:00–16:00h). Again, these results are consistent with previous studies that have shown that sustained attention is sensitive high levels of fatigue^{16, 18}. These findings also provide further evidence that participants experienced higher levels of fatigue in the latter stages of the study than they did in the early stages of the study. The study was designed this way so that the effects of fatigue OSPAT performance could be examined.

Analyses of the OSPAT data indicate that as hours of
wakefulness increased, participants' OSPAT performance decreased. Specifically, OSPAT performance was lower between 02:00–06:00h than during the daytime baseline period (i.e., 08:00–16:00h). These findings suggest that OSPAT performance is sensitive to sustained wakefulness during the night-time and that OSPAT may be an effective measure for detecting fatigue in the workplace.

Notably, a positive relationship was found between OSPAT and PVT performance, and OSPAT performance dropped below the daytime baseline period at the equivalent time as PVT performance dropped below the baseline period (i.e., 02:00h). This indicates that OSPAT may be as sensitive to fatigue as the PVT. Interestingly though, the task duration of OSPAT was 1 min, whereas the PVT was 10 min. This is a substantial difference and in industries where time is critical to work operations, using a 1-min task in place of a 10-min task may be important in terms of productivity and efficiency. Moreover, a task with a short duration may be less likely to be influenced by variables that confound the effects of fatigue such as boredom or monotony2).

As alluded to earlier, this experiment was designed to approximate the conditions experienced by shiftworkers changing from day shift to night shift, where sleep may not be possible prior to the night shift. In this study, it was assumed that during the night-time/early morning phase of the experiment, participants experienced high levels of sleepiness associated with hours of wakefulness and time-of-day effects, when circadian rhythms are at a nadir. Thus, the results of this study may be generalizable to these types of conditions only. Future research should therefore attempt to separate hours of wakefulness and time-of-day effects, and potentially consider the sensitivity of OSPAT to other sources of fatigue such as partial sleep deprivation, or to other sources of impairment, such as drugs and alcohol. It should also be pointed out that some Australian industries use 30-s OSPATs. Thus it would be important for future research to assess the impact of fatigue on 30-s OSPATs, as the results of this study may not be generalizable to this task duration. Additionally, OSPAT should be compared to other measures that are currently being researched as potential fatigue detectors such as the Critical Flicker Fusion Test1) and Pupillometry3).

Importantly, fatigue is becoming a growing concern in many industries, particularly in industries involving shiftwork10). As one of the consequences of fatigue is impaired performance, fitness-for-duty measures offer a viable strategy for preventing and protecting workplaces from errors that are caused by fatigue-related impairment. Findings of this study indicate that OSPAT may be a suitable fatigue fitness-for-duty measure because it is sensitive to the impact of sleepiness caused by sustained wakefulness during the night-time, a condition that is experienced by many shiftworkers. Consequently, the implementation of OSPAT as a fatigue fitness-for-duty measure may help to reduce the occurrence of workplace incidents and accidents derived from fatigue-related errors.

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References