CAND A SHORTER PSYCHOMOTOR VIGILANCE TASK BE USED AS A REASONABLE SUBSTITUTE FOR THE TEN-MINUTE PSYCHOMOTOR VIGILANCE TASK?

Gregory D. Roach, Drew Dawson, and Nicole Lamond

Centre for Sleep Research, University of South Australia, Adelaide, SA, Australia

The 10 min psychomotor vigilance task (PVT) is commonly used in laboratory studies to assess the impact of sleep loss, sustained wakefulness, and/or time of day on neurobehavioral performance. In field settings, though, it may be impractical for participants to perform a test of this length. The aim of this study was to identify a performance measure that is sensitive to the effects of fatigue but less burdensome than a 10 min test. Sixteen participants (11 female, 5 male; mean age = 21.7 years) slept in the sleep laboratory overnight then remained awake for 28 h from 08:00 h. During every second hour, participants completed three PVTs of differing duration (10 min, 5 min, 90 sec). For the 5 min/10 min comparison, ANOVA indicated that response time was significantly affected by test length ($F_{1,14} = 26.9, p < .001$) and hours of wakefulness ($F_{13,182} = 46.1, p < .001$) but not by their interaction ($F_{13,182} = 1.7, ns$). There was a strong correlation between response time on the 5 and 10 min PVTs ($r = .88, p < .001$). For the 90 sec/10 min comparison, ANOVA indicated that response time was significantly affected by test length ($F_{1,14} = 65.9, p < .001$) and hours of wakefulness ($F_{13,182} = 29.7, p < .001$) as well as by their interaction ($F_{13,182} = 6.0, p < .001$). There was a strong correlation between response time on the 90 sec and 10 min PVTs ($r = .77, p < .001$). The effects of hours of wakefulness on neurobehavioral performance were similar for the 5 min and 10 min PVTs. In contrast, performance on the 90 sec PVT was less affected by hours of wakefulness than on the 10 min PVT. In addition, performance on the 10 min PVT was more highly correlated with the 5 min PVT than the 90 sec PVT. These data indicate that the 5 min PVT may provide a reasonable substitute for the 10 min PVT in circumstances where a test shorter than 10 min is required.

Keywords Sustained wakefulness, Test length, Neurobehavioral cognitive performance, Psychomotor vigilance task

This paper was presented at the 17th International Symposium on Shiftwork and Working Time, September 18–22, 2005, Hoofddorp, The Netherlands.

Address correspondence to Gregory D. Roach, Centre for Sleep Research, University of South Australia, Level 7 Playford Building, City East Campus, Frome Road, Adelaide SA 5000, Australia. Tel.: +61 8 8302 6624; Fax: +61 8 8302 6623; E-mail: greg.roach@unisa.edu.au
INTRODUCTION

The prevalence of shift work has substantially increased in most industrialized economies in the last three decades, largely due to increased customer demands, changes in community expectations, and the expansion of global competition (Smith et al., 1998). Consequently, more employees are now required to work outside the hours of the standard 09:00–17:00 h, Monday–Friday work week, and are thus exposed to higher levels of work-related fatigue.

For shift workers, the symptoms of fatigue typically manifest as reduced alertness and performance, increased sleepiness, and greater risk of injury and accident (Dinges, 1995; Hakkanen and Summala, 2000; Hanecke et al., 1998; Lauber and Kayten, 1988; Mitler et al., 1988, 1994). Indeed, the level of neurobehavioral impairment associated with fatigue may be similar to that associated with moderate levels of alcohol intoxication (Dawson and Reid, 1997; Lamond and Dawson, 1999; Roach et al., 2001; Williamson and Feyer, 2000). In recognition of the potentially deleterious effects of shift work, occupational health and safety legislation in some countries now places a duty of care on organizations to minimize fatigue-related risks to their employees (e.g., Occupational Health and Safety Regulation, 2001). It is clear then that fatigue poses a hazard that must be managed similar to other workplace hazards (e.g., exposure to chemicals, dust, and noise).

A key component of any hazard management system is the ability to quantify the hazard. For hazards caused by disturbed sleep, sustained wakefulness, or time of day, this is not a simple matter, as there is no universal measure of fatigue. In laboratory settings, the 10 min psychomotor vigilance task (PVT; see Dinges and Powell, 1985) has become a widely accepted tool for assessing the impact of fatigue on neurobehavioral performance (e.g., Belenky et al., 2003; Dinges et al., 1997; Jewett et al., 1999; Lamond et al., 2003). In field settings, though, requirements of the job can make it impractical for participants to perform a test of this length.

Generally, longer performance tests are more sensitive to the effects of fatigue than shorter tests (Dinges and Kribbs, 1991; Johnson, 1982). Nevertheless, the present authors have previously found significant fatigue-related impairment during the first 5 mins of a 10 min PVT (Loh et al., 2004) and during a 5 min PVT adapted for use on a personal digital assistant (Lamond et al., 2005). The results of these studies suggest that a shorter task may be sufficiently sensitive to the effects of fatigue. Consequently, the current study was designed to compare the performance on two shorter PVTs (i.e., 5 min and 90 sec) with that on a 10 min PVT during 28 h of sustained wakefulness. It was hypothesized that performance impairment during sustained wakefulness would be similar for the
shorter PVTs and the 10 min PVT. The aim of the study was to identify a performance measure for field settings that is sensitive to the effects of fatigue but not overly burdensome for participants.

**METHODS**

**Participants**

Sixteen volunteers (11 female, 5 male) with a mean (± S.D.) age of 21.7 (± 2.2) years and a mean body mass index of 23.4 (± 2.4) obesipascals (kg/m²) gave written, informed consent to participate in the study. Participants were in good mental and physical health as determined by interview and responses to a general health questionnaire. They were free of neurological diseases, psychiatric disorders, and sleep disorders, and they did not consume large doses of caffeine (no more than 350 mg/day), alcohol (no more than six standard drinks/week), or nicotine (no more than four cigarettes/day). With the exception of female participants who were taking birth control medication, participants were medication-free. Participants had not undertaken shift work or international flight in the month prior to the study. Ethics approval for the study was granted by the University of South Australia Human Research Ethics Committee using guidelines established by the National Health and Medical Research Council of Australia, and the research methods conformed to the standards of good practice outlined in Touitou et al. (2004).

**Apparatus and Measures**

Neurobehavioral performance was assessed using a psychomotor vigilance task, the PVT-192 (Ambulatory Monitoring Inc., Ardsley, New York, USA). The PVT provides a measure of sustained attention based on repeated reaction time trials (Dorrian et al., 2005). The PVT is a hand-held device with an upper surface that contains a four-digit LED display and two push-button response keys.

Participants attended to the LED display for the duration of the test (either 10 min, 5 min, or 90 sec) and pressed the appropriate response key with the thumb of their dominant hand as quickly as possible after the appearance of a visual stimulus (presented at a variable interval of 2–10 sec). If the correct response key was pressed, the LED display exhibited the participant’s response time, in milliseconds, for 500 ms. If the wrong response key was pressed, an error message was displayed (ERR). If a response was made prior to the stimulus being presented, a false start message was displayed (FS). During practice and test sessions, participants were kept free from distraction by being seated alone in a room in front of a blank wall.
The dependent measure derived from the PVT was the mean response time (RT: mean of the response times for each stimulus presentation). For all analyses, anticipated responses (i.e., those with response time less than 100 ms) were excluded. In the interest of brevity, some commonly reported PVT measures are not included in the current paper (i.e., mean reciprocal response time, percentage of lapses, mean response time for the fastest 10% of responses, mean response time for the slowest 10% of responses). These data can be made available to interested parties upon request.

**Protocol**

The study was conducted at the Centre for Sleep Research Sleep Laboratory at the Queen Elizabeth Hospital, Woodville, South Australia. Participants spent two consecutive nights in the sleep laboratory: the first as a preparatory night, and the second as a night of sleep deprivation. On the preparatory night, participants attended a training session at the sleep laboratory from 19:00 to 22:30 h (with a 30 min meal break). During training, participants completed three 10 min PVTs, three 5 min PVTs, and three 90 sec PVTs to familiarize themselves with the apparatus and procedures and extinguish any practice effects. (Practice effects for the PVT are typically extinguished after a maximum of three trials; see Kribbs and Dinges, 1994.)

Following training, participants went to bed for 9 h, from 23:00 to 08:00 h. In the morning, participants ate breakfast and showered prior to beginning the first test session at 09:00 h. Subsequently, performance was assessed in test sessions that began every 2 h until 11:00 h the following day (i.e., 14 test sessions during 28 h of sustained wakefulness).

During each 1 h test session, participants performed a 10 min PVT, a 5 min PVT, a 90-sec PVT, and a 90 sec tracking task (OSPAT), presented in random order at 15 min intervals. Participants had free time every second hour between test sessions. During this time, they were required to remain in the sleep laboratory where they could eat, read, study, listen to music, watch television or videos, or play computer games. Throughout the study, participants were not permitted to consume caffeine, smoke, exercise, or nap.

**Statistical Analysis**

To compare performance on the shorter (5 min and 90 sec) PVTs with performance on the 10 min PVT, two separate repeated measures ANOVA with two within-subjects factors were conducted. The first ANOVA determined the interaction (and main) effects of test length (10 min, 5 min) and hours of wakefulness (every two hours, until 28 h) on response time. The second ANOVA determined the interaction (and
main) effects of test length (10 min, 90 sec) and hours of wakefulness on response time. In addition, the linear relationships between response time on the shorter (5 min and 90 sec) PVTs and response time on the 10 min PVT were determined using Pearson product–moment correlations.

For the ANOVA analyses, $p$ values were based on Greenhouse-Geisser’s corrected degrees of freedom (Winer, 1971), but the original degrees of freedom are reported. Missing values were replaced by the group mean. One participant’s dataset was incomplete due to technical difficulties, so his data were excluded from all analyses.

**RESULTS**

Response time tended to be less for the shorter PVTs than the 10 min PVT, but the general pattern of results for each test length was similar (see Figure 1). Specifically, response time was relatively stable during the first seven test sessions, progressively increased during the next five test sessions to a maximum at 24 h of sustained wakefulness, and then decreased in the last two test sessions. The percentage increases from average response time (at 2–14 h of wakefulness) to the maximum response time (at 24 h of wakefulness) for the 10 min, 5 min, and 90 sec PVTs were 37.6%, 32.2%, and 21.3%, respectively.

For the 5 min/10 min comparison, ANOVA indicated that response time was significantly affected by test length ($F_{1,14} = 26.9$, $p < .001$) and hours of wakefulness ($F_{13,182} = 46.1$, $p < .001$) but not by their interaction ($F_{13,182} = 1.7$, ns). There was a strong correlation between response time on the 5 min and 10 min PVTs ($r = .88$, $p < .001$).

For the 90 sec/10 min comparison, ANOVA indicated that response time was significantly affected by test length ($F_{1,14} = 65.9$, $p < .001$) and hours of wakefulness ($F_{13,182} = 29.7$, $p < .001$), as well as by their interaction ($F_{13,182} = 6.0$, $p < .001$). There was a strong correlation between response time on the 90 sec and 10 min PVTs ($r = .77$, $p < .001$).

**DISCUSSION**

The ANOVA results indicated that performance on each of the PVTs (10 min, 5 min, and 90 sec) was significantly affected by fatigue (i.e., the combination of sustained wakefulness and time of day). For each test length, neurobehavioral performance was generally better during the daytime, after participants had had a 9 h sleep opportunity, than it was during the nighttime, when participants had been awake for an extended period of time (see Figure 1).

The first ANOVA indicated that neurobehavioral performance on the 5 min and 10 min PVTs was reasonably similar over the 28 h of sustained wakefulness. Although response time was generally less for the 5 min PVT
than the 10 min PVT, indicating better performance on the shorter PVT, performance on both PVTs was similarly affected by hours of wakefulness (see Figure 1). In addition, correlation analysis indicated a strong linear relationship between response time on the 5 min and 10 min PVTs. These data are consistent with those of a recent sustained wakefulness experiment, which showed that performance on a 5 min PVT adapted for use on a personal digital assistant was similar to performance on a standard 10 min PVT (Lamond et al., 2005). Furthermore, these data support the hypothesis that performance impairment during sustained wakefulness would be similar for shorter PVTs and the 10 min PVT.

In contrast, results of the second ANOVA, comparing neurobehavioral performance on the 90 sec and 10 min PVTs, were less impressive, even
though the correlation analysis indicated a strong linear relationship between response time for these two PVTs. Specifically, response time was generally less for the 90 sec PVT than the 10 min PVT, indicating better performance on the shorter PVT. Most importantly, though, there was a significant interaction effect, indicating that performance was less affected by hours of wakefulness for the 90 sec PVT than for the 10 min PVT. Consequently, these data do not support the hypothesis that performance impairment during sustained wakefulness would be similar for shorter PVTs and the 10 min PVT.

Taken together, the results indicate that the 5 min PVT may provide a reasonable substitute for the 10 min PVT, but that the 90 sec PVT does not. Two particular circumstances where a shorter test may be more suitable than a 10 min test are field studies, where participants have limited time for performance testing, and workplace settings, where performance testing is a component of fitness for duty screening. In field studies, participants may not have time to perform a 10 min test, particularly if multiple tests are required in each duty period (e.g., the start, middle, and end of shift). In such cases, a choice must be made between having participants do fewer tests per duty period and having them do a shorter test. Similarly, with fitness for duty testing, it may be impossible to screen a large number of employees using a 10 min test, particularly if they begin work at similar times and there are a limited number of test units. Consequently, a choice must be made between screening a smaller sample of the workforce and using a shorter test. The results of the current study indicate that in both of these circumstances, it may be reasonable to use the 5 min PVT as a substitute for the 10 min PVT, which would enable a greater volume of data to be collected.

A couple of notes of constraint should be made at this point. The current study was conducted under controlled laboratory conditions, on a relatively small sample of young, healthy participants, during 28 h of sustained wakefulness. Consequently, some caution should be taken in generalizing the study’s findings beyond these circumstances. To expand the generalizability of the results, future studies could consider the viability of the 5 min PVT with participants drawn from different populations (e.g., older, experienced shift workers), in different settings (e.g., workplace field study), and under different conditions (e.g., multiple consecutive night shifts). In addition, it must be stressed that the current results should not be interpreted as a suggestion that the 10 min PVT be replaced with the 5 min PVT in all situations. Rather, the results should be taken as an indication that in circumstances where it is impractical for participants to perform a 10 min test such that the volume of data collected is restricted, then the 5 min PVT could be considered as a substitute for the 10 min PVT.

In summary, the PVT is a widely accepted measure of fatigue-related impairment that is simple to use, easy to transport, and has minimal
learning effects. Consequently, the PVT has the potential to be used in workplace settings to quantify the hazards (i.e., performance impairment) associated with fatigue, caused by disturbed sleep, sustained wakefulness, and/or time of day. A potential obstacle to using the PVT in workplace settings, though, is that participants may not have time to complete a 10 min performance test. However, the results of the current study indicate that in such circumstances, the 5 min PVT may provide a reasonable substitute for the 10 min PVT. Future comparisons will indicate whether these findings can be generalized more widely.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of Qantas Airways, the Civil Aviation Safety Authority, the Australian and International Pilots Association, and the Australian Research Council.

REFERENCES


