Accident Analysis and Prevention 45S (2012) 55–61

Contents lists available at SciVerse ScienceDirect

Accident Analysis and Prevention

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

Simulated driving under the influence of extended wake, time of day and sleep restriction

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ARTICLE INFO

Article history:
Received 2 May 2011
Received in revised form 2 August 2011
Accepted 11 August 2011

Keywords:
Driving
Time of day
Prior wake
Sleep
Forced desynchrony

ABSTRACT

Around a fifth of all road accidents can be attributed to fatigued drivers. Previous studies indicate that driving performance is influenced by time of day and decreases with sustained wakefulness. However, these influences occur naturally in unison, confounding their effects. Typically, when people drive at a poor time of day and with extended wake, their sleep is also restricted. Hence, the aim of the current study was to determine the independent effects of prior wake and time of day on driving performance under conditions of sleep restriction. The driving performance of fourteen male participants (21.8 ± 3.8 years, mean $\pm$SD) was assessed during a 10 min simulated driving task with speed/lane mean, variability and violations (speeding and crashes) measured. Participants were tested at 2.5 h intervals after waking, across 7×28 h days with a sleep:wake ratio of 1:5. By forced desynchrony each driving session occurred at 9 doses of prior wake and within 6 divisions of the circadian cycle based on core body temperature. A mixed models ANOVA revealed significant main effects of circadian phase, prior wake and sleep debt on lane violations. In addition, three significant two-way interactions (circadian phase $\times$ prior wake, prior wake $\times$ sleep debt, sleep debt $\times$ circadian phase) and one three-way interaction (circadian $\times$ prior wake $\times$ sleep debt) were identified. The presence of the large interaction effects shows that the influence of each factor is largely dependent on the magnitude of the other factors. For example, the presence of the time of day influence on driving performance is dependent on the length of prior wake or the presence of sleep debt. The findings suggest that people are able to undertake a low-difficulty simulated drive safely, at least for a short period, during their circadian nadir provided that they have had sufficient sleep and have not been awake too long.

1. Introduction

Globally, it has been acknowledged that fatigue is a significant contributor to road accidents. While fatigue may be a causal factor in around a fifth of all road accidents (Campagne et al., 2004; Lyznicki et al., 1998; Maycock, 1997), surveys conducted in the U.K., U.S., Australia and Finland suggest that crash statistics may portray conservative estimates of the prevalence of fatigue. For example, when 1000 licensed drivers were randomly sampled in New York, more than half reported having ‘driven while being drowsy’ and more than a quarter reported ‘falling asleep at the wheel’ (McCartt et al., 1996). A study of naturalistic driving gathered video data from 100 vehicles over one year totalling 43,000 h of driving data (Klauer et al., 2006). Drowsy drivers were close to three times more likely to be involved in a road accident or near accident than non-drowsy drivers. Clearly, driving while fatigued is both prevalent and dangerous.

Understanding and managing the determinants of fatigue is an essential part of minimising the safety hazard that it presents to our society (Gander et al., 2011; Williamson et al., 2011). Fatigue however, is a broad, multi-dimensional and usually ill-defined concept (Noy et al., 2011). Recently, it has been agreed that when using the term ‘fatigue’, the wisest solution is to adopt a definition that best suites the context (rather than a universal definition) (e.g., Dawson et al., 2011; Horrey et al., 2011; Noy et al., 2011; Williamson et al., 2011). Therefore, for the purposes of this paper, the term fatigue is used as analogous to sleepiness leading to decreased performance. In this context, the factors that contribute to fatigue include: time of day (or circadian phase; Colquhoun, 1971), prior wake (Dinges and Kribbs, 1991), sleep dose (Belenky et al., 2003), and task-related factors (Richter et al., 2005).

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doi:10.1016/j.aap.2011.09.027