ARTICLE IN PRESS

Transportation Research Part F xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Transportation Research Part F

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

Sleep loss and change detection in driving scenes

Ashleigh J. Filtness [a,b,*], Vanessa Beanland [c]

[a] Loughborough Design School, Loughborough University, LE11 3TU, UK
[b] Queensland University of Technology, Centre for Accident Research and Road Safety – Queensland (CARRS-Q), Kelvin Grove, QLD 4059, Australia
[c] Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, QLD 4558, Australia

A R T I C L E I N F O

Article history:
Received 14 February 2017
Received in revised form 30 July 2017
Accepted 3 October 2017
Available online xxxx

Keywords:
Driver sleepiness
Sleepy drivers
Driver fatigue
Driver drowsiness
Change detection
Change blindness
Visual attention

A B S T R A C T

Driver sleepiness is a significant road safety problem. Sleep-related crashes occur on both urban and rural roads, yet to date driver-sleepiness research has focused on understanding impairment in rural and motorway driving. The ability to detect changes is an attention and awareness skill vital for everyday safe driving. Previous research has demonstrated that person states, such as age or motivation, influence susceptibility to change blindness (i.e., failure or delay in detecting changes). The current work considers whether sleepiness increases the likelihood of change blindness within urban and rural driving contexts. Twenty fully-licenced drivers completed a change detection 'flicker' task twice in a counterbalanced design: once following a normal night of sleep (7–8 h) and once following sleep restriction (5 h). Change detection accuracy and response time were recorded while eye movements were continuously tracked. Accuracy was not significantly affected by sleep loss; however, following sleep loss there was some evidence of slowed change detection responses to urban images, but faster responses for rural images. Visual scanning across the images remained consistent between sleep conditions, resulting in no difference in the probability of fixating on the change target. Overall, the results suggest that sleep loss has minimal impact on change detection accuracy and visual scanning for changes in driving scenes. However, a subtle difference in response time to change detection between urban and rural images indicates that change blindness may have implications for sleep-related crashes in more visually complex urban environments. Further research is needed to confirm this finding.

1. Introduction

Driver sleepiness remains one of the leading contributors to road crashes, implicated in approximately 15–30% of all crashes (Åkerstedt, 2000; Connor et al., 2002; Horne & Reyner, 1995). Sleep-related crashes are particularly prevalent on high speed motorways and rural roads, where they are often high speed, serious injury, single vehicle, run-off-road events (Connor et al., 2002; Filtness, Armstrong, Watson, & Smith, 2017; Philip et al., 2014). Traditionally driver sleepiness research has focused on these environments (e.g. Anderson & Horne, 2013; Anund, Kecklund, Vadeby, Hjälmdahl, & Åkerstedt, 2008; Filtness, Reyner, & Horne, 2012). However, sleep-related crashes are not confined to high speed roads: a recent study found that 41% of all police-reported sleep-related crashes occurred on low speed (≤50 km/h) roads (Filtness et al., 2017). Drivers also self-report having sleepiness-related driving incidents on low speed urban roads (Armstrong, Filtness, Watling,

---

* Corresponding author at: Loughborough Design School, Loughborough University, LE11 3TU, UK.
E-mail address: A.J.Filtness@lboro.ac.uk (A.J. Filtness).

https://doi.org/10.1016/j.trf.2017.10.003
1369-8478/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Filtness, A. J., & Beanland, V. Sleep loss and change detection in driving scenes. *Transportation Research Part F* (2017), https://doi.org/10.1016/j.trf.2017.10.003

Barraclough, & Haworth, 2013). Urban roads present unique challenges in that they include a greater variety of road users (i.e., pedestrians, cyclists, motorised road users), have higher visual complexity, and the environment changes more frequently compared with rural areas. Understanding how sleep loss impairs driving ability in such complex situations, as well as lower complexity rural situations, is a first step to developing appropriate countermeasures to reduce crash risk.

One area that has received relatively little attention to date is the effect that sleepiness has on complex visual attention tasks such as change detection. The ability to detect changes is crucial for safe driving, and is positively correlated with safe decision making (Caird, Edwards, Creaser, & Horrey, 2005). Observers often fail to detect changes to a visual scene, however, which is a psychological phenomenon known as *change blindness* (Rensink, O'Regan, & Clark, 1997). This has implications for safe driving, especially the need to notice changes to the driving environment in order to respond appropriately. Change blindness in drivers has been observed using both static images of driving scenes (Beanland, Filtness, & Jeans, 2017; Velichkovsky, Dornhoefer, Kopf, Helmert, & Joos, 2002) and driving simulator paradigms (Charlton & Starkey, 2013; Martens & Fox, 2007). It is difficult to quantify the extent of crashes involving change blindness, or the failure to detect changes, but recent research suggests that the failure to detect vehicles or hazards, due to factors including change blindness, is a contributing factor in up to 10% of serious injury crashes (Beanland, Fitzharris, Young, & Lenné, 2013).

1.1. Change blindness

The exact mechanism which underpins the identification of changes (and conversely the failure to achieve this, which results in change blindness) is currently unknown. However, the ability to detect a change can be enhanced by both bottom-up mechanisms (e.g. external factors) or top-down mechanisms (e.g. internal person factors) and interactions between the two. External stimulus-related factors can include saliency and relevance of the change target. For example, changes to salient objects are detected faster (Theeuwes, 1994), and drivers are faster at detecting changes to task-relevant objects, such as road signs, compared with task-irrelevant changes such as to nearby buildings or walls (Galpin, Underwood, & Crundall, 2009). The relevance of objects can also be influenced by instructions given to participants. Change detection is improved if participants are instructed to view the scene in a manner relevant to the changes being made. For example, instructing participants to make driving-related decisions about road images (e.g. is it safe to proceed across an intersection?) improves detection of vehicle change targets (Koustanaï, Van Elslande, & Bastien, 2012). External factors may also interact, for example, increasing the safety relevance of a change has a greater influence on accuracy and speed of change detection in visually cluttered urban driving scenes compared with rural driving scenes (Beanland et al., 2017). Internal person factors include: motivation, as observers who are motivated by money are more accurate at detecting changes (Sänger & Wascher, 2011); and, age, as older adults are more susceptible to change blindness (Rizzo et al., 2009). Internal and external factors may also interact, for example, personal relevance (person factor) to the type of stimuli (external factor) improves change detection for that specific object. Insomnia patients are more likely to notice changes to sleep-related objects than non-sleep-related objects in visual scenes (Marchetti, Biello, Broomfield, Macmahon, & Espie, 2006), and experienced football players are more likely than novices to notice changes that are meaningful to game play (Werner & Thies, 2000).

To be successful at change detection requires comparison of an image to a subsequent image, meaning the object of change must be tracked across the images. This is particularly relevant to driving as road environments are dynamic. In the real world many changes are accompanied by motion. Often it is noticing the motion itself which alerts the observer to the change occurring and directs attentional resources to track the object of interest (Rensink et al., 1997). However, change blindness is more likely to occur if there is a disruption to the visual scene; for example, if the object is obscured by something in the environment (such as the A-pillar of a car) or due to blinks or eye movements. Change blindness paradigms intentionally create visual interruptions to reproduce these situations (Velichkovsky et al., 2002). A common approach is the flicker paradigm (Rensink et al., 1997) where two images interspersed with a blank screen are repeatedly shown to an observer.

1.2. Sleep loss and change blindness

There has been almost no research examining the relationship between sleep and change blindness. However, sleep research does have an established history with the study of vigilance. Sustained vigilance is widely accepted to be one of the most sensitive mechanisms with which to study sleep-related impairment. The most commonly used tool is the psychomotor vigilance task (PVT). In this simple task, participants must respond as quickly as possible to a visual stimulus (usually a digital timer counting up in milliseconds) presented at random intervals. PVT performance is sensitive to both time-of-day circadian variation (Cajochen, Khalsa, Wyatt, Czeisler, & Dijk, 1999; Graw, Kräuchi, Knoblauch, Wirz-Justice, & Cajochen, 2004; Van Dongen & Dinges, 2000) and sleep loss (Anderson, Wales, & Horne, 2010; Dinges et al., 1997; Van Dongen, Maislin, Mullington, & Dinges, 2003).

When examining the detrimental effects of sleep loss on PVT performance, the most sensitive outcome measures are those which relate to the increase in the extremity of outliers: lapses (responses >500 ms), response time (RT) variability, and the slowest 10% of RTs (Basner & Dinges, 2011). It is important to focus the RT analysis of any sleep loss investigation on the most poorly performed trials of a test battery because sleepy participants are susceptible to intermittent failures (or lapses) of performance, which can result from microsleeps (Dinges & Kribbs, 1991). However, it has been demonstrated that

Please cite this article in press as: Filtness, A. J., & Beanland, V. Sleep loss and change detection in driving scenes. *Transportation Research Part F* (2017), https://doi.org/10.1016/j.trf.2017.10.003