I just woke up behind the wheel: Sleep Inertia as a new risk in semi-automated cars

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ABSTRACT

Semi-autonomous driving introduced new challenges and expectations from the driver. It requires sustained attention during a monotonous task. The long automated mode might cause boredom due to too low stimulation. Because of these factors, it has the potential to induce sleep episodes. Unlike in manual driving, the driver might shift from an awake state to sleep and back to awake without leading to an accident. However, sleep inertia caused by a such sleep might decrease cognitive and psychomotor functions of the driver and jeopardise the driving safety. Because of that, sleep inertia is a new driving risk that might emerge from semi-automated driving. This paper reviewed literature about sleep inertia in work, shift work and machine operations in order to provide evidence that sleep inertia should be treated and studied as a new risky driver state in semi-automated driving.

KEYWORDS

Semi-automated driving, automation, sleep inertia, driver state

Introduction

The emerging technology of semi-automated vehicles introduced new challenges and expectations from the driver. One of the cognitive functions that might gain importance is sustained attention and sustained vigilance. Periods of automated mode might require the driver to shift towards more monitoring role (Kyriakidis et al., 2019). Tasks that require sustained attention frequently led to boredom, vigilance decrease, sleepiness or even sleep (Körber, Cingel, Zimmermann, & Bengler, 2015). Falling asleep behind the wheel is a common driving risk, however, it might have different consequences if the driver fell asleep during the automated mode. In such cases they might wake up before take-over of the manual control and thus be affected by the aftermaths of sleep often addressed as sleep inertia. Sleep inertia is a state of increased sleepiness, hypovigilance, as well as decreased mental and physical functions after waking up (Ferrara & De Gennaro, 2000). In manual driving, consequences of falling asleep behind the wheel often surpass potential effects of sleep inertia, and therefore, sleep inertia has not been treated as a driving risk as so far. This paper introduces it as a new threat emerging from semi-automated driving. To achieve this, a literature review was conducted on sleep inertia and driving, work performance and shift work. Some characteristics of sleep inertia have been specified in the paper in order to provide a framework for research about sleep inertia in semi-automated driving.

Methods

The search was conducted in three databases: Pubmed, Web of Science and Scopus. The search terms were: sleep inertia AND (shift work* OR work* perform* OR driv*). Three hundred results were evaluated based on abstracts to check for inclusion and exclusion criteria. Inclusion Criteria: peer-reviewed papers in English with full text available, describing the effects of sleep inertia on performance either after a nap or normal length sleep. Exclusion criteria: research on animals, cells or clinical groups, intervention studies and studies that did not analyse the effects of sleep inertia on performance but describe sleep inertia from different perspectives. As a result, 52 papers were included in a further evaluation.

Results

Napping is often recommended as a way to improve performance and restore energy, however, many studies report some level of sleep inertia after waking up. In fact, sleep inertia was one of the most important contraindications of napping during shift-work or prolonged operations (Muzet, Nicolas, Tassi, Dewasmes, & Bonneau, 1995). Sleep inertia was detected after waking up from normal night sleep and after day-time or night-time naps, and its duration and magnitude differed depending on the circadian phase, level of sleep deprivation, and the length of the nap (Signal, Van Den Berg, Mulrine, & Gander, 2012). The list of studies assessing the duration of sleep inertia is presented in Table 2. Figure 1 presents an average reported duration of sleep inertia after different sleep types.

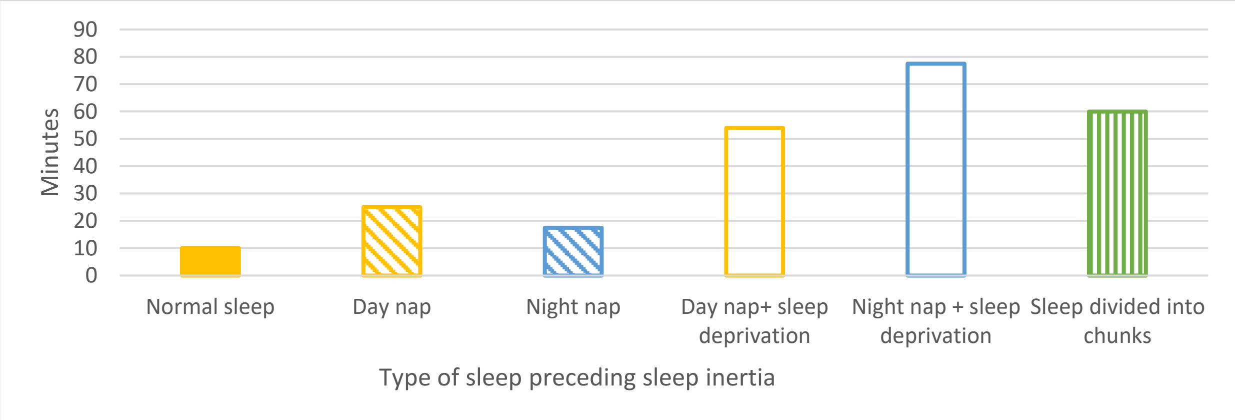

Figure 1: Average length of sleep inertia after normal sleep (sufficient amount of night-time sleep), day-time nap, night-time nap, day-time nap in sleep-deprived people, night-time nap in sleep-deprived people and sleep divided into smaller chunks over 24 hours. All resources are listed in Table 1.

Night-time naps can cause larger and longer sleep inertia (Scheer, Shea, Hilton, & Shea, 2008). Some work patterns require fragmentation of sleep into a few shorter periods over the 24 hours, for example, 6h on/ 6h off schedule. Such fragmented sleep can also result in increased sleep inertia (C J Hilditch et al., 2016). A combination of night work and sleep deprivation can result in the highest sleep inertia after a nap and was even attributed to a near crash of a military aircraft (Armentrout, Holland, O'Toole, & Ercoline, 2006). At least half of night-working pilots reported that sleep inertia after napping compromised safety of a flight (Gregory, Winn, Johnson, & Rosekind, 2010). Studies also show the magnitude of decreased cognitive functioning after a nap was higher and lasted longer in more difficult tasks and executive cognitive functions (Groeger, Lo, Burns, & Dijk, 2011). The tasks mostly affected by sleep inertia appear to be those that require high attention, and accuracy is one of the most affected functions (Ferrara & De Gennaro, 2000). It has also been reported that individuals experiencing sleep inertia were not aware of it and the magnitude of its effect on their performance (McHill et al., 2019; Signal et al., 2012).

Table 1: List of the reported length of sleep inertia (SI) after different types of sleep together with references.

Type of sleep preceding SI	Length of SI	References
Sufficient night-time sleep	10 minutes	(McHill et al., 2019)
Nap during the day	30 minutes	(Groeger et al., 2011)
	20 minutes	(Scheer et al., 2008)
Nap during the night	20 minutes	(Scheer et al., 2008)
	15 minutes	(Sallinen, Härmä, Åkerstedt, Rosa, & Lillqvist, 1998)
Sufficient sleep divided into a few periods over 24 hours	60 minutes	(C J Hilditch et al., 2016)
Nap when sleep-deprived	70 minutes	(McHill et al., 2019)
	47 minutes	(Cassie J Hilditch, Centofanti, Dorrian, & Banks, 2016)
	45 minutes	(Signal et al., 2012)
Nap when sleep-deprived during the night	70 minutes	(McHill et al., 2019)
	60 minutes	(Signal et al., 2012)
	120 minutes	(Takahashi, Arito, & Fukuda, 1999)
	60 minutes	(Basner et al., 2017)

Discussion and Conclusions

Studies have shown that sleep inertia occurred after a sufficient night-time sleep and both day-time and night-time naps (Ferrara & De Gennaro, 2000). The magnitude of sleep inertia differed depending on the circadian phase, level of sleep deprivation and other sleep characteristics (McHill et al., 2019; Scheer et al., 2008). Similarly, the length of sleep inertia varied between ten minutes (McHill et al., 2019) and two hours (Takahashi et al., 1999). Cognitive functions most affected were the ones that required high attention and accuracy (Ferrara & De Gennaro, 2000). The automated phase has the potential to induce sleep (Körber et al., 2015). Considering the length of sleep inertia, if the driver woke up from a sleep phase during the automated mode or at the take-over, manual driving might be affected. Sleep inertia has already been studied in the context of shift-work but not in the driving domain. In manual driving people rarely experience risk-related sleep inertia but it might change in semi-automated driving. The paucity of knowledge about the influence of sleep inertia on driving might decrease the safety of semi-autonomous driving and because of this sleep inertia should be treated as a new risk emerging from a semi-automated driving. It should be studied in the context of driving and included in systems of driver state monitoring in semi-autonomous cars, especially considering that people are not able to accurately assess the effect of sleep inertia on their performance (Signal et al., 2012).

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