Towards a validation of a method to induce driver fatigue

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Abstract: Fatigue affects performance in driving and can have severe consequences. It is estimated that up to 20% of all road accidents are fatigue related, highlighting the need for research in the field of driver fatigue. As real-road experiments on driver fatigue can be dangerous, it would be useful to have a validated instrument for inducing driver fatigue. This study examines whether a 30-minute drive on a driving simulator is a possible tool to induce driver fatigue. Participants drove 30 minutes on our driving simulator. Before, during, and after the driving task, participants' sleepiness was recorded. The results indicate that a 30-minute drive on our driving simulator is a fatigue factor, manifested through increased subjective sleepiness. In a next step, the effect of the 30-minute drive on driver fatigue should be investigated objectively by measuring, for example, the blink durations or sleep intrusions in the EEG.

Keywords: Driver fatigue, driving simulator, simulator sickness, subjective sleepiness

1. Introduction

Fatigue impacts performance in many daily activities and is one of the most common causes of accidents and errors. Fatigue is often defined as physical or mental exhaustion counted by changing the over or under challenging task, or by rest (Philip et al. 2005; Phillips 2015). May and Baldwin (2009) subcategorized driver fatigue into sleep-related (SR) and task-related (TR) fatigue. SR fatigue is affected by sleep deprivation, extended duration of wakefulness, and circadian rhythm effect (time of day). Certain characteristics of driving, such as the demands of the task and duration, can lead to TR fatigue. Furthermore, driver fatigue is produced by active or passive TR fatigue. Active TR fatigue is related to mental overload driving conditions meaning the current condition is high demanding like driving on crowded highways. Whereas passive TR fatigue is caused by low demanding tasks such as driving on monotonous highways with low traffic (May and Baldwin 2009; Thiffault and Bergeron 2003).

As several studies assume that 10-20 % of all road accidents are fatigue related, it is important to perform further studies in the field of driver fatigue to prevent accidents caused by fatigue (BFU 2019; Patel et al. 2011; Schmidt et al. 2009; Tjolleng et al. 2017). Driver fatigue has been particularly studied on driving simulators as conducting real-road driving studies is dangerous. It would be useful for studies on driver fatigue if there was a validated tool inducing driver fatigue. In our work, we investigate whether a 30-minute drive on a driving simulator is a possible tool to induce driver fatigue.

2. Method

A total of 42 participants (24 m, 18 f), who were between 19 and 81 years (standard deviation [SD] = 17.38 y, mean = 42.45 y), drove 30 minutes on our driving simulator. The driving simulator was composed of a motion platform equipped with a driving seat and a wooden frame for mounting a steering wheel, pedals, a 8-gear shifter and three screens. Three 27-inch monitors have been arranged to offer a field of view of up to 120 degrees. Force feedback was applied to the steering wheel and a 6 DOF motion simulator supported a linear displacement of the driving platform along the x, y, and z axes, as well as rotation in all three directions. An overview of all components used in the simulation, and their interaction with each other is shown in the work of Ropelato et al. (2017).

The driving scene was designed in Unity (version 2020.2.1f1). Participants drove on an oval shaped track. For realism, the environment contained typical roadside objects such as traffic signs and reflector poles. The scene took place during a sunset, which is why the environment was darkened. There was no traffic apart from the car that the participant was driving and a car ahead, which the participants were instructed to follow at a constant distance. Before, during and after the driving task, participants' sleepiness was recorded using the Karolinska Sleepiness Scale (KSS) (Akerstedt et al. 2005), and their mental workload was recorded using the Instantaneous Self Assessment (ISA) questionnaire (Hering and Coatleven 1996). The KSS and ISA questionnaires were administered all five minutes during the driving task. Before the driving task, participants conducted the Motion Sickness Susceptibility Questionnaire (MSSQ) (Golding, 2006) for predicting individual motion sickness. After the 30 minutes, they were asked to answer the Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993) and the Presence Questionnaire (PQ) to characterize the experience in the environment (Witmer and Singer 1998).

3. Results

After 30 minutes the KSS value increased on average by 1.93 [Friedman test: $\chi^2(5) = 84.82$, $p < 0.01$, n=42)]. The post hoc analyses, for which Bonferroni-corrected pairwise comparisons were performed, revealed that the subject sleepiness significantly increased after 15 minutes ($z = -1.33$, $p_{adjusted} < 0.02$, Effect size (Cohen 1988): $r = 0.21$). The subjective sleepiness increased significantly again between the 15th minute and the 30th minute ($z = -1.48$, $p_{adjusted} < 0.01$, Effect size (Cohen 1988): $r = 0.23$).The ISA value did not change with time. The scores of the experienced presence in the virtual environment of this study ranged between 104 and 194 (median = 138, SD = 20.63, possible maximum = 224). The median of the SSQ was 18.70 (SD = 25.06) and the median of the MSSQ was 4.00 (SD = 8.60). Furthermore, there was a strong positive correlation between the SSQ and the MSSQ ($r = 0.58$, $p < 0.01$) and a medium negative correlation between the SSQ and PQ ($r = -0.34$, $p = 0.26$).

4. Discussion

The results indicate that a 30-minute drive on a driving simulator is a fatigue factor, manifested through increased KSS values over time. This is a first indication that the 30-minute drive on the driving simulator can be used as a tool to induce driver fatigue.

Participants overall had medium to high presence scores in the virtual environment. A high presence level can help participants behave more naturally in the virtual environment (Xu et al. 2021). The negative correlation between the SSQ and PQ agrees with previous studies (e.g., Weech et al. 2019; Witmer & Singer 1998). Witmer and Singer (1998) believe that symptoms associated with simulator sickness, such as nausea or disorientation, divert attention away from the virtual environment and focus attention inwards, resulting in a decreased involvement in the virtual environment, and thus reducing the sense of presence. The positive correlation between the scores of the SSQ and MSSQ indicates that a person with a high MSSQ score is more likely to suffer from simulator sickness. For further studies, it may be considered to exclude participants with high MSSQ scores.

Furthermore, a SSQ of 18.70 is associated with concerning symptoms. However, it is important to note that the SSQ includes an item “fatigue”. Since the aim of the 30-minute drive was to induce fatigue, a high SSQ score is not necessarily bad, which makes the interpretation of the SSQ score difficult.

5. Conclusion

The study demonstrated that driving 30 minutes in a monotonous scene on our driving simulator is a possible tool to induce driver fatigue. The drive increased the subjective sleepiness, and the sense of presence in the virtual environment was high. In a next step, the effect of the 30-minute drive on driver fatigue should be investigated objectively by measuring, for example, the blink durations or sleep intrusions in the EEG.

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