The Influence of Advanced Driver Assistance Systems on Fatigue Development among Long-Haul Truck Drivers

SUMMATIVE STATEMENT:

An on-road driving experiment with 120+ hours of data found that being different from passenger car drivers, the fatigue levels of heavy truck drivers when driving with the assistance of advanced driver assistance systems (ADAS) are lower compared to that of manual driving.

KEYWORDS: Fatigue, ADAS, Truck drivers, Prolonged driving tasks, Manual driving

PROBLEM STATEMENT:

To reduce the workload of long-haul truck drivers and thereby reduce their fatigue levels, some companies have begun to deploy ADAS on heavy trucks to assist drivers with some driving tasks (such as adaptive cruise control, lane centering, etc.). Previous research among drivers of passenger cars found that drivers using ADAS are more likely to experience fatigue compared to those who drive manually (e.g., Vogelpohl et al. 2019). Therefore, before the widespread deployment of ADAS on heavy trucks, it is necessary to investigate the impact of ADAS on the fatigue levels of truck drivers during long-haul driving.

OBJECTIVE/QUESTION:

To compare the fatigue levels of long-haul truck drivers when they drive with and without ADAS.

METHODOLOGY:

A Jie Fang J7 truck (total length: 18 m, total weight: 31.75 t) with SAE L2 ADAS was used in the experiment, which runs on a real operation route of an express company in China, from Suzhou, Jiangsu, to Xiaogan, Hubei, totaling 802 km, of which 785 km was highway. The average driving time was 10.8 hours with a standard deviation of 0.36 hours. The experiments were conducted on weekdays to avoid the potential influence of traffic flow variations on weekends and holidays. To avoid potential sleep-related fatigue, the departure time was always at around 7.30 am.

Three professional truck drivers (all males, with a mean age of 43 years of old) participated in the experiment, each driver did four whole-day drives (i.e., drove manually for two days and drove with ADAS for the other two days), leading to 12 drives and over 120 hours data. During the experiment, drivers' eye movements were tracked using Smart Eye Pro. Drivers also provided ratings on the Karolinska Sleepiness Scale (KSS) every hour. Further, a reaction task was conducted every two hours, in which drivers were asked to press a steering-wheel-mounted button in response to the audial stimulus as quickly as possible. In total, we extracted six fatigue-related metrics following previous studies (e.g., Feldhütter et al. 2019; Körber et al. 2015), i.e., blink duration, blink frequency, pupil diameter, percentage of eye closure (PERCLOS), KSS score, and reaction time. Based on the assumption that drivers were well-alerted in the first hour of drive, all fatigue metrics in the first hour of the day were used as the baseline to calibrate the metrics throughout the day.

Six generalized linear models were fitted, with the six fatigue metrics as dependent variables while driving time, driving mode, and their two-way interaction as independent variables. Repeated measures from different drivers were modeled as random effects. All significant results and their significant post-hoc contrasts by the Tukey method ($p > .05$) were reported.

RESULTS:

The driving mode significantly influenced drivers' blink duration, blink frequency, pupil diameter, and PERCLOS. Compared to driving manually, drivers had higher pupil diameter (Δ = 17.61%, 95% confidence intervals (CI): [8.18%，27.04%], t(103) = 3.70, *p* = .0003), lower blink frequency (Δ = -24.07%, 95%CI: [-32.27%，-15.87%], t(103) = -5.82, *p* < .0001), lower blink duration (Δ = -9.28%, 95%CI: [-11.77%，-6.81%], t(103) = -7.41, *p* < .0001), and lower PERCLOS when driving with ADAS (Δ = -130.76%, 95%CI: [-165.20%，-96.32%], t(103) = -7.53, *p* < .0001).

Moreover, the interaction between driving mode and driving time significantly influenced drivers' reaction time (F(1, 54) = 4.38, *p* = .04). In manual driving conditions, for every 2 hours increase in the driving time, drivers' reaction time increased 0.03 seconds (95%CI: [0.02, 0.05], t(54) = 4.30, *p* < .0001). We also found that, with the increase in driving time, the marginal effect of driving mode on drivers' reaction time increased, which means that the benefit of ADAS would be more obvious with the increase in driving time.

DISCUSSION:

We found that driving with ADAS could reduce the fatigue levels of truck drivers in long-haul driving tasks, which is different from the conclusions in passenger cars. We suggest two explanations. First, as professional drivers, as professional drivers, truck drivers hold higher levels of responsibility during driving and thus are less likely to forego driving tasks such as hazard perception even when driving with ADAS. Second, most existing studies in passenger cars were conducted in driving simulators, which may easily induce passive fatigue, as they were not exposed to real traffic risks in the virtual environment. With longer driving time, drivers' reaction times increased when driving manually while we did not observe this trend with ADAS, indicating that ADAS can help drivers keep better capability to react to emergencies in long-haul drives.

CONCLUSIONS:

This is one of the first on-road studies that investigated the influence of ADAS on fatigue development in long-haul driving. We found that, compared to manually driving, truck drivers had lower fatigue levels when driving with ADAS, as evidenced by both subjective (i.e., KSS scores) and objective metrics (i.e., reaction time, blink frequency, blink duration, pupil diameter, PERCLOS).

REFERENCES:

Feldhütter, Anna, Tobias Hecht, Luis Kalb, and Klaus Bengler. 2019. "Effect of Prolonged Periods of Conditionally Automated Driving on the Development of Fatigue: With and without Non-Driving-Related Activities." *Cognition, Technology & Work* 21(1):33–40. doi: 10.1007/s10111-018-0524-9.

Körber, Moritz, Andrea Cingel, Markus Zimmermann, and Klaus Bengler. 2015. "Vigilance Decrement and Passive Fatigue Caused by Monotony in Automated Driving." *Procedia Manufacturing* 3:2403–9. doi: 10.1016/j.promfg.2015.07.499.

Vogelpohl, Tobias, Matthias Kühn, Thomas Hummel, and Mark Vollrath. 2019. "Asleep at the Automated Wheel—Sleepiness and Fatigue during Highly Automated Driving." *Accident Analysis & Prevention* 126:70–84. doi: 10.1016/j.aap.2018.03.013.