Highly Automated Platooning: Effects on Mental Workload, Stress, and Fatigue

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Abstract. Automatically driving platoons of vehicles are a likely candidate for solving many existing issues of road safety and congestion. However, the psychological effects of such technology are yet to be understood. Therefore, by means of a driving simulator experiment, we aimed to assess the psychological effects of driving in a highly automated platoon. The results showed that the type of task had no substantial effect on heart rate and self-reported stress, fatigue, and workload. However, time-on-task substantially reduced participants' heart rate.

Keywords. Platooning, Mental Workload, Stress, Fatigue

1. Introduction

In recent years, the development of vehicle automation has been accelerating. Congestion, pollution, energy, and safety issues are of primary impetus to the development of amongst others Cooperative Adaptive Cruise Control (e.g., Van Arem et al., 2006) and platooning systems (e.g., Gouy et al., 2014). The transition from manual to automated driving entails psychological changes for the person driving the vehicle. Specifically, the driver changes from a manual controller to a passive monitor, with the risk of understimulation and mental underload (Young & Stanton, 2002). This may be especially true in highly automated platooning (HAP) in which long periods of monotonous monitoring are expected (Hancock & Parasuraman, 1992; Körber et al., 2015). A recently developed psychological model described the psychology of a driver in an automated vehicle (Heikoop et al., 2015). This research aimed to assess the psychological effects of driving in a monotonous HAP situation.

2. Methods

Twenty-two participants (13 males, 9 females) aged between 19 and 45 (M = 29.6; SD = 6.8) with at least 1 year of driving experience (M = 10.0 years; SD = 6.7 years) took part in this experiment at the Southampton University Driving Simulator (SUDS), which is comprised of a Jaguar XJ Saloon connected to STISIM Drive 3 software.

For eye- and electrocardiogram (ECG) measurements, Seeing Machines FaceLab 5 and AD Instruments PowerLab 26T with LabChart 8 software were used, respectively. In addition, the NASA-Task Load Index (TLX) and Dundee Stress State Questionnaire (DSSQ) were administered.

Participants were transported automatically within a 5-vehicle HAP along a 4-way highway with low-density traffic. The speed of the HAP was set at 120 km/h, after acceleration from standstill. The longitudinal and lateral movements of the vehicles within the HAP were synchronous. Seven automated overtaking manoeuvres by a single lane change back and forth were implemented.

The experiment consisted of three 40 min conditions in counterbalanced order: (1) “Task Restricted” (TR), requiring participants to count red cars by pressing a handheld button, (2) “No Task, Restricted” (NTR), in which no extra task was to be performed, and (3) “Voluntary” (Vol), where they were free to do whatever they wanted. Although no critical events occurred, participants were told to pay attention to the road during all conditions, as intervention may be necessary. The TR condition assessed the effects of task demands, whereas Vol created a realistic situation that is expected in real-world implementation of HAPs. The NTR condition served as a baseline.

3. Results

Heart rate (HR) and heart rate variability (HRV) were not significantly different between the three conditions. However, a substantial drop in HR ($p = .0002$, $t = 4.51$) and rise in HRV ($p = .0078$, $t = -2.94$) were found between runs 1 and 3.

The self-report measures of fatigue, stress, and workload were generally not statistically significant between the three task conditions. However, in the DSSQ, self-focused attention was significantly lower for TR than for NTR ($p = .0018$, $t = 3.58$). Furthermore, the NASA-TLX mental demand was significantly higher for TR compared to Vol ($p = .0048$, $t = -3.15$).

4. Conclusion

The hypothesis that the type-of-task substantially affects mental workload, stress and fatigue levels appears to be prone for rejection. Only a small number of statistically significant psychological effects between conditions were observed. However, the strongest effect was found for time-on-task on HR. These results suggest that time-on-task should be given higher priority than type-of-task in the design of HAP technology.

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