Maximizing Driver Satisfaction and Productivity in Side Activities by using Context-Aware Take-Over Timing

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Summary

An often highlighted advantage of automated driving is the promise to free drivers from the driving task, allowing to perform additional activities. In case a highly automated vehicle is unable to continue performing the driving task on its own, a so called "Take-Over-Request" (TOR) notifies the driver to regain manual vehicle control. At the time of receiving such a notification, drivers may perform secondary tasks. As it is proven, that task switches at random times lead to stress and cognitive overload, they may also result in a reduced driving performance. With this work we present a system trying to minimize such negative effects by issuing context-sensitive TORs at emerging task boundaries, as successfully demonstrated for office-work settings. Context-aware TORs could help to improve the human-machine interface in highly automated vehicles und further reduce the number of safety critical driving situations.

1 Introduction

Automated driving promises to come with various advantages, such as increased road safety, improved traffic flow, reduced fuel consumption, mobility for the impaired, and more leisure time. Although people basically accept automated driving [11], in a recent survey [10], only 22% of the participants could "imagine to own a vehicle without lateral/longitudinal controls" (as suggested by Google's automated vehicle), while more than 80% "want to gain control of the car in any situation" and will not allow an automated driving function to overrule their input (even in safety critical situations). This suggests that people like the opportunity to drive and will not buy fully automated vehicles just for the sake of technology. On the other hand, recent incidents with existing automated driving systems (like the Tesla Autopilot) show, that many drivers do not follow manufacturers' instructions to permanently monitor their vehicles. People investing in automated vehicle technology thus want to engage in side activities other than driving or driving related monitoring tasks, like working, sleeping or consuming media. We argue, that what is the primary task from a safety perspective (driving) will become the secondary task from a consumer's perspective, and that drivers will rate the interaction quality of their vehicles based on being supported in both tasks. Automated driving thus becomes a special case of shared control - instead of substituting the driving task by a joint human-machine system, a new dimension of yet unknown secondary tasks must be supported to fulfill the operators' needs. As many automated driving systems will be introduced for specialized and limited environments (highway driving, congestion assistance), vehicles will regularly demand system input or even switching back to the driving task (because of unexpected events, sensor outages, etc.). Such a task switch will be delivered to the driver via notifications in form of a "Take-Over-Request" (TOR). In case of a TOR, a driver must suspend other ongoing activities ("primary tasks", from a consumer's perspective). As notifications delivered at random times lead to stress, cognitive overload, a higher error rate and resumption lags [3], presenting TOR while being deeply engaged in secondary tasks may result in a reduced driving performance, what is not an ideal condition in potentially safety critical driving situations. As dual-task studies in office-work settings have shown, that notifications provoking task-switches work best when presented between task boundaries or at times of low mental workload [2, 3], we present a system trying to minimize negative effects by issuing context-sensitive TORs at emerging task boundaries. Such a system mediating between tasks may not only increase driving performance, but could also help to re-engage the driver in secondary tasks more comfortable. Although the idea of using driver-state assessment to determine driver interruptibility is not new [4,8], a concept trying to reduce the negative effects of TORs, based on context and driver state, does, to our best knowledge not exist.

2 Related Work

Take-Over-Requests in automated driving have been examined in various publications over the last years. Bahram, Aeberhard and Wollher [7] presented a theoretical framework allowing to analyze TOR processes. Walch et al. [5] evaluated a handover assistant in a user study and suggested to use multimodal notifications (visual and auditory). Radlmayr and colleagues [6] have shown, that Take-Over quality is strongly influenced by the traffic situation to be overcome by drivers. Zeeb et al. [9] investigated TOR and state that "cognitive rather than motor processes determine take-over performance". Iqbal and Bailey [2] conducted a user study and demonstrated that task switches presented in moments of low mental workload caused least annoyance and resumption lags, in another work Bailey and Konstan [3] showed, that the timing of interruptions have a "disruptive impact on completion time and error rate of primary tasks". Merging these findings for the context of Take-Over scenarios might allow to build a system that increases interaction quality in automated vehicles while reducing the number and severity of safety critical driving situations.

3 System Overview

Future vehicles will communicate and form a socio-technical system [1]. Assuming a future global safety system or high penetration of C2X communication would allow a vehicle to know upcoming hazards way in advance, the delivery of TORs could be timed in an optimal way. An automated driving system could trigger such requests at the potentially best moment within an allowed time window. A schematic illustration of the concept can be inspected in Fig. 1. A preceding vehicle (1) senses an obstacle/situation (2) that requires manual control. Information about the presence of such an obstacle can be sent to the automated vehicle (4) by using C2X communication (3). The automated driving system now gets additional time to observe the driver's behavior and engagement in secondary tasks and may issue the TOR at any moment within an allowed time window (5), but latest before the minimum TOR time (6) is reached.

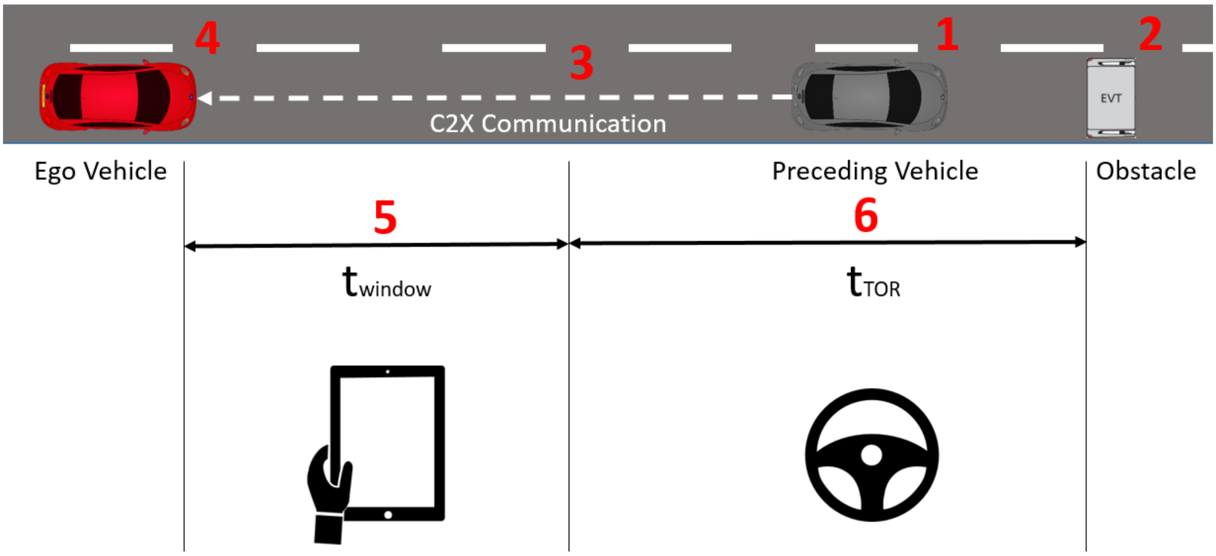

Fig. 1: Illustrative explanation of the proposed concept.

4 Research Questions and Hypothesis

In extensive driving simulator studies (using a high-fidelity movement platform simulator) we will analyze and evaluate the effects of context-sensitive TORs on quantitative and qualitative parameters.

Our research hypothesis is, that timed TORs lead to improved driving performance, higher situation awareness, less cognitive workload and a subjectively more pleasurable driving experience compared to randomly issued notifications.

5 Study Setup

In our user studies, we will compare **quantitative data related to driving performance** (reaction times, lane-performance indicators, steering wheel fluctuations), **performance in secondary tasks** (error rate, resumption lags, throughput, etc.), **physiological stress parameters** (ECG, heart rate variability, respiration, eye movements) **and quantitative self-evaluation** (stress, comfort, acceptance, joy) of participants **in a between-subjects design**. The control group will receive TOR notifications (presented in form of a multimodal visual/auditory cue as suggested in [5]) at random times while the other will gain advantage of our proposed context aware system. The system observes a participant's interaction with devices often used in side activities (smartphone, tablet, notebook) and will be implemented for different types of tasks, for instance a writing task (boundaries will be given by completion of sentences or paragraphs), a reading/media consumption task (analyzation of the reading flow with eye tracking devices), or watching a video (a loss of attention might be provoked by interrupting the video for presentation of an advertisement). In each experiment a different secondary task will be selected and participants will be instructed to perform a longer trip that contains multiple traffic environments (highway driving, urban crossings, rural roads, construction sites, all with varying traffic density). During the trip, subjects will receive Take-Over-Requests multiple times. Evaluating the collected data with statistical methods will then allow to assess potential differences between the groups.

6 Conclusion and Impact

In a small pre-study using between-subjects design we evaluated the difference of timed versus untimed TORs. Participants had to write a message consisting of two sentences. While texting a TOR was issued, subjects had to overtake another vehicle and then continue texting. The control group received TOR at random times while the other group was notified exactly when the first of the two sentences was completed. Considering the total time needed (texting and overtaking) we indeed found a significant difference, but due to the small number of participants (6 in each group), no statistically valid conclusion can be drawn. Nevertheless, the results suggest to perform additional experiments - timed TORs could be used to improve productivity in side-activities, increase road safety and further maximize driver-vehicle interaction quality, what is an important factor for the success of automated driving systems as they must be accepted by potential customers.

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