Transportation Research Part F 58 (2018) 253–263

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Secondary task engagement and disengagement in the context of highly automated driving

Bernhard Wandtner [a,*], Nadja Schömig [b], Gerald Schmidt [a]

[a] Opel Automobile GmbH, D-65423 Ruesselsheim, Germany
[b] WIVW GmbH (Wuerzburg Institute for Traffic Sciences), D-97209 Veitshoechheim, Germany

ARTICLE INFO

Article history:
Received 9 December 2016
Received in revised form 20 February 2018
Accepted 4 June 2018

Keywords:
Highly automated driving
Self-regulation
Secondary task
Non-driving related task

ABSTRACT

During highly automated driving (level 3 automation according to SAE International, 2014) people are likely to increase the frequency of secondary task interactions. However, the driver must still be able to take over control within a reasonable amount of time. Previous studies mainly investigated take-over behavior by forcing participants to engage in secondary tasks prior to take over, and barely addressed how drivers voluntarily schedule secondary task processing according to the availability and predictability of automated driving modes. In the current simulator study 20 participants completed a test drive with alternating sections of manual and highly automated driving. One group had a preview on the availability of the automated driving system in upcoming sections of the track (predictive HMI), while the other drivers served as a control group. A texting task was offered during both driving modes and also prior to take-over situations. Participants were free to accept or reject a given task, taking the situational demands into account. Drivers accepted more tasks during highly automated driving. Furthermore, tasks were rejected more often prior to take-over situations in the predictive HMI group. This was accompanied by safer take-over performance. However, once engaged in a task, drivers tended to continue texting even in take-over situations. The results indicate the need to discriminate different aspects of task handling regarding self-regulation: task engagement and disengagement.

1. Introduction

In the recent years an increasing number of Advanced Driver Assistance Systems (ADAS) has entered the market. These systems are capable to take over longitudinal (e.g. Adaptive Cruise Control) or lateral (Lane Keeping Assistant) vehicle control. By combining these systems, nowadays we have reached the level of partially automated driving (Level 2 according to Gasser et al., 2012; SAE International, 2014). At this level of automation, longitudinal and lateral control is delegated to the vehicle while the driver is still responsible for monitoring the traffic environment and the automation system. This changes with the next level: highly automated driving (Level 3 according to Gasser et al., 2012; SAE International, 2014), also defined as conditionally automated driving (SAE International, 2014). Here, the driver is allowed to temporarily withdraw himself or herself from monitoring the driving task, "with the expectation that the human driver will respond appropriately to a request to intervene" (SAE International, 2014) when reaching a system limit (e.g. construction sites, highway exits).

* Corresponding author.
E-mail address: bernhard.wandtner@opel.com (B. Wandtner).

https://doi.org/10.1016/j.trf.2018.06.001
1369-8478/

The increasing proliferation of automated driving offers major advantages: Up to 90% of all road accidents are caused by human failure (Graab, Donner, Chiellino, & Hoppe, 2008; Statistisches Bundesamt, 2016). Thus, automation has a huge potential to increase traffic safety. Additionally, with a sufficient market penetration, benefits towards more efficient driving styles and traffic flow can be expected. For the driver, enhanced comfort can be experienced by relieving him or her from the driving task.

Unfortunately, automated driving can be accompanied by some human performance problems well known from aviation and engineering psychology (e.g. Out-of-the-loop performance problems: vigilance decrements, over-reliance, loss of situation awareness, manual skill decay; Kaber & Endsley, 1997). These aspects are crucial for partially automated driving, where the driver has to be prepared to intervene at any point in time, and they are still relevant for highly automated driving. Thus, human factors in the field of automated driving have to be critically examined. Focusing on highly automated driving, several studies addressed the influence of vigilance on situation awareness and take over performance (e.g. Neubauer, Matthews, & Saxby, 2012; Schömig, Hargutt, Neukum, Petermann-Stock, & Othersen, 2015) and also trust in automation was subject to research (Hergeth, Lorenz, Krems, & Toenert, 2015; Gold, Körber, Hohenberger, Lechner, & Bengler, 2015).

However, possibly the most significant research field in the recent years was take-over performance of distracted drivers. This is a relevant question because distraction is a well-known safety issue in manual driving (e.g. Dingus et al., 2016) and during highly automated driving people are likely to increase the frequency of interactions with secondary (non-driving related) tasks (Carsten, Lai, Barnard, Jamson, & Merat, 2012; Llaneras, Salinger, & Green, 2013).

For the investigation of take-over behavior, often rigid experimental block designs are used. Drivers are forced to engage in specific secondary tasks prior to a critical take over situation. Different timing aspects of the driver reaction are then assessed e.g. time to first gaze at the scenery, time until the hands touch the steering wheel and time until the driving maneuver is initiated (e.g. Damböck, Farid, Toenert, & Bengler, 2012; Gold, Damböck, Lorenz, & Bengler, 2013, Gold & Bengler, 2014). Additionally, quality aspects of the take-over reaction are analyzed, e.g. crash avoidance, trajectories, and maximum accelerations. The secondary task engagement is usually not separately analyzed. As participants are forced to engage into a specific secondary task, results should be interpreted as worst-case performance out of maximum distraction.

The purpose of the present study was to extend the understanding of driver's behavior when dealing with secondary tasks in the context of highly automated driving. From research on manual driving it is known that "self-regulation in the context of driver distraction can be understood as the way drivers adjust their driving behavior in response to changing or competing task demands to maintain an adequate level of safe driving" (Young, Regan, & Lee, 2008, p. 336). In addition, there is considerable evidence that people not only adjust their driving behavior according to driving demands but also their secondary task engagement. In a simulator study by Schömig, Metz, and Krüger (2011) drivers were free to decide whether they want to engage in a given secondary task or not depending on the current driving situation. When the participants had a choice, they engaged in a secondary task mainly in low demanding situations, and during task engagement they monitored the driving situation with short control glances. Tivesten and Dozza (2015) showed in a naturalistic driving study that experienced drivers used information about current and upcoming driving demands to decide when to interact with a visual–manual phone task. In a simulator study by Wandtner, Schumacher, and Schmidt (2016) drivers were free to engage in a self-paced texting task at any time over the whole test track. Results showed that drivers interacted less with the secondary task during demanding or critical driving situations. Self-regulated task engagement was associated with less impairment in driving performance compared to a control group with mandatory distraction.

However, it is not without controversy to which extent drivers show situation-adaptive interactions with secondary tasks. In a closed track study by Horrey and Lesch (2009) drivers' situation awareness had little influence on performing a secondary task. The task was performed regardless of the current driving demands. Liang, Horrey and Hoffman (2015) showed that drivers did not tend to postpone secondary tasks until they reached a lower demanding section. On the other hand, participants avoided initiating the secondary task before a transition to higher driving demands.

Self-regulation of secondary task interaction in manual driving has been described within a three-level model (Schömig & Metz, 2013). At a planning level it is determined how a driver will generally deal with secondary tasks during a drive. At the decision level, it is assessed whether the current driving situation allows for secondary task engagement. These anticipative processes require an adequate mental model of the current and future driving situation. Finally, when the driver has decided to engage in a secondary task, the driving situation is constantly monitored and the task is interrupted if there are increases in situational demands (control level). When transferring the model to highly automated driving, appropriate self-regulatory behavior can be defined for the separate levels (described in Table 1).

Table 1
Three-level model of self-regulation in highly automated driving (modified from Schömig & Metz, 2013).

Level	Description	Appropriate self-regulation
Planning	Determination, how a driver will generally deal with secondary tasks during a drive	Limiting task engagement to sections of highly automated driving (considering predicted system availability)
Decision	Decision, whether the current situation allows for an engagement in a secondary task	Assessment of traffic situation/system status. Task engagement only if applicable (considering estimated task duration and predicted system availability)
Control	Regulating current secondary task processing, interruption if necessary	Maintenance of take-over readiness. Rapid task disengagement and take over when prompted by the system