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The effect of visual and cognitive distraction on driver's anticipation in a simulated car following scenario

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ABSTRACT

Distraction is a common cause of accidents (e.g. NHTSA, 2009), and different distraction conditions influence the driving behaviour in a specific way. Despite a lot of research in this area, most studies concentrate on perception errors as a result of visual distraction. The effects of different distraction conditions on higher cognitive processes are still unclear. The fact that accidents happen even if the drivers perceive all relevant information implies that cognitive factors contribute to accidents, too. For this reason, this study was conducted to investigate how different distraction conditions influence the anticipation of events in a car–following scenario. Anticipation is required to know what will happen next, and to react adequately to the situation. In a driving simulator, scenarios with different manoeuvres of a preceding car were created to generate various anticipations and therefore a different adaptation of the driving behaviour. Additionally, a cognitive and a visual secondary task were introduced. The question was in which way either a cognitive or visual distraction influences the generation of anticipations and the construction of an appropriate situation model.

The results indicate that in the phase when the preceding car showed braking manoeuvres, drivers prolonged their safety distance only when being visually distracted which is probably done to compensate for this visual distraction. This compensation ensued to some extent in the second phase where the preceding cars drove with a constant speed. Additionally, drivers who were visually distracted went somewhat slower when the car in front had braked in phase one. Thus, the drivers seemed to anticipate that the car might brake again and adapted their speed accordingly. This was not found in drivers with cognitive distraction. Thus, cognitive distraction seems to disturb this anticipation.

Finally, at an intersection, drivers with visual distraction had a smaller TTC and a higher velocity when the car in front made an unexpected turn. Thus, the impairment of perception due to the visual distraction leads to a slower reaction as compared to a cognitive distraction. Overall, cognitive distraction influences the anticipation of possible future actions of other car drivers negatively while visual distraction deteriorates perception and thus the reaction to critical, sudden events. Thus, different intervention strategies are required to prevent these kinds of accidents.

1. Introduction

A multitude of studies show that distraction while driving is often found (e.g. Stutts & Hunter, 2003; Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; NHTSA, 2009). It is estimated that drivers engage in potentially distracting secondary tasks approximately 30% of the time while their vehicles are in motion (Ranney, 2008).

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The data from the Fatality Analysis Reporting System (FARS) show that in 16% of all fatal crashes in 2008, driver distraction was involved (NHTSA, 2009). According to data from the General Estimates System (GES), 22% of crashes with injuries were reported to have involved distracted drivers (NHTSA, 2009). In the 100-Car Naturalistic Driving Study, driver involvement in secondary tasks contributed to over 22% of all crashes and near crashes in the period from 2003 to 2004 (NHTSA, 2009).

When looking at accidents, distraction is a primary cause for a special type of accident, the rear-end crash. This is one of the most frequent crash types. Vollrath, Briest, and Drewes (2006) showed, that 26.4% of all severe accidents in Germany in 2002 were rear-end crashes. The German Federal Statistical Office documented that 21.7% of all accidents in the year 2008 were rear-end crashes (German Federal Statistical Office, 2009). According to the NHTSA General Estimates System (GES) rear-end crashes are responsible for approximately 29% of all accidents in 2003 (Najm, Sen, Smith, & Campell, 2003).

In order to examine the causes of driver errors leading to a rear-end crash, Muhrer and Vollrath (2009) conducted an in-depth accident analysis using data from Braunschweig 2002 involving expert ratings of accident protocols. They found that decision errors were involved in 86% of the rear-end crashes. Drivers did not select a safe distance towards the preceding car and did not adapt the distance to traffic, road or weather conditions. When a sudden braking manoeuvre of the preceding vehicle occurred in this situation, the driver was not able to react in time. There may be several reasons why drivers did not chose a safe distance which could not be distinguished in the analyses. However, it seems that drivers do not expect that something will happen in this situation and thus do not concentrate as much as necessary on the preceding car. Distraction may be relevant here with regard to two aspects: Drivers may be distracted and that is the cause why they do not notice the braking of the car in front. Additionally, as the situation seems uncritical, drivers may be inattentive and may conduct secondary tasks which then prevent them from adapting their distance and reacting if required. This idea is supported by results from the Indiana Tri-Level study. Treat et al. (1979) analysed 57 rear-end crashes. They found that inattention lead to a delayed recognition of stationary vehicles resulting in rear-end crashes. When rear-end crashes with moving vehicles occurred, a decision error preceded, and drivers did not adapt their behaviour to the car in front. Similarly, Knipling et al. (1992) analysed 74 rear-end crashes and found two common causes for them: inattention, which is more often related to a crash where the vehicle in front is stationary, and following too closely, which is more related to a moving preceding vehicle.

Baldock, Long, Lindsay, and Mclean (2005) analysed crashes from the Traffic Accident Reporting System maintained by the South Australian Department for Transport, Energy and Infrastructure. They examined 203,140 accidents that occurred between 1998 and 2002, and 33% of these were classified as rear-end crashes. In their analyses, inattention was the most common cause (73.8%). In 23.5% of the cases following too closely was responsible for the crash. Other studies suggest that distracted drivers are particularly at risk to be involved in rear-end crashes. Green and Shah (2004) postulated that distraction plays a greater role in rear-end crashes than in other crash types. Muhrer (2009) found out that next to the decision error, the perception error because of distraction was the second common reason for the crash. Lee, Llaneras, Klauer, and Sudweeks (2007) analysed 27 rear-end crashes from the database of the 100-Car Naturalistic Driving Study, and showed that most rear-end crashes occurred in free traffic flow or flow with only few restrictions. They showed that 87% of the drivers were distracted. In 31% of the cases, this distraction had something to do with driving (e.g., checking the mirror, looking out of the window) and led to neglecting the road in front. While these results are based on a very small sample, they fit the overall pattern also found in other studies.

Hughes and Cole (1986) and Stutts et al. (2005) showed that while driving, drivers attend to a range of non-driving stimuli. When distracted by these stimuli, drivers tend to decrease their headway distance (Rosenbloom, 2006), their detection of vehicles decelerating ahead of them is impaired (Lamble, Kauranen, Laakso, & Summala, 1999), and their brake reaction time is significantly increased (Alm & Nilsson, 1995; Hancock, Lesch, & Simmons, 2003).

Distraction may occur at different levels. The most important distinction is that between visual distraction – "eyes off road" – and cognitive distraction – "mind off road". Both types of distraction interfere in a different way with the driving task. Visual secondary tasks lead to decrements in steering and lane keeping (e.g. Carsten & Brookhuis, 2005). Increased lane keeping variation as a consequence of visual distraction is a typical finding (Engström, Johansson, & Östlund, 2005; Greenberg et al., 2003). Reduced speed as compensation behaviour (Antin, Dingus, Hulse, & Wierwille, 1990) and impaired event detection performance as a consequence of misperception can also be found (Olsson, 2000).

Carsten and Brookhuis (2005) revealed that cognitive secondary tasks impaired car following and reactions to leading cars. Surprisingly, lane keeping improved with cognitive distraction. The analyses of the gaze behaviour showed that drivers focused their attention on the center of the road when cognitive load increased. That may be beneficial for lane keeping. Many studies showed improvement in terms of reduced lane keeping variation in a cognitive distraction condition (Engström et al., 2005; Mattes, Föhl, & Schindhelm, 2007; Östlund et al., 2004). However, there is also an impaired event detection and/or recognition (Recarte & Nunes, 2003). In the Meta analysis of Horrey and Wickens (2004), increased reaction times could also be measured.

These studies point out that different distraction conditions influence the driving behaviour in a different way. The question arises how visual and cognitive distraction contributes to the driver errors, leading to rear-end crashes. When we summarise the results of the accident studies, there seem to be two types of errors involved in these rear-end crashes.

On the one hand, drivers do not watch the car in front as attentively as they should because they are visually distracted. This may lead to a missing perception of possible manoeuvres of the lead car. According to this interpretation, some studies could show increasing reaction times or missing reactions under visual distraction.