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Driving context influences drivers' decision to engage in visual–manual phone tasks: Evidence from a naturalistic driving study

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ABSTRACT

Introduction: Visual–manual (VM) phone tasks (i.e., texting, dialing, reading) are associated with an increased crash/near-crash risk. This study investigated how the driving context influences drivers' decisions to engage in VM phone tasks in naturalistic driving. *Method:* Video-recordings of 1,432 car trips were viewed to identify VM phone tasks and passenger presence. Video, vehicle signals, and map data were used to classify driving context (i.e., curvature, other vehicles) before and during the VM phone tasks (N = 374). Vehicle signals (i.e., speed, yaw rate, forward radar) were available for all driving. *Results:* VM phone tasks were more likely to be initiated while standing still, and less likely while driving at high speeds, or when a passenger was present. Lead vehicle presence did not influence how likely it was that a VM phone task was initiated, but the drivers adjusted their task timing to situations when the lead vehicle was increasing speed, resulting in increasing time headway. The drivers adjusted task timing until after making sharp turns and lane change maneuvers. In contrast to previous driving simulator studies, there was no evidence of drivers reducing speed as a consequence of VM phone task engagement. *Conclusions:* The results show that experienced drivers use information about current and upcoming driving context to decide when to engage in VM phone tasks. However, drivers may fail to sufficiently increase safety margins to allow time to respond to possible unpredictable events (e.g., lead vehicle braking). *Practical applications:* Advanced driver assistance systems should facilitate and possibly boost drivers' self-regulating behavior. For instance, they might recognize when appropriate adaptive behavior is missing and advise or alert accordingly. The results from this study could also inspire training programs for novice drivers, or locally classify roads in terms of the risk associated with secondary task engagement while driving.

1. Introduction

Driver distraction is widely acknowledged as one of the leading causes of crashes and a major concern for traffic safety (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Stutts, Reinfurt, Staplin, & Rodgman, 2001; Wang, Knipling, & Goodman, 1996). Distraction can be defined as a diversion of attention away from activities critical for safe driving toward a competing activity (Lee, Young, & Regan, 2008). Recent naturalistic studies promise cutting-edge insights into the mechanisms underlying distraction. For instance, the 100-car naturalistic driving study (100-car study) has demonstrated that complex secondary tasks that require several manual inputs and/or several glances away from the road are associated with an increased risk of crash and near-crash involvement (Dingus et al., 2006; Klauer et al., 2006). Visual–manual (VM) phone tasks such as dialing, sending a text message, or reading are associated with an increased risk of crash/near-crash involvement (Klauer et al., 2006; Olson, Hanowski, Hickman, & Bocanegra, 2009), while talking on the phone seems to have a neutral or even protective effect (Hickman & Hanowski, 2012; Klauer et al., 2006; Olson et al., 2009). Evaluating drivers' crash/near-crash risk while they are performing a task, without considering their exposure to distraction, will only address part of the safety problem.

The exposure to driver distraction (i.e., how often and for how long drivers are engaged in different secondary tasks) influences the number of crashes where distraction can be considered a contributing factor (Young & Regan, 2008). There are several factors that influence the exposure and overall risk of crash/near-crash involvement (Dingus, Hanowski, & Klauer, 2011), such as driver risk adaptation, driver state, and how frequently—and in what situations—drivers engage in potentially risky behavior. For instance, dialing a phone number in low traffic density on a motorway may not impose an increased risk, while the same task may be risky in high traffic density where other vehicles are likely to brake or change lanes. In the IVBSS naturalistic study, Funkhouser and Sayer (2012) found that drivers are more likely to engage in VM phone tasks when standing still. This finding suggests that secondary task engagement does not occur randomly. A driver may use different strategies to decide whether, and when, to engage

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in VM tasks (Lee, Regan, & Young, 2008; Schömig & Metz, 2013). Improved understanding of drivers' exposure to secondary tasks can improve the ability to estimate both crash/near-crash risk and the safety impact of driver distraction (Dingus et al., 2011). These issues point to the central questions of this paper: in which situations do drivers choose to engage in VM phone tasks?

1.1. Willingness to engage in secondary tasks

Lerner, Singer, and Huey (2008) investigated drivers' willingness to engage in secondary tasks, using an on-road study and focus groups. They found that task-related motivation was more important than the immediate or upcoming driving situation, although maneuvers such as exits, merges, and turns were identified as having some influence. Many drivers report that they do not engage in secondary tasks in poor weather, on winding roads, in heavy traffic, at night, or close to schools (Young & Lenné, 2010). In contrast, Horrey and Lesch (2009) found that drivers did not strategically adapt the timing of secondary tasks to areas of low demand when driving on a closed test-track they were familiar with, and no other vehicles were present. Additionally, young drivers are more likely than mature drivers to initiate VM phone tasks while driving (Funkhouser & Sayer, 2012; Pöysti, Rajalin, & Summala, 2005).

1.2. Timing of secondary tasks

There is little research on how secondary task engagement is influenced at the tactical level (i.e., task timing). It is, however, likely that drivers adapt their task timing based on immediate and upcoming driving task demand. For instance, if a driver only dials while stopped, it is likely that this driver will initiate the task just after slowing down to a complete stop. Other driving maneuvers, such as sharp turns or overtaking, may also influence the timing of secondary task initiation.

1.3. Driver adaption to driving and secondary task demand once engaged in a secondary task

At the operational level, drivers can use different strategies to manage the demands of the driving task and secondary tasks. Firstly, a driver may reduce the amount of effort invested in the driving task by permitting degraded driving performance. Several driving simulator and on-road experiments have demonstrated that VM tasks influence driving performance and safety, in the form of reduced lane-keeping performance (Engström, Johansson, & Östlund, 2005; Hosking, Young, & Regan, 2009; Törnros & Bolling, 2005), higher variations in distance to lead vehicle (Hosking et al., 2009), impaired event detection (Törnros & Bolling, 2005), and increased reaction times to sudden events (Kircher et al., 2004).

Secondly, while engaged in a secondary task, drivers can also modulate their attention to the secondary task depending on the demand of the driving tasks. For VM tasks, this is reflected by a change in glance behavior. For instance, the driver takes shorter glances away from the road when driving demand increases, both in driving simulator studies (Tsimhoni, Smith, & Green, 2004) and naturalistic driving (Tivesten & Dozza, 2014).

Thirdly, drivers can reduce driving demand by increasing safety margins themselves during secondary tasks. Several driving simulator studies have demonstrated that drivers reduce speed (Engström et al., 2005; Törnros & Bolling, 2005) and increase time headway to a lead vehicle (Hosking et al., 2009) when engaged in a VM secondary task. However, in a naturalistic driving study analyzed by Fitch et al. (2013), drivers sending a text message did not seem to reduce speed, although they did increase time headway to the lead vehicle. It is not known whether this adaptation (or self-regulation) occurs as a consequence of secondary task demand once the driver is engaged in the task, or as a preparation before the task is initiated.

1.4. Research questions

This study investigated how driving contexts (with different driving demands) influence drivers' decision to engage in VM secondary tasks, using naturalistic driving data to address the following research questions: (a) What driving contexts influence the overall propensity to engage in VM phone tasks? (b) For those drivers who do engage in VM phone tasks, which driving contexts influence the task timing? (c) Do drivers self-regulate, that is, adapt the demand of the driving task before or after the task is initiated, to increase their safety margins?

2. Materials and methods

2.1. The Swedish EuroFOT database for passenger cars

This study analyzed naturalistic driving data collected from 100 Volvo cars for one year as part of the EuroFOT project. The cars were driven in real traffic by the primary drivers and other members of the household. The drivers all resided in the Gothenburg region of Sweden. No advanced driver assistance system was activated during the first 3–4 months of driving, which are the data used in this study. Cameras (forward road view, rearward road view, and driver view), on-board sensors, and the CAN-bus were used to collect continuous data at 10 Hz. Data collection covered trips in their entirety, that is, from ignition of the motor to when the motor was shut down. Approximately 1 million km was recorded and stored in a database that included information about the 198 drivers who participated in the study ($M = 45.3$ years, $SD = 10.8$ years, 57% male, 43% female). More information on driver demographics and the data collected can be found in Sanchez et al. (2012).

A few CAN-bus signals were selected, either to corroborate the video coding (see Sections 2.2–2.3) or for inclusion directly in the analysis (see Section 2.4). These signals were yaw rate (deg/s), speed (km/h), gear (category), forward radar (m), and line crossings (category). Yaw rate was used as an indicator of turning maneuvers. Speed and gear signals were used to establish speed distributions and to distinguish reversing from forward motion. The forward radar was used to measure distance to a lead vehicle and calculate time headway in car-following. A lead vehicle was considered to be present if the radar signal could be interpolated into a smooth signal indicating a distance to another vehicle of 150 m or less. The line crossing signal indicated whether line markings were crossed, either to change lanes or overtake.

2.2. Selection of trips and general coding of whole trips

A 5-week period of data collection during late spring 2010 was targeted for analysis. There were approximately 6,000 trips in the database during this time period. Three analysts viewed and coded entire trips (from start to end), which were randomly selected from the 6,000 trips. Each trip was coded according to the categorical variables *purpose of trip*, *passengers*, *light conditions*, and *phone-related sequence*, itemized in Table 1. A trip was not coded if: (a) it was extremely short (i.e., less than 30 s), (b) forward or driver video was missing, or (c) the vehicle was not in traffic (e.g., car wash, car service). The available resources allowed for coding of 1,432 trips with a total of 391 h of driving (trip duration: $M = 984$, $Mdn = 626$, $SD = 1309$ s). In total, 103 different drivers were observed from different age groups (18–29 years ($N = 9$), 30–55 years ($N = 77$); 56–65 years ($N = 14$); unknown age ($N = 3$)), and gender (61 males; 42 females). Out of all coded trips, 193 trips presented at least one VM phone task (i.e., dialing, texting, or reading). A total of 374 VM phone tasks were identified in the dataset. All coding was performed using an updated