Journal of Safety Research 55 (2015) 81–87

Contents lists available at ScienceDirect

Journal of Safety Research

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

Real-world effects of using a phone while driving on lateral and longitudinal control of vehicles

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ARTICLE INFO

Article history:
Received 5 May 2015
Received in revised form 23 June 2015
Accepted 29 September 2015
Available online 14 October 2015

Keywords:
Traffic safety
Driver behavior
Distraction
Naturalistic data
Age

ABSTRACT

Introduction: Technologies able to augment human communication, such as smartphones, are increasingly present during all daily activities. Their use while driving, in particular, is of great potential concern, because of the high risk that distraction poses during this activity. Current countermeasures to distraction from phone use are considerably different across countries and not always widely accepted/adopted by the drivers. *Methods:* This study utilized naturalistic driving data collected from 108 drivers in the Integrated Vehicle-Based Safety Systems (IVBSS) program in 2009 and 2010 to assess the extent to which using a phone changes lateral or longitudinal control of a vehicle. The IVBSS study included drivers from three age groups: 20–30 (younger), 40–50 (middle-aged), and 60–70 (older). *Results:* Results from this study show that younger drivers are more likely to use a phone while driving than older and middle-aged drivers. Furthermore, younger drivers exhibited smaller safety margins while using a phone. Nevertheless, younger drivers did not experience more severe lateral/longitudinal threats than older and middle-aged drivers, probably because of faster reaction times. While manipulating the phone (i.e., dialing, texting), drivers exhibited larger lateral safety margins and experienced less severe lateral threats than while conversing on the phone. Finally, longitudinal threats were more critical soon after phone interaction, suggesting that drivers terminate phone interactions when driving becomes more demanding. *Conclusions:* These findings suggest that drivers are aware of the potential negative effect of phone use on their safety. This awareness guides their decision to engage/disengage in phone use and to increase safety margins (self-regulation). This compensatory behavior may be a natural countermeasure to distraction that is hard to measure in controlled studies. *Practical Applications:* Intelligent systems able to amplify this natural compensatory behavior may become a widely accepted/adopted countermeasure to the potential distraction from phone operation while driving.

1. Introduction

In the last decade, mobile phone use has led to rising concerns about distraction during driving. Although phone use while driving has been widely addressed by researchers (McCartt et al., 2006) and legislative actions in several countries, a comprehensive examination of its effect on driving performance in real traffic has not been performed. Agreement on the most promising countermeasures to address potential distraction posed by phones and legislation is even farther away. In addition, current countermeasures are not always widely accepted or adopted by the drivers. For example, bans on phone use have been shown to provoke unsafe driving behaviors (Gauld et al., 2014).

Current legislation related to phone use while driving ranges from total prohibition, as in Japan, to ban of hand-held devices, as in most of Europe and several states in the United States, to no limits on conversation, as in Sweden. In some jurisdictions, special restrictions apply to specific types of drivers (e.g., young or professional drivers). The variety of legislations around the world may, in part, reflect the lack of a common understanding about the effect of cell phone use on vehicle control.

Research on phone use while driving employs several types of data, both subjective and objective. These include questionnaires (Backer-Grondahl & Sagberg, 2011), interviews (Brusque & Alauzet, 2008), crash databases (Redelmeier & Tibshirani, 1997; Violanti, 1998; McEvoy et al., 2005), driving simulators (Horberry et al., 2006), real traffic observations (Taylor et al., 2007, Vivoda et al., 2008), test tracks (Hancock et al., 2003), and naturalistic studies (Hickman & Hanowski, 2012). With the exception of naturalistic driving studies, most of the other aforementioned studies report that all uses (including talking) of cell phones while driving increase risk.

Different types of data may suffer from different biases and consequently produce results that are difficult to reconcile. For instance, subjective data from interviews and questionnaires may be guided by crash

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http://dx.doi.org/10.1016/j.jsr.2015.09.005

databases, in which only crash-involved drivers are included. Research also shows that drivers who use the phone while driving are more likely to have a prior history of citation and crash involvement (Beck et al., 2007), thus potentially biasing crash databases. In addition, phone users may be inclined, correctly or not, to attribute the crash to mobile phone use when asked after the fact (Backer-Grondahl & Sagberg, 2011).

Data from driving simulators and test tracks offer the unique opportunity to safely and repeatedly provoke critical situations. However, participants in these controlled conditions may accept higher levels of risk than they would in reality, especially if asked to do so by the researcher before they are fully acquainted with the environment (Hancock et al., 2003). In contrast, Schömig and Metz demonstrated that participants in driving simulators select lower levels of risk if they are allowed to compensate for phone distraction by, for instance, stopping the vehicle (Schömig & Metz, 2012); furthermore, Shinar showed that repetition reduces the negative interference of distraction due to phone use (Shinar et al., 2005).

Studies based on crash databases and observational studies have the great advantage of anchoring the results to the real world, and the disadvantage of dealing with complex biases while showing only correlational, but not causal, relationships. For instance, naturalistic studies only include *volunteers* who may not come from a random population. Among others, one advantage of *naturalistic driving studies* is that they allow drivers to be compared to themselves when on or off the phone so that possible compensatory behavior when using a cell phone may be assessed. Naturalistic data also offer the opportunity to analyze different driver age groups and have been successful in explaining how experience modulates driving behavior (Lee et al., 2011). Thus, the analysis of naturalistic data seems to offer the best opportunity to advance our understanding of the effect of using a phone while driving, especially in very large datasets.

The present study used a large naturalistic driving data set to investigate (a) how changes in driver behavior might arise from two opposing components, distraction and driver compensatory behavior; and (b) how these components are balanced.

2. Methods

The data used in this study, from the IVBSS Field Operational Test (FOT) (Sayer et al., 2011), were collected from 108 randomly sampled passenger-car drivers in 2009 and 2010. Drivers were equally distributed in three different age groups: 20–30 (younger), 40–50 (middle-aged), and 60–70 (older). For each age group, the number of female and male drivers was the same. In order to qualify for the study, participants were required to drive not less than 25% below the National Personal Transportation Survey reported average for their age and gender category. Further, drivers who had any felony motor vehicle convictions, such as driving while intoxicated or under the influence of alcohol, within 36 months of recruitment were excluded from the study. Data were collected using 16 Honda Accords, which were equipped with several advanced safety systems, including forward collision warning, lane departure warning, and blind-spot detection. The vehicles were rotated among the drivers, and each driver was unsupervised while pursuing her/his normal driving behavior for 40 days. In this study, drivers used their personal phones, and records were not kept as to the types of phones that drivers used. In 2006–2007 Honda Accords, there was not an option to sync a driver's phone to the research vehicle. If drivers did use their phones in a hands-free manner, they did so with their personal hands-free equipment (e.g., a headset).

Throughout the study, driving and video data, including warning-system triggers (silent alerts) from the vehicle's active safety systems, were collected continuously. However, the safety warnings were not presented to the drivers until after the 12-day baseline period had elapsed. Data collected included longitudinal radar information (range and range rate), vehicle dynamics (e.g., speed and lateral velocity), and lane offset. Five video-cameras recorded forward scene, driver's face, in-cabin view of the controls, and rear scene (two cameras). Video data were recorded continuously at 10 Hz.

The present study only used IVBSS data from the baseline period, in order to assess the effects of engaging in a conversation or manipulating a cell phone on driving performance without the safety warnings. Video data for all drivers in the first week of data collection were manually coded for cell phone use. A total of 3519 segments of data in which the driver was either engaged in a phone conversation (Talk) or manipulating a phone, that is, interacting visually and manually with a phone (Manip), were identified in the dataset (Funkhouser & Sayer, 2011). The average duration of these data segments was 70 s; 86% of the segments were shorter than 2 min; 4% of the segments were longer than 5 min. For all Manip and Talk segments, two matching baseline segments were identified: the Pre-Phone segment, in the 5 min preceding the phone segment; and the Post-Phone segment, in the 5 min following the phone segment (Phone). Baseline segments had to have the same duration as the corresponding phone segment, and an average vehicle speed within 25% of the phone segment's average speed. This speed filter helped keep the context similar between phone and baseline segments and was not sufficiently selective to mask the possible effect of cell phone use on speed. In fact, changes in speed from cell-phone use are reported to be much smaller than 25% in several studies (Haigney & Westerman, 2001; Jenness et al., 2002; Charlton, 2004; Shinar et al., 2005). Baseline segments were not permitted to contain any phone use. For 1033 of the identified Phone segments from 91 different drivers, it was possible to find the two comparison baselines. All other phone segments (2487) were excluded from analysis. Of the three criteria, the speed-match criterion was the most stringent, responsible for the exclusion of most of the phone segments from analysis. The duration-match criterion mainly precluded phone segments of longer duration; however, since these segments were rare from the beginning, this selection is not likely to have biased the analysis. Exclusion of phone segments because the baseline periods also included phone use occurred only rarely.

For the Pre-phone, Phone, and Post-Phone segments, four indicators of driver performance were selected. Two indicators were related to the longitudinal control of the vehicle: minimum time-to-collision (MinTTC) and median headway (MedHW). The two remaining indicators were related to the lateral control of the vehicle: minimum time-to-lane-crossing (MinTLC) and maximum lane offset (MaxLO). Time-to-collision is a longitudinal safety indicator used in commercial safety systems and collision mitigation systems to issue forward collision warnings and initiate autonomous braking (Kaempchen et al., 2009). Thus, MinTTC represents the highest longitudinal risk taken by the driver during each data segment or, in other words, the limit of the driver's longitudinal safety margin. Time-to-collision was computed as the ratio of the distance between the driver's vehicle and the one ahead and their relative speed; both these measures were obtained from a forward-looking radar. MedHW, an indicator of driver car-following behavior, has been successfully used to compare driver performance across different driving and distraction conditions (Rakauskas et al., 2008). MedHW complemented MinTTC by indicating the usual longitudinal safety margin of the driver.

Time-to-lane-crossing is a lateral safety indicator used in commercial safety systems to initiate lane departure warnings and, in current research projects, to control automated steering (Mammar et al., 2006). Thus MinTLC represents the highest lateral risk taken by the driver during each data segment or, in other words, the limit of the driver's lateral safety margin. Time-to-lane-crossing was computed as the offset from the center of the lane divided by the lateral velocity, using car width, lane width, lateral offset, and lateral velocity. Time-to-lane-crossing was calculated only when lateral speed was available and greater than 0.2 m/s in either direction. The direction of the lateral velocity determined whether to use the distance to the left or to the right lane edge to compute lateral offset.