Accident Analysis and Prevention 72 (2014) 287–295

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Texting while driving: Is speech-based text entry less risky than handheld text entry?

J. He[a,*], A. Chaparro[a], B. Nguyen[a], R.J. Burge[a], J. Crandall[a], B. Chaparro[a], R. Ni[a], S. Cao[b]

[a] Department of Psychology, Wichita State University, 1845 Fairmount, Wichita, KS 67260, USA
[b] Department of Systems Design Engineering, University of Waterloo, Waterloo N2L 3G1, Canada

ARTICLE INFO

Article history:
Received 30 November 2013
Received in revised form 13 July 2014
Accepted 13 July 2014
Available online 2 August 2014

Keywords:
Driver distraction
Cellphone
Car following
Texting
Speech-based interaction

ABSTRACT

Research indicates that using a cell phone to talk or text while maneuvering a vehicle impairs driving performance. However, few published studies directly compare the distracting effects of texting using a hands-free (i.e., speech-based interface) versus handheld cell phone, which is an important issue for legislation, automotive interface design and driving safety training. This study compared the effect of speech-based versus handheld text entries on simulated driving performance by asking participants to perform a car following task while controlling the duration of a secondary text-entry task. Results showed that both speech-based and handheld text entries impaired driving performance relative to the drive-only condition by causing more variation in speed and lane position. Handheld text entry also increased the brake response time and increased variation in headway distance. Text entry using a speech-based cell phone was less detrimental to driving performance than handheld text entry. Nevertheless, the speech-based text entry task still significantly impaired driving compared to the drive-only condition. These results suggest that speech-based text entry disrupts driving, but reduces the level of performance interference compared to text entry with a handheld device. In addition, the difference in the distraction effect caused by speech-based and handheld text entry is not simply due to the difference in task duration.

1. Introduction

Texting while driving is a growing public safety hazard (Caird et al., 2013; Wilson and Stimpson, 2010). For example, a multivariate regression analysis based on the Fatality Accident Reporting System (FARS) database found that the percentage of distraction-related fatalities increased from 10.9% in 1999 to 15.8% in 2008. One reason for the increases in fatalities from 2002 to 2007 was the increased frequency of texting while driving, which was estimated to result in 16,141 additional fatalities in this period (Wilson and Stimpson, 2010). A survey by the American Automobile Association (2008) reported that 14.1% of all drivers and 48.5% of young drivers aged 18–24 admitted that they text while driving. Naturalistic studies of cell phone use suggest that driver distraction increases crash risk by 2.8–5 times (Klauer et al., 2006; Redelmeier and Tibshirani, 1997; Violanti, 1998; Violanti and Marshall, 1996), risk-levels comparable to drunk driving (Redelmeier and Tibshirani, 1997). The increasing usage of cell phones has been accompanied by an accelerating increase in the number of traffic accidents (Alm and Nilsson, 1994; Wilson and Stimpson, 2010; Strayer and Johnston, 2001; World Health Organization, 2011). The risk posed by texting while driving has attracted the attention of legislators, automakers, and safety researchers.

A common misperception underlying legislative efforts is that the task of holding a phone represents the primary source of interference with driving, despite evidence showing that that hands-free cell phone use still impairs driving performance (McEvoy et al., 2005; Strayer and Johnston, 2001). This assumption has influenced automotive interface design and legislation in the United States. Thirty-nine states have passed laws banning texting while driving and ten states have banned handheld cell phone use for all drivers. However, interestingly, all states still allow hands-free cell phone use while driving (National Highway Traffic Safety Administration, 2010). In addition, automotive manufacturers are designing speech-based systems to replace handheld interaction (Lee et al., 2001). A critical question underlying these legislative and system design decisions is “whether texting using a speech-based phone is less risky than using a handheld phone?”

* Corresponding author at: Wichita State University, 1845 Fairmount Street, Wichita, KS 67260, USA. Tel.: +1 217 417 3830.
E-mail addresses: jibo.he@wichita.edu, hejibo@gmail.com (J. He).

http://dx.doi.org/10.1016/j.aap.2014.07.014
0001-4575/

According to one theoretical account termed as the manual and visual *structural interference hypothesis*, the effect of cell phone use on driving performance derives from the manual distraction of holding the phone and pressing the keys, and the visual distraction caused by the need to move the eyes and attention between the cell phone and the road scene (Wickens, 1980). Driving is primarily a visual–spatial–manual task, requiring frequent steering control (Strayer and Drews, 2007; Wickens, 2002). Handheld cell phone use requires the same manual and visual resources as driving, causing structural interference (Wickens, 1980, 1984). Manual manipulation tasks such as dialing and answering the phone, tuning the radio and DVD player are known to negatively impact driving performance (Briem and Hedman, 1995; Brookhuis et al., 1991; Hatfield and Chamberlain, 2005; Horberry et al., 2006; Tsimhoni et al., 2004).

According to the structural interference hypothesis, task interference will be reduced if two tasks share fewer common resources (Wickens, 1980). For example, a secondary task requiring, say a vocal response, will interfere with driving performance less than another secondary task, which requires a manual response. It follows that speech-based cell phone use should be less disruptive of driving performance than traditional handheld cell phone. In agreement with the structural interference hypothesis, performance advantages of speech-based cell phone over handheld cell phone have been reported previously (McCallum et al., 2004; Strayer et al., 2003). For example, Owens, McLaughlin and Sudweeks (2010) reported that speech-based interaction reduced the number of glances, the total glance durations and subjective mental demand compared to handheld interactions for the dialing and music track selection tasks. The frequency and duration of "eyes off the road" glances increased when talking or texting (Hosking et al., 2009; Tsimhoni et al., 1999). Drivers using a speech-based personal digital assistant (PDA) were faster in responding to an emergency than when they are required to interact manually with the PDA. Reactions times in both speech-based and manual interaction conditions were slower than the drive-only condition (McCallum et al., 2004). In addition, a recent study showed that performing a secondary speech comprehension task may not affect the primary task performance of lane keeping, although concurrent comprehension increased drivers' mental workload and reduced drivers' capability to comprehend speech correctly (Cao and Liu, 2013).

An alternative perspective is that speech-based texting may provide little advantage over handheld texting, because the bottleneck of performances for driving while texting is at the cognitive process, rather than the visual perception or manual response processes. Cognitive distraction is associated with the central executive component of working memory (Kunar et al., 2008; Levy et al., 2006). We refer to this hypothesis as the *cognitive interference hypothesis* hereafter. Interference between driving and other tasks (i.e., talking or texting using a cell phone) is a direct result of the serial processing nature of the central executive. The central executive executes only one information-processing task at a time, such as language production or steering control but not both tasks concurrently (Kunar et al., 2008; Strayer and Johnston, 2001). If one task (such as texting) occupies the central executive, other tasks (such as steering control component of driving) need to wait in the queue until the central executive is freed up, therefore creating a performance decrement of either or both tasks. Although speech-based interaction reduces manual distraction compared to handheld interaction, the cognitive demand of texting in unavoidable for both speech-based and handheld cell phone, which is regarded as the major cause of task interference by the cognitive interference hypothesis. Thus, this hypothesis predicts similar levels of driving performance decrement for both speech-based and handheld cell phone.

The cognitive interference hypothesis is supported by meta-analytic and empirical studies of cell phone conversation while driving. These findings reveal that a speech-based cell phone conversation provides little performance benefit over handheld conversation (Caird et al., 2008; Horrey and Wickens, 2006; Levy et al., 2006; McEvoy et al., 2005;). Levy et al. (2006) reported similar brake response times for manual and verbal responses to a choice task. Similarly, it has been shown that performance in a simulated driving task was not impaired by listening to radio broadcasts, listening to a book on a tape, or by a continuous shadowing task using a handheld cell phone (Strayer and Johnston, 2001). In contrast, a word generation task hindered driving performance (Strayer and Johnston, 2001). These data imply that cognitive interference, rather than structural interference, is the major cause of the performance decrement caused by distracted driving due to talking. Cell phone conversations disrupt driving performance by diverting attention to cognitive tasks (Strayer and Johnston, 2001).

Most of the abovementioned studies used non-texting tasks, such as cell phone conversations. Although texting and conversations using cell phones have some elements in common, it is important to acknowledge their differences. For instance, a manual texting task requires the driver to look at the phone and press the correct buttons, while a handheld cell phone conversation imposes less visual and manual distraction. Drivers who are manually texting can choose when to text, whereas a driver engaging in a cell phone conversation may feel obligated to maintain the conversation (Crisler et al., 2008; Hosking et al., 2009). The task interference found in hands-free versus handheld cell phone conversation may not apply to texting while driving directly (Drews et al., 2009).

Despite its importance, few studies have compared the distracting effect of speech-based and handheld texting directly (for limited number of examples, see Drews et al., 2009 and Jamson et al., 2004). These studies did not equate the task durations when comparing the distracting effects of the secondary tasks. The overall level of task interference represents the interactive effects of the duration of secondary tasks and the type of attentional demand (Drews et al., 2009). Secondary tasks such as texting, which requires task switching and extended periods of secondary task duration, can impair driving performance more severely than secondary tasks that are short in task duration. Moreover, duration-related driving performance measures often co-vary to some extent with task duration (Burns et al., 2010). Burns et al. (2010) emphasized the importance of controlling task duration stating that "*Any metric that ignores task duration and duration-related metrics in the assessment of visual-manual tasks will have an incomplete and possibly misleading, estimation of distraction risk*" (Burns et al., 2010, p. 17). Thus, for a fair comparison of speech-based and handheld texting, the duration of the secondary texting task needs to be controlled. This study addresses the confounding variable of task duration of speech-based and handheld texting by controlling the duration of the texting tasks to be exactly the same using a smartphone texting application (Burns et al., 2010; Tsimhoni et al., 1999). This study uses a car following task which is motivated by research showing that mobile users have a higher risk of rear-end collisions (Wilson et al., 2003) and that cell phone use has a larger effect on driver reaction time than tracking performance (Horrey and Wickens, 2006).

2. Methods

2.1. Participants

Thirty-five college-age participants (11 men and 24 women, M = 21.6 years of age, SD = 3.67 years of age) from the community of Wichita State University volunteered to participate in this driving experiment. All participants were screened prior to participation to