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Texting while driving using Google Glass™: Promising but not distraction-free

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ABSTRACT

Texting while driving is risky but common. This study evaluated how texting using a Head-Mounted Display, Google Glass, impacts driving performance. Experienced drivers performed a classic car-following task while using three different interfaces to text: fully manual interaction with a head-down smartphone, vocal interaction with a smartphone, and vocal interaction with Google Glass. Fully manual interaction produced worse driving performance than either of the other interaction methods, leading to more lane excursions and variable vehicle control, and higher workload. Compared to texting vocally with a smartphone, texting using Google Glass produced fewer lane excursions, more braking responses, and lower workload. All forms of texting impaired driving performance compared to undistracted driving. These results imply that the use of Google Glass for texting impairs driving, but its Head-Mounted Display configuration and speech recognition technology may be safer than texting using a smartphone.

1. Introduction

Driver distraction, such as cell phone conversation and texting while driving, is a prominent safety hazard. Approximately 6 billion text messages were sent and received per day in 2011 (Yager et al., 2012). In two surveys, 74.3–91% of college students admitted they text while driving, with 51.8% doing so on a weekly basis (Cook and Jones, 2011; Harrison, 2011). The increasing usage of cell phones has been accompanied by an accelerating increase in the number of traffic accidents (Wilson and Stimpson, 2010; World Health Organization, 2011). Texting while driving was identified as one of the major risk factors for commercial vehicle drivers, and could increase driving risks up to 23.2 times, compared to a baseline driving condition without texting (Olson et al., 2009). According to the Fatality Analysis Reporting System (FARS), the proportion of fatalities caused by driver distraction increased from 10.5% in 2005 to 15.8% in 2008. It is estimated that texting while driving caused an additional 16,141 driving fatalities between the years 2002–2007 as a result of the increase in texting volumes (Wilson and Stimpson, 2010).

To mitigate the risks of driver distraction, auto manufacturers and technology companies have developed technologies such as speech recognition systems (e.g., Apple's Siri, Google's Google Now and Microsoft's Cortana) (He et al., 2014a,b), Head-Up Displays (HUDs) (Liu and Wen, 2004), and Head-Mounted Displays (HMDs, e.g., Google Glass). Google Glass is a wearable device that incorporates both a speech-recognition system and an HMD (see Fig. 2b for an example). The HMD is worn on spectacles and sits in front of the right eye. Google Glass' display projects visual information at a distance of 3.5 m (about 11.5 ft). Google also provides a prescription version of Glass for people wearing corrective lenses. Google Glass functions similarly to a smartphone and allows users to make phone calls and send text messages. The question remains, though, as to whether these portable devices actually reduce distraction and improve driving safety or simply offer new forms of driver distraction.

Research examining the influence of speech-recognition technology on driving performance has produced mixed results. In some studies, interacting with technology through a speech interface allowed better driver performance than manual interaction (Beckers et al., 2014,b; He et al., 2014a,b; Peissner et al., 2011), producing smaller lane deviations, fewer off-road glances, smaller steering variance, and lower cognitive workload (Barón and Green, 2006; Beckers et al., 2014; Owens et al., 2011). In contrast, other studies found no significant benefit to driving performance by

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using a speech-based interface to replace manual inputs (Ishigami and Klein, 2009). The benefits of speech-recognition technology over manual inputs may be mediated by the quality of speech recognition and task duration (He et al., 2014a,b; Kun et al., 2007), implying that under appropriate circumstances, speech-based interaction may indeed improve driver safety.

Few studies have examined the potential benefits of HMDs to driving performance. Studies in aviation and healthcare, though, have found performance benefits of HMDs. For example, pilots in simulated flight tasks detect targets and avoid obstacles more easily using an HMD than they do flying with only Head-Down Displays (HDDs) (Beringer and Dreschler, 2013; Tannen et al., 2004 Tannen et al., 2004). Similarly, anesthesiologists wearing HMDs spend more time looking at their patients than when they use a standard patient monitoring display (Liu et al., 2009). Unfortunately, HMDs can cause headaches, dizziness, nausea, disorientation, eye strain, visual accommodation, binocular disparity, and attentional tunneling (Krupenia and Sanderson, 2006; Morphew et al., 2004; Patterson et al., 2006; Wickens and Alexander, 2009; Wolffsohn et al.,1998a,b) effects that would clearly reduce the potential value of an HMD to task performance.

Both speech-recognition and HMD technology attempt to reduce visual and manual distractions. According to the multiple resource theory of attention (Wickens, 2008, 2002), concurrent tasks that demand similar resources engender stronger mutual interference than concurrent tasks that require no common resources. Therefore, because driving is mainly a spatial-visual-manual task, a concurrent task allowing speech input should produce less of a cost to driving performance than a concurrent task requiring manual input. Likewise, a display that presents information in a head-mounted or head-up position should compromise driving less severely than a display requiring head-down gaze shifts (Liu and Wen, 2004; Liu, 2003). However, visual and manual demands are not the only sources of driver distraction. The cognitive demand imposed by secondary tasks is a central bottleneck (Levy et al., 2006), and cannot be removed by speech-recognition or HMD technology. Thus, the impairment of driving performance may be reduced by implementing speech recognition and HMD, but performance will still be impaired because of the central bottleneck of cognitive processing.

Currently, only a few studies on driving with Google Glass have been reported and showed that texting using either smartphone or Google Glass impaired driving performance by increasing hazard response time and reducing safety margins during a lead vehicle brake hazard (Beckers et al., 2014; Sawyer et al., 2014). When compared to smartphone users, drivers wearing Google Glass produced better lane-keeping performance when replying, and were able to return to their normal roadway speed sooner, which suggested a relative advantage of Google Glass over smartphones (Sawyer et al., 2014). Sawyer et al. (2014) recommended several important directions for future studies on Google Glass. First, a language-based texting task is needed to complement their mathematical transformation task. Second, a component-by-component analysis of the distracting effect of each subsystem of Google Glass, such as speech recognition and HMD, is critical to guide the design of portable devices. It is likely that one component plays a central role in determining the overall distracting effect of the mobile devices, and other components play a minor role or even contribute negatively to the effect of the mobile devices. Thus, without a component-by-component analysis of Google Glass, it is hard to explain the relative distraction effect of Google Glass vs. smartphone, and difficult to calibrate the cost and benefit of design features of portable devices.

This research studies the relative distraction effect of the subsystems of Google Glass, including HMD and speech recognition, using a natural language texting task. Participants performed a classic car-following task in a driving simulator, while concurrently exchanging text messages using either Google Glass or a smartphone. Two questions about the influence of technology on driving performance were addressed: first, can speech-recognition technology for producing outgoing messages reduce dual-task interference compared to manual text entry? Second, can an HMD reduce dual-task interference as compared to an HDD?

We hypothesized that Google Glass with speech recognition and an HMD will reduce driver distraction relative to texting manually using a smartphone. Texting with both Google Glass and smartphone, however, will still likely result in performance decrements when compared to driving without texting.

2. Method

2.1. Participants

Twenty-five students (12 males and 13 females; $M = 20.48$ years, $SD = 2.14$ years, ages range from 18 to 25 years) from Wichita State University participated in the driving experiment for course credit. The desired sample size was estimated using the G*Power software (Faul et al., 2009) based on the study comparing Head-Up Displays (HUDs) vs. Head-Down Displays (HDDs) (Liu and Wen, 2004) and the study comparing speech-based vs. manual texting (He et al., 2014a,b), which indicated that 24 participants were required in order to have 95% power to detect a statistically significant difference. The data-collection stopping rule was to recruit at least 24 participants and to stop by the end of the semester, provided that number had been reached (or to continue otherwise). Participants could wear contact lenses, but they were not allowed to wear spectacles during the experiment since spectacles would interfere with Google Glass. All participants were screened prior to the experiment to verify they had normal or corrected-to-normal vision. All participants were active drivers with a valid driver's license. They were required to have at least three years of driving experience. They had on average 5.70 years of driving experience ($SD = 2.23$ years). Twenty-two of the participants were right-handed, two were left-handed and one participant was ambidextrous. Participants were also required to be fluent English speakers with Midwestern-American accents and to own a smartphone. Twenty-four out of the 25 participants reported that they had used a cell phone while driving.

2.2. Equipment

The driving scenarios were created using HyperDrive Authoring Suite™ Version 1.6.1 and Drive Safety's Vection Simulation Software™ Version 1.6.1. The driving simulator consisted of three 26 in. ASUS monitors (1920×1080). Drivers sat approximately one meter away from the front monitor, at a visual angle of 76°. The monitors simulated the driving environment through front and side windows. Vehicle dynamics were sampled at 60 Hz. The simulator used a Logitech Driving Force GT steering wheel and pedals. Fig. 1 depicts the driving simulator.

A smartphone and Google Glass were used for the texting tasks. The phone was a 4.0 in. Samsung touch-screen smartphone running Android 4.04 operating system with a 1.2 GHz dual-core processor. The resolution of the Super AMOLED™ display was 800×480 WVGA. The keyboard was in a QWERTY layout.

Google Glass was a monocular optical HMD, which was similar to a 25 in. high definition screen in visual angle viewed from eight feet away. The display was placed in front of the right eye, and the participants were allowed to adjust the display to the angle they were most comfortable with. There was a touchpad on the side that allowed users to interact with the device by swiping or tapping on