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Does wearable device bring distraction closer to drivers? Comparing smartphones and Google Glass

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ABSTRACT

Background: Head-up and wearable displays, such as Google Glass™, are sometimes marketed as safe in-vehicle alternatives to phone-based displays, as they allow drivers to receive messages without eye-off-the-road glances. However, head-up displays can still compromise driver performance (e.g., He et al., 2015b), as the distracting effect of interacting with any device will depend on the user's multitasking strategies. The present experiment examined drivers' interaction with a head-down smartphone display and a wearable head-up display.
Method: Participants performed a simulated driving task while receiving and responding to text messages via smartphone or the head-mounted display (HMD) on the Google Glass™. Incoming messages were signaled by an auditory alert, and responses were made vocally.
Results: When using Google Glass, participants' responses were quicker than that of smartphone, and the time to engage in a task did not vary according to lane-keeping difficulty. Results suggest that a willingness to engage more readily in distracting tasks may offset the potential safety benefits of wearable devices.

1. Introduction

Engaging in secondary tasks, such as talking on cell phone or texting, is a popular risky behavior while driving and one of the major factors that impair driving performance (Drews et al., 2009; 2014; 2015b; He et al., 2013b; Sawyer et al., 2014) and contribute to traffic crashes (Wilson and Stimpson, 2010). The number of accidents involving cell phone use has increased, which represents 26% of the total of motor vehicle accidents in 2014 (National Safety Council, 2014; National Highway and Transportation Administration, 2011). Wilson and Stimpson (2010) estimated that texting while driving caused 16,141 more driving fatalities than would have been otherwise expected from 2002 to 2007.

Driver distraction has been found to be as dangerous in some ways as drunk driving at the 0.08 blood alcohol level (Strayer et al., 2006), and impairs various aspects of driving performance (Caird et al., 2014; Caird et al., 2008). For example, drivers who talk or text over a cellphone while behind the wheel produce longer braking response times (Drews et al., 2009; He et al., 2014) and take longer to recover speed after braking (Strayer et al., 2006). Those who text also show higher lane and speed variability (Alosco et al., 2012; He et al., 2014, 2015a; Hosking et al., 2009). Distracted drivers also report higher workload (He et al., 2015b; Owens et al., 2011) and make longer off-road glances (Hosking et al., 2009; Libby et al., 2013; Owens et al., 2011) than undistracted drivers. Drivers who talk while driving increase their crash risk by about three times (Klauer et al., 2006), and those who text while driving increase their risk by as much as 8 to 23 times (Olson et al., 2009). The recent booming of wearable devices, such as Google Glass and smartwatches, may exacerbate these trends, by bringing more distracting devices into the vehicle (Beckers et al., 2014; Giang et al., 2015; He et al., 2015b; Sawyer et al., 2014) and raising new questions for transportation safety.

Motivated by the potential safety benefits of speech-based inputs and head-mounted display, wearable devices (such as Google Glass) are intuitively believed to reduce the costs of distraction to driving performance, as compared to conventional hand-held cellphones. Preliminary studies have provided evidences for some benefits of wearable devices (Beckers et al., 2014; Giang et al., 2014; Giang et al.,

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2015; He et al., 2015b; Sawyer et al., 2014). For example, Sawyer et al. (2014) asked participants to drive following a lead vehicle while texting using either Google Glass or a smartphone. Drivers who texted through Google Glass showed a lower standard deviation of lane position (SDLP) than those texting through a smartphone, implying lower driving risk. Google Glass users also returned to the roadway speed more quickly after texting, and maintained shorter following distances. Studies reported that drivers using Google Glass showed lower costs to driving performance than those using a smartphone (He et al., 2015b; Sawyer et al., 2014). The two studies provided important preliminary evidence of the effects of Google Glass use on driving performance. Nevertheless, neither study directly examined distracted drivers' multitasking strategies.

Studies have shown, though, that the costs of distraction to driving performance depend on the duration of secondary task (Burns et al., 2010), the location and format of the secondary task display (head-up vs head-down vs head-mounted, e.g., He et al., 2015b; Horrey et al., 2006; Liu and Wen, 2004; Sawyer et al., 2014), and the secondary task input modality (speech-based versus manual entry; He et al., 2014; Maciej and Vollrath, 2009; Weinberg et al., 2010). Message entry using hands-free, speech-based inputs is often reported to be less distracting than hand-held, manual message entry, as it requires less motor and visual resources (He et al., 2014). Similarly, drivers generally show less of a performance decrement when viewing information on a head-mounted or head-up display, or on displays at small retinal eccentricity, than when viewing information on a head-down display or at large eccentricity (He et al., 2015b; Horrey and Wickens, 2004; Liu and Wen, 2004; Sawyer et al., 2014), as a result of fewer and shorter glances off-road.

More research is needed to uncover the whole picture of the potential effect of wearable devices on driving performance for two major reasons. First, wearable devices may have very different effects than conventional cell phones and other forms of distracting technologies that have already been well studied. The proximity of a wearable display to the human body and eyes may reduce the effort needed to initiate a secondary task, encouraging drivers to multitask more than they might with a conventional cell phone. Tactile and auditory alerts from a wearable device may be harder to ignore than visual and auditory alerts from a cellphone (Calhoun et al., 2004; Lee and Starner, 2010), and the onset of new visual information with a wearable display may tend to draw drivers' attention reflexively away from the road (Yantis and Jonides, 1990). Transparent wearable displays may also reduce text contrast, making information difficult to read and engendering longer shifts of visual attention away from the driving task. Conversely, wearable interfaces rely primarily on speech input, which tends to be less distracting than manual inputs that is typically used for smartphones (He et al., 2013a, 2014, 2015b). A comparison of the difference between smartphone and Google Glass in the driving context is shown in Table 1.

Second, compared to the emphasis on driving performance, secondary task performance and strategy of multitasking have received relatively little attention in the literature. But driving performance can hardly be thoroughly investigated without considering drivers' multitasking strategy. Multitasking strategy can also moderate the costs of a secondary task driving performance (Horrey and Lesch, 2009; Liang et al., 2012). More specifically, distracted drivers can potentially moderate the multitasking demands by delaying, interrupting, or abbreviating the secondary task (Becic et al., 2010). Two important variables need to be compared to provide a fair comparison of the effect of HMDs and smartphones on driving performance and describe the multitasking strategy: *time-to-engagement* and *time-on-task*.

Time-to-engagement is defined as the period between when the message is sent to the device and when drivers make their first reaction (visual glance, movement, or button clicks) towards the device (Giang et al., 2014) (See Fig. 1 for an illustration). In this study, time-to-engagement was operationally defined as the time from the auditory alert signaling that a message had arrived until participants clicked the "Time to Replay" button. Time-on-task was the duration of the secondary task. The two variables were used to describe the reaction and time taken on the secondary distraction task. Because wearable devices, such as HMDs and smartwatches, are situated on the human body and sometimes directly in front of the eyes, the effort required to initiate a secondary task on a wearable device may be smaller than needed on a smartphone task or a dashboard task. This may make wearable device users more likely to initiate a secondary task, producing shorter time-to-engagement. To the best of our knowledge, only one study has investigated the time-to-engagement for smartwatch, reporting that the time-to-engagement was shorter for a smartwatch task than a smartphone task (Giang et al., 2014). The rejection or the delay of a distraction task can be an adaptive strategy to accommodate the increased workload of multitasking (Iqbal et al., 2011; Liang et al., 2012; Schömig et al., 2011), but is a behavior that drivers may not always use (Horrey &Lesch, 2009). For example, Liang and colleagues found that drivers sometimes avoided transitioning from low-demand driving tasks to high-demand driving tasks when initiating secondary tasks with in-vehicle devices (Liang et al., 2012). However, they did not intentionally start the secondary task in a low-demand driving scenario, and they did not delay the secondary task when driving demands have been already high. These studies demonstrated that the multitasking strategy of when to initiate a distraction task might be specific to the driving context and the adaptive anticipatory delaying of a secondary task may not be perfect, especially in the high driving load condition. However, till now, no efforts have been made to investigate the time-to-engagement for drivers who use a wearable HMD.

Time-on-task may also modulate the distracting effects of in-vehicle technology use (See Fig. 1 for an illustration). Burns et al. (2010) emphasized 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). If drivers intuitively believe wearable devices are less distracting to driving performance, they may spend longer times interacting with wearable devices than with smartphones, offsetting any potential

Table 1
Comparisons of smartphone and Google Glass in the driving context.

	Drive with a smartphone	Drive with HMD (e.g. Google Glass)
Saliency	Low	High
Eccentricity	Far	Close
Effort	High	Low
Values	Task-dependent, low for texting while driving	Task-dependent, low for texting while driving
Size	Mostly at least 720 × 1280 pixel resolution with 4.3–6 inch physical size	640 × 360 pixels (equivalent of a 25 in/64 cm screen from 8 ft/2.4 m away
Contrast	Good	Poor for the transparent display
Tactile alerts	Most often not, if phone is not vibrating in the pocket or vibrating on the dashboard	Yes
Auditory alerts	Yes	Yes
Visual onset	No, if not in the field of view	Yes
Input methods	Manual, vocal	Vocal

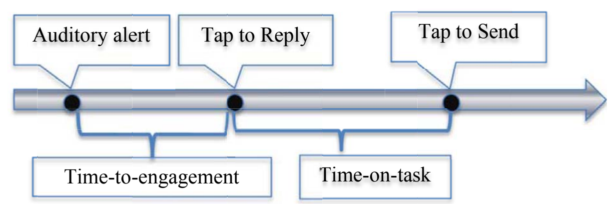

Fig. 1. The Definition of time-to-engagement and time-on-task of a texting task.