Applied Ergonomics 58 (2017) 25–34

Contents lists available at ScienceDirect

Applied Ergonomics

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

Comparing the demands of destination entry using Google Glass and the Samsung Galaxy S4 during simulated driving

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ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form
11 April 2016
Accepted 10 May 2016

Keywords:
Attention
Workload
Detection response task
Distraction

ABSTRACT

The relative impact of using a Google Glass based voice interface to enter a destination address compared to voice and touch-entry methods using a handheld Samsung Galaxy S4 smartphone was assessed in a driving simulator. Voice entry (Google Glass and Samsung) had lower subjective workload ratings, lower standard deviation of lateral lane position, shorter task durations, faster remote Detection Response Task (DRT) reaction times, lower DRT miss rates, and resulted in less time glancing off-road than the primary visual-manual interaction with the Samsung Touch interface. Comparing voice entry methods, using Google Glass took less time, while glance metrics and reaction time to DRT events responded to were similar. In contrast, DRT miss rate was higher for Google Glass, suggesting that drivers may be under increased distraction levels but for a shorter period of time; whether one or the other equates to an overall safer driving experience is an open question.

1. Introduction

Though navigation devices started appearing in vehicles in the mid 1980's, it was not until recently that in-vehicle navigation devices have come into widespread use (Quaresma, 2012). This can be attributed to the introduction of navigation applications on smartphones coupled with the dramatic increase in smartphone use (Oracle, 2011; Quaresma, 2012) and an overall increase in the availability of embedded navigation systems. Navigation systems have been shown to create visual, auditory and cognitive demands on attention (Green, 1997; Ranney, 2008; Dopart et al., 2013; Klauer et al., 2014). Destination entry can occupy drivers for significant amounts of time and has been identified as the most demanding part of using a navigation device while driving (Young and Regan, 2003).

Due to potential detrimental effects of mobile device use in vehicles, it is vital to study new devices before their introduction to the market to evaluate their impact on driving performance and safety. The recent proliferation of wearable technology has dramatically changed the technology landscape used by the general populace. The introduction of the Google Glass Explorer edition in 2013 and the potential release of the second generation of Google Glass in the near future (Oliver, 2015) as a new form of wearable mobile device present a marked departure from existing smartphones and other mobile devices. Google Glass represents a new paradigm by combining a voice interface with a head-mounted display (HMD). HMD devices display visual information on a transparent surface in the field of view, facilitating the ability to process visual inputs while supporting a forward vision orientation. As reviewed in Sawyer et al. (2014), previous studies in aviation indicate some mixed benefits of conceptually related heads-up displays (HUDs). In specific, such work focuses on runway approach, and has shown an increase in operator control due to the use of HUDs, but a decrease in operator ability to detect unexpected events (Fischer and Haines, 1980; Wickens and Long, 1994) likely due at least in part to the clutter caused by overlapping imagery (Oppitek, 1973). Several automobile studies confirm these findings: the use of a HUD generally improves vehicle control (Flannagan and Harrison, 1994; Kiefer and Gellatly, 1996), but decreases in control have been observed during high workload conditions (Gish and Staplin, 1995) and reductions in unexpected event detection (Fadden et al., 2000; Horrey et al., 2003).

Furthermore, although it has long been postulated that voice interfaces are less distracting than visual-manual interfaces

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http://dx.doi.org/10.1016/j.apergo.2016.05.005

(Tijerina et al., 1998), the cognitive load of a given interaction needs to be considered (Levy et al., 2006; Strayer et al., 2013) and recent research suggests that voice interfaces are still often multi-modal, calling upon a sizable level of visual resources (Reimer et al., 2013; Mehler et al., 2015). By combining a voice interface with a head-mounted display, it is unclear how Google Glass affects driver behavior and attention allocation in comparison to traditional voice and touch interface smartphone systems.

These questions are timely. It seems likely that there will be a natural tendency among Google Glass adopters to use it while driving and the head-mounted nature of Google Glass may lead the general populace to assume that it is safer to use than traditional hand-held devices; at least one spokesperson for Google has stated that the latter assumption is in fact in line with what Google Glass was designed to support (Shanhani, 2014). The public debate concerning the impact of Google Glass on driving performance and safety is a popular one (Reuters, 2014; Fitch et al., 2013), but can draw upon only relatively limited data directly considering the Google Glass interface. In a driving simulation study, Sawyer et al. (2014) compared the use of Google Glass and a smartphone-based visual-manual interface to deliver messages consisting of arithmetic problems. Interacting with both devices resulted in longer response time to unexpected breaking events compared to single task driving and no advantage was observed for Google Glass in the response time metric. The authors interpreted this driving performance data as indicating possible advantages over a smartphone when using the Google Glass interface, specifically in the reply and recovery phases of the tasks. Further, more fine grained study of interaction components of Glass was suggested. Subsequent studies used a desktop driving simulator to compare Google Glass and a handheld smartphone interface for reading short passages that might be considered to approximate the reading aspect of receiving text-messages or e-mails (He et al., 2015b) and looked at a texting task in which messages were delivered visually by each device and participants responded manually on the smartphone and verbally with Google Glass (He et al., 2015a). Again, interaction with both devices impacted driving relative to not reading or texting, although the impact was less with Google Glass. Reaction to external events were not evaluated. Tippey et al. (2014) also employed a desktop driving simulator in a pilot study of texting with seven participants, comparing reading texts on a smartphone and responding manually, reading texts on the smartphone and responding verbally, and reading or listening to texts with Google Glass and responding verbally. While the authors noted a number of potential limitations, absolute steering rate values and standard deviation of lane position values suggested advantages to the Google Glass interface over the manual-touch keypad method of texting.

Studying destination entry using Google Glass provides a complementary avenue for assessing the impact of using such a novel device while driving. Since its display is close to the line of sight on the road, Google Glass may have advantages for navigation purposes compared to other devices, such as smartphones. On the other hand, having the eyes oriented toward the forward roadway might reduce a perceived need to complete the task relatively quickly.

To this end, the authors conducted a study to analyze the impact of destination entry tasks using Google Glass on workload, driving performance, glance behavior and attention. Google Glass was compared against two different benchmarks: production voice and touch interfaces available on the Samsung Galaxy S4 smartphone. The operation of Google Glass requires the wearer to learn a novel mental model of operation. Given our objective to understand the demands of the interfaces under study (as opposed of the ability of one to learn the interaction model of Google Glass), this study was framed by drawing the majority of participants from a population of highly educated students that would be expected to be a best case model of lead technology adopters.

2. Methods

2.1. Participants

Twenty-five participants between the ages of 22 and 33 were recruited from MIT and other nearby academic and research institutions. Participants were required to have held a valid driver's license for 3 + years and be in self-reported good health. To reduce bias against voice interfaces, only native English speakers were considered. The research protocol was approved by MIT's IRB and compensation of $40 provided. One participant was excluded from analysis for being unable to successfully use the Samsung voice interface, leaving a gender-balanced sample of 24 participants. The mean age of the analysis sample was 25.0 years (SD 2.6).

2.2. Apparatus

The driving simulator was a stationary, full cab 2001 Volkswagen Beetle situated in front of a projection screen with approximately a 40-degree view of a virtual roadway. In past validation efforts, participants have been observed to glance off-road to device interfaces following patterns highly consistent with field conditions (Wang et al., 2010). Changes in arousal to increased cognitive demand, appear highly consistent between the simulator and field, while the overall arousal level during actual field driving is greater than that observed in the simulator (Reimer and Mehler, 2011).

Graphical updates were generated at a minimum frame rate of 20 Hz by STISIM Drive version 2.08.02 (Systems Technology, Inc.). The simulation scenario consisted of a two lane rural road with a 2 ft (0.61 m) shoulder on each side of the roadway. Lane width was 15 ft (3.62 m) and the posted speed limit during the evaluation period was 50 mph (80.5 km/h). Average oncoming traffic density was 9 vehicles/mile (5.6 vehicles/km), staggered by ± 200 ft (0.061 km) to prevent uniform spacing. The speed of oncoming vehicles was equal to the posted speed limit of 50 mph. There were 8 straight segments, 2 left curves and 2 right curves, which were randomly shuffled for each drive. Curves became visible at a distance of 2000 ft (610 m) and had a curvature of 0.00015 (1/ft) (0.000492 1/m) and a length of 2000 ft (610 m).

Physiological data were collected by using a MEDAC System/3 instrumentation unit (NeuroDyne Medical Corporation). Skin conductance level was measured using a constant current configuration and non-polarizing, low-impedance gold-plated electrodes. The electrodes were placed on the underside of the ring and middle finger of the left hand (participants were instructed to only use their right hand to interact with the mobile devices). For electrocardiogram (EKG) recordings, the skin was cleaned with isopropyl alcohol and disposable electrodes (Vermed A10005) were applied in a modified lead II configuration that located the negative lead just under the right clavicle, the ground just under the left clavicle, and the positive lead over the lowest left rib. Data sampling was carried out at a rate of 250 Hz to provide sufficient resolution for detecting the EKG R-wave to calculate heart rate.

A Detection Response Task (DRT) was implemented via a CogLens remote-mounted LED stimulus and a finger-mounted micro-switch response (http://coglens.com). In compliance with the draft ISO Standard (ISO 17488, 2013) for utilizing a remote visual stimulus, the LED was mounted near the center of the participant's field-of-view on the windshield. Following the proposed standard, the LED activated for 1 s with a uniformly distributed inter-stimulus interval between 3 and 5 s. The LED deactivated after