Applied Ergonomics 75 (2019) 8–16

Contents lists available at ScienceDirect

Applied Ergonomics

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

The relative impact of smartwatch and smartphone use while driving on workload, attention, and driving performance

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ARTICLE INFO

Keywords:
Attention
Workload
Detection response task (DRT)
Distraction
Age

ABSTRACT

The impact of using a smartwatch to initiate phone calls on driver workload, attention, and performance was compared to smartphone visual-manual (VM) and auditory-vocal (AV) interfaces. In a driving simulator, 36 participants placed calls using each method. While task time and number of glances were greater for AV calling on the smartwatch vs. smartphone, remote detection task (R-DRT) responsiveness, mean single glance duration, percentage of long duration off-road glances, total off-road glance time, and percent time looking off-road were similar; the later metrics were all significantly higher for the VM interface vs. AV methods. Heart rate and skin conductance were higher during phone calling tasks than “just driving”, but did not consistently differentiate calling method. Participants exhibited more erratic driving behavior (lane position and major steering wheel reversals) for smartphone VM calling compared to both AV methods. Workload ratings were lower for AV calling on both devices vs. VM calling.

1. Introduction

The ubiquitous use of smartphones has exploded in recent years, and so too has interest in companion devices that expand on their capabilities. A new genre of personal electronic device has emerged that brings many of the smartphone's core functions to its owner's wrist. Smartwatches, long limited to fictional secret agents, now offer smartphone owners easy access to notifications, navigation instructions, and voice input for placing phone calls, text messaging, and internet searches. Though convenience is a key selling point, it may also represent a significant concern for driving safety advocates. Drivers already tempted to interact with their smartphone will now have the ability to do so directly from their wrist.

A growing body of research has investigated the inherent demands of smartphone use while driving (e.g., Basacik et al., 2012; Munger et al., 2014; Reimer et al., 2016b; Ranney et al., 2011), but more limited work exists looking at the driving safety concerns associated with wearable devices. Beckers et al. (2017) found that participants in a driving simulation experiment showed similar response times but a higher miss rate to a detection response task (DRT) while entering an address into a navigation application using Google Glass's voice recognition function compared to voice entry on a smartphone; conversely, task completion time was shorter with Glass. Sawyer et al. (2014) and He et al. (2015) found that viewing and responding to text messages while driving using Google Glass was moderately less distracting than using a smartphone, but did not entirely eliminate cognitive distractions. Looking more specifically at smartwatches, Giang et al. (2014) reported initial findings on a small sample of drivers' use of a smartwatch to read notifications, finding that drivers were quicker to glance at notifications displayed on the smartwatch and viewed the notification for a longer period of time, compared to reading the same notifications on a smartphone. Giang et al. (2015) also found that drivers viewing notifications on a smartwatch, as opposed to a smartphone, took longer to respond to external stimuli such as braking events ahead, yet they perceived similar levels of risk in using the two devices while driving. A follow-on paper (Giang et al., 2017), provides an integrated presentation and extended discussion of both smartwatch studies.

Authorities in the United States, Canada, and the United Kingdom have warned drivers over the use of smartwatches, but concede that their laws, as written, do not clearly prohibit smartwatch use while driving (Wiggers, 2014; The Canadian Press, 2014; BBC, 2014). Yet

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https://doi.org/10.1016/j.apergo.2018.09.001
Received 9 June 2017; Received in revised form 23 August 2018; Accepted 5 September 2018

concerns are growing, even prompting a lawsuit against smartwatch manufacturers seeking for them to lead a $1 billion safety campaign (see Dave, 2015). Moreover, Deborah Hersman, President and CEO of the nonprofit National Safety Council and former chair of the National Transportation Safety Board, publically commented that “Smartwatches will be just as distracting, if not more so, than cell phones,” continuing that, “I think it's going to be an even higher hurdle to get people to take their watches off” (see Langfield, 2015). Given the recent availability of smartwatches that not only offer notifications, but also voice and touchscreen-based inputs for key functions, it seems necessary to examine the potential for increased demand posed by the use of a smartwatch as an interactive interface and examine the validity of these concerns.

In light of the likelihood of increased smartwatch use during driving, a study was undertaken to investigate and extend upon the limited literature regarding the potential for smartwatch use to impact driver workload, attention, and performance. While Giang and colleagues (Giang et al., 2014, 2017) studied participants' responding to notifications on a smartwatch, the present study considered the demand associated with a different task, placing a phone call using a voice-based interface, which, in concept, should minimize the amount of secondary task visual demand placed on the driver. Since engaging in any secondary task is likely to increase overall demand on a driver, the demand of the smartwatch interface was assessed along with both auditory-vocal and visual-manual based methods of placing the same calls directly on a smartphone. This supports consideration of the smartwatch interface relative to other interfaces that a driver might use as well as to “just driving”. In a fixed-base driving simulator, self-report ratings of workload, physiological arousal, eye glance behavior, responses to a detection response task (DRT), and driving performance characteristics of participants were examined during “just driving” and when driving and placing phone calls using each of the three interfaces. In addition, the study was designed to consider a somewhat broader sample of participants; the larger of the two studies by Giang and colleagues (Giang et al., 2017) was limited to a sample of twelve males, all in their 20's.

2. Methods

2.1. Participants

Participants were recruited from the greater Boston area and were experienced drivers (holding a driver's license for more than three years and driving at least once per week), between the ages of 20 and 29 or 55 and 69, and physically and mentally healthy based on self-report. Of the 43 participants consented, seven were excluded from the analysis due to experimental interruptions, technical issues, or voluntary withdrawals for factors such as symptoms of simulator sickness. The 36 participants considered in the final results are equally balanced by gender and age group. The study was approved by MIT's institutional review board.

2.2. Apparatus

The study employed the MIT AgeLab's medium-fidelity driving simulator built around the full cab of a 2001 Volkswagen New Beetle. At the time, it was configured as a fixed-base simulator employing an STISIM Drive version 2.08.02 (System Technology, Inc.) simulation environment projected on a 2.44m by 1.83m screen mounted in front of the vehicle cab. Steering, throttle, and brake inputs used the original steering wheel and pedals. Previous work demonstrated strong correspondence between behaviors observed in this simulator and field data (Wang et al., 2010; Reimer and Mehler, 2011).

A CogLens unit (http://coglens.com) was employed to support a remote detection-response task (R-DRT). The setup consisted of a red light-emitting diode (LED) mounted on the windshield in the direct line of sight of the forward roadway and followed ISO standard (ISO 17488, 2016) with the exception that a foot switch mounted on the vehicle's left foot rest was implemented in place of a finger switch. The foot activated response was used since a finger configuration would have interfered with participants' interactions with the smartwatch. During experimental periods involving the R-DRT, the LED stimulus was activated at random intervals of between three and five seconds. Previous studies have validated the use of R-DRTs using a foot pedal to detect differences in cognitive task difficulty in miss percentage and reaction time (Bruyas and Dumont, 2013; Angell et al., 2002).

Heart rate and skin conductance were collected as physiological indicators of workload (Mehler et al., 2012a; Solovey et al., 2014) using a MEDAC System/3 unit (NeuroDyne Medical Corporation). 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. 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). 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.

The study tested a Motorola Moto 360 smartwatch, which was paired with a Motorola Droid RAZR M smartphone. The Motorola Moto 360 was released in September 2014 and runs Google's Android Wear operating system on a 1.56 inch circular display. The watch is designed to interact with a smartphone via Bluetooth. The Droid RAZR M features a 4.3 inch display and was equipped with Android 4.4, “Kit-Kat.” The smartphone was configured to automatically activate the speakerphone option when a call was placed, allowing the researchers to hear when the task had been completed correctly. All calls were routed to a Google Voice mailbox which then instructed the participant to hang up the call. Participants made calls using two methods, visual-manual (VM) and auditory-vocal (AV). As we have noted previously, most AV interfaces encountered in the driving context, whether mobile or embedded in the vehicle, involve some degree of visual-manual interaction in addition to the voice and auditory components and are in actuality perhaps best characterized as mixed-mode interfaces (Reimer et al., 2016a); the term AV is used in this paper to refer to the voice-involved interfaces in-line with common usage and for ease of distinguishing from the primary visual-manual based interfaces. Fig. 1 illustrates the calling procedures for each method included in the study.

Step	Smartwatch AV	Smartphone AV	Smartphone VM
1	Rotate wrist to wake up watch screen	Pick-up phone & press home button to wake up screen	Pick-up phone & press home button to wake up screen
2	Speak: “Okay Google”	Swipe up from home button to activate Google Now	Select Contacts
3	Speak: “Call Mary Sanders	Speak: “Okay Google”	Tap Search Icon
4		Speak: “Call Mary Sanders	Begin typing letters of contact's last name
5			Select contact's name once visible

Fig. 1. Sequential steps (reading downward) for placing a phone call using each of the three interfaces.