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An on-road assessment of cognitive distraction: Impacts on drivers' visual behavior and braking performance

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Abstract

In this on-road experiment, drivers performed demanding cognitive tasks while driving in city traffic. All task interactions were carried out in hands-free mode so that the 21 drivers were not required to take their visual attention away from the road or to manually interact with a device inside the vehicle. Visual behavior and vehicle control were assessed while they drove an 8 km city route under three conditions: no additional task, easy cognitive task and difficult cognitive task. Changes in visual behavior were most apparent when performance between the No Task and Difficult Task conditions were compared. When looking outside of the vehicle, drivers spent more time looking centrally ahead and spent less time looking to the areas in the periphery. Drivers also reduced their visual monitoring of the instruments and mirrors, with some drivers abandoning these tasks entirely. When approaching and driving through intersections, drivers made fewer inspection glances to traffic lights compared to the No Task condition and their scanning of intersection areas to the right was also reduced. Vehicle control was also affected; during the most difficult cognitive tasks there were more occurrences of hard braking. Although hands-free designs for telematics devices are intended to reduce or eliminate the distraction arising from manual operation of these units, the potential for cognitive distraction associated with their use must also be considered and appropriately assessed. These changes are captured in measures of drivers' visual behavior.

Keywords: Driving; Distraction; Driver visual behavior; Road safety

1. Introduction

Hands-free and voice-based technologies are increasingly popular choices for telematics interfaces (ITSA, 2005; PR Newswire, 2005). The obvious safety advantage of these technologies is that drivers can interact with in-vehicle devices using spoken commands and listening to output without having to direct their visual attention away from the road to the interior of the vehicle. Given that hands-free and speech-based devices largely eliminate the distraction resulting from visual/manual interaction, it is often assumed that their use does not impact driver behavior and safety. This assumption is reflected in current North American legislation regulating the use of cell phones while driving, which is largely directed at banning hand held, but not hands-free, devices (Sundeen, 2005).

Driver distraction is an acknowledged safety problem with serious consequences (e.g., Strayer et al., 2006). Considerable research has accumulated documenting the dangers arising from visual/manual distraction inside the vehicle. The recently released naturalistic study of 100 instrumented vehicles (the "100 Car Study") reported that driver inattention to the roadway was a contributing factor to 78% of the crashes and 65% of the near-crashes observed in that study (NHTSA, 2006). Green (1999) produced an extensive review and analysis of in-vehicle tasks that draw drivers' visual attention away from the road. Wierwille and Tijerina (1998) found that they were able to use the visual requirement (glance length and number of glances) for the use of in-vehicle devices, incorporated with the frequency of in-vehicle device use, to predict crash rates. A clear, logical connection relates this research to safety concerns: when you are looking inside the vehicle, you are not looking at the road.

The connection between the use of hands-free or speech-based interfaces and driver distraction is less obvious, but research pointing to "cognitive distraction" as a road safety concern is accumulating. The Insurance Institute for Highway

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Safety reported that when drivers use a cell phone while driving there is a four-fold increase in the likelihood of a crash serious enough to require medical attention (McEvoy et al., 2005). This study also concluded that using a hands-free phone was not any safer than hand-held.

A number of simulator studies have examined the impact of cognitive distraction on driver behavior. Strayer and Johnston (2001) found that participants engaged in cell phone conversations during a tracking task were more likely to miss traffic signals and reacted to signals they did detect more slowly than when they were not engaged in cell phone conversations. The effects were similar for both hand held and hands-free phone configurations. In a later study, participants exhibited an 18% increase in brake reaction times when talking on hands-free cell phones compared with driving without a cell phone (Strayer and Drews, 2004).

The research has expanded beyond cell phones to the larger domain of interfaces for in-vehicle use in general. Lee et al. (2001) reported a 300 ms delay to the braking of a lead vehicle when drivers used a speech-based email system while driving a simulator. In a later simulator study, Harbluk and Lalande (2005) observed reductions or delays in the detection of visual stimuli in the side mirrors when drivers interacted with a speech-based email system.

In an attempt to better understand the visual behavior of drivers, Recarte and Nunes (2000) examined the effects of performing concurrent cognitive tasks on drivers' eye fixations while driving on-road. An experimenter seated in the vehicle interacted with the drivers, asking them to perform verbal and spatial-imagery tasks. Recarte and Nunes reported that drivers' visual functional-field was reduced vertically and horizontally. In addition, during the spatial-imagery task, fixations were longer and glance frequency to mirrors and the speedometer decreased. In a later experiment, they reported that performing demanding cognitive tasks while driving reduced drivers' detection performance for lights displayed in the vehicle and on the windshield (Recarte and Nunes, 2003). The findings from their previous study, reductions in inspections for the mirror and speedometer, were also replicated.

The present experiment was designed to further investigate the impact of performing demanding cognitive tasks (without visual/manual distraction) on driver behavior and performance. The primary questions of interest were:

(1) What are the changes in driver visual behavior that arise as a consequence of using hands-free devices while driving?
(2) How are these changes reflected in drivers' visual behavior at intersections?
(3) Is vehicle control (braking) affected by these activities?
(4) Are drivers sensitive to the increased task demands as reflected in drivers' ratings of workload, safety and distraction?

There were a number of critical considerations in the design of the study. All task interactions took place via the technology in the vehicle (in this case a cell phone) rather than interacting with an experimenter in the vehicle. The mode of interaction was entirely hands-free via speakerphone with a person at a remote location. Drivers did not have to look away from the road or interact manually with an interface. Given the importance of vision in driving, the primary measures of interest were measures of drivers' visual behavior. The participants drove on-road in real city traffic. This provided increased ecological validity and also permitted an assessment of drivers' visual behavior with respect to safety-relevant objects in the driving environment (intersections and traffic lights) as well as general evaluations of scanning patterns out the windshield and to the mirrors and instruments. Measures of braking behavior were collected, as were drivers' self evaluations with respect to workload, safety and distraction.

2. Method

2.1. Participants

Twenty-one participants (9 women and 12 men) aged 21–34 years old ($M = 26.50$, S.D. = 4.71) took part in this study. All held valid drivers licenses, were insured and were experienced drivers (minimum 5 years driving experience; $M = 9.70$, S.D. = 4.26) who drove at least 10,000 km annually. Their vision was good or corrected with contacts. Participants were recruited via an advertisement in a local newspaper and were paid $50.00 for their participation.

2.2. Equipment

Participants drove a 1999 Toyota Camry equipped with a Micro-DAS data collection system (Barickman and Goodman, 1999). The driver side airbag was deactivated and a safety brake was installed on the front passenger side where the experimenter was seated. Participants wore a head-mounted eye tracking system (VISION 2000, El Mar Inc., Toronto, Ontario, Canada), a lightweight (300 g) unit fitted with a visor (70 g) to filter IR (Eizenman et al., 1999). The cell phone (Nokia model 5160) remained in the cradle mounted to the right of the console. Its microphone was attached to the upper left A-pillar and its speaker was mounted under the dash.

2.3. Design, materials, and procedure

A one-way repeated measures design was used where presentation order of task conditions (two levels of cognitive task and the control condition) was counterbalanced across participants.

After a description of the procedure, driver information was collected and the consent form was completed. Participants wore the eye tracker and drove a practice route for 25 min to become familiar with the vehicle, the eye tracker, and the tasks. After a brief break, during which the eye tracker was removed, the eye tracker was calibrated on the participant.

The test route was a 4-km stretch of a busy 4-lane city road on which the drivers drove north and south for a total of 8 km per condition. The posted speed limit was 50 km/h. Each participant completed three drives, one for each of the Easy Task, Difficult Task, and No Task conditions. Math problems were used as the cognitive task. Single digit addition problems (e.g.,