Cell Phone Communication and Driver Visual Behavior: The Impact of Cognitive Distraction

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ABSTRACT
With the advent of new technology in vehicles, drivers can access information in many different forms (email, address books, Web pages) and from many information sources (cell phones, PDAs, driver support systems). With these new information sources finding their way into cars comes increasing concern about the potential adverse effects resulting from drivers' interactions with such multi-function devices. This paper examines the disruptive impact of complex, interactive, hands-free cell phone communications upon the visual awareness of drivers proceeding through high volume intersections. The present study documents changes in driver visual behavior, resulting from cognitive distraction of speech-based interactions, that may contribute to intersection crashes. The results of this research raise significant HCI implications for the design of interactive Intelligent Transportation Systems (ITS) within the automotive sector.

Keywords
Hands-free cell phone, telematics, speech-based interaction, cognition, adaptation, safety

INTRODUCTION

The progressive introduction of Intelligent Transportation Systems (ITS) into new generation automobiles represents a challenge for the HCI community to ensure that the design of such systems fully integrates safety and usability.

Intelligent transportation systems (ITS) integrate advanced electronics and computer systems into modern automobiles, to facilitate performance of both driving related and non-driving related functions. Some of the principal driving-related ITSs include: on-board tutorial systems, navigation and route-guidance systems, collision avoidance and adaptive cruise control systems.

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Non-driving-related ITSs are in-vehicle devices, designed to facilitate performance of tasks other than driving. Amongst non-driving ITSs are: on-board computers, web browsers, radio/stereo systems and cellular telephones.

ITS telematics devices are becoming increasingly popular in vehicles and their functionality is expanding. The use of these devices while driving can impair performance and increase the risk of collision. Telematics refers to the information and computer-based accessories in-vehicles. Cell phones are currently the most popular type of telematics devices used in vehicles and they are now widespread. A boom is predicted for in-vehicle telematics systems and a wealth of new technologies and applications will emerge. Information and communications services in vehicles will expand to provide email, Internet access, entertainment and location based services. Although these systems are intended to support safe driving, there may be unforeseen side effects to this technology.

A common assumption pertaining to speech recognition technology for in-vehicle devices is that speech-based interactions do not distract drivers, because drivers are not required to take their eyes off the road or their hands off the steering wheel. Laboratory and simulator-based studies [2] have shown benefits in such a "eyes-free, hands-free" method of interaction for in-vehicle systems in empirical terms. Nevertheless, voice-based interactions are not effortless and they have the potential to place cognitive demands on drivers [3]. The cognitive demand of this mode of interface may result in high driver workload. Lack of attention on the road and distraction are already major contributing factors in many road accidents [4]. Therefore, systems that have the potential to add to this problem must be carefully designed. In the present study, the impact of cognitive distraction, arising from the use of a hands-free cell phone, on drivers' behavior was investigated in an on-road experiment. Parallels can be drawn to other interactive speech-based interfaces.

Intersections pose a special problem for drivers. Driving through intersections is one of the most complex conditions drivers encounter and they are a particular concern for new and elderly drivers. This is because many different

complex perceptions, decisions and maneuvers are required to successfully negotiate intersections. Drivers must be aware of traffic signal changes, pedestrians and on-coming traffic. Estimates vary, but crashes at intersections have been shown to account for as many as 50% of all crashes involving injury. A 1998/99 cross-Canada survey concluded that intersection crashes were a factor in 13.1% of fatal collisions resulting in 415 fatalities, 46,802 injuries and a cost of $1.2 billion annually [1]. Clearly intersections are a relatively dangerous feature of the road traffic environment.

METHOD

The goal of the research reported in this paper was to examine what drivers do visually at intersections, both when they are driving normally and when they are distracted by a complex cognitive task. Data were collected on the visual behavior of twenty drivers while they drove though 14 signalized intersections on a busy 4-lane city street in Ottawa, Ontario. The drivers wore eye-tracking equipment that enabled the assessment of differences in their visual behavior while driving the route, under a secondary task load and a no-secondary task load condition. The secondary task load involved performance of a demanding cognitive task (difficult arithmetic questions), communicated through cell phone query and response.

RESULTS

The mean number of glances to the traffic lights, the mean percent times drivers completely shed the task of looking at the traffic lights, and the mean number of glances to the right and to the left were of main interest in this study. Clear differences in visual behavior were observed under the two conditions of driving. Specifically, when driving and performing the demanding cognitive task, drivers made significantly fewer glances (mean 1.70) to the traffic lights compared to driving without the task (mean 2.68, $F(1,19) = 21.34$, $p < .001$). In some cases, drivers did not inspect the signal lights at all. Specifically, the percent time drivers completely shed the task of looking at the traffic light, under the load condition (mean 21.9%), was significantly larger than in the no-load condition (mean 7.8%, $F(1,19) = 10.95$, $p < .004$). In addition, there were differences in how they inspected the environment around the intersection. Specifically, drivers reduced the frequency with which they looked to the right, under the load condition (mean 1.34), versus the no-load condition (mean 1.70, $F(1,19) = 4.65$, $p < .05$). Conversely, the drivers were relatively consistent with respect to the frequency with which they looked to the left, for both the load (mean 1.48) and no-load conditions (mean 1.34). This research was conducted with a hands-free cell phone. It is interesting to note that significant levels of visual distraction occurred despite use of the hands-free design. A better understanding of the ways in which drivers interact with hand-free devices, emanating from future research, should result in improved designs that minimize the amount of distraction.

DISCUSSION

Safety will be amongst the primary objectives of future HCI innovations for telematics. Safety must be accorded at least equal importance to functionality; consequently. HCI research must address the concern that innovative telematics may pose dangerous distractions for drivers. With the explosion in the application of ubiquitous computing within future vehicles, there is an urgent need for usable, integrated designs to ensure that drivers' interactions with systems do not cause an increase in distraction and mental workload, with potential negative implications for safety.

Understanding how to support the interactions with hands-free, speech-based interfaces is critical in minimizing driver distraction. The systematic application of human factors in product development would help to ensure these telematics devices do not directly or indirectly increase the risk of collision or injury to vehicle occupants or other road users. The process would further enhance the usability and appeal of products because it would lead to the development of telematics devices that match user needs in a way that is compatible with and suitable for driving.

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