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Reductions in self-reported stress and anticipatory heart rate with the use of a semi-automated parallel parking system

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ABSTRACT

Drivers' reactions to a semi-autonomous technology for assisted parallel parking system were evaluated in a field experiment. A sample of 42 drivers balanced by gender and across three age groups (20–29, 40–49, 60–69) were given a comprehensive briefing, saw the technology demonstrated, practiced parallel parking 3 times each with and without the assistive technology, and then were assessed on an additional 3 parking events each with and without the technology. Anticipatory stress, as measured by heart rate, was significantly lower when drivers approached a parking space knowing that they would be using the assistive technology as opposed to manually parking. Self-reported stress levels following assisted parks were also lower. Thus, both subjective and objective data support the position that the assistive technology reduced stress levels in drivers who were given detailed training. It was observed that drivers decreased their use of turn signals when using the semi-autonomous technology, raising a caution concerning unintended lapses in safe driving behaviors that may occur when assistive technologies are used.

1. Introduction

While taking an automobile for a drive in the country or just around the community is sometimes seen as a source of escape from the pressures of daily life, seemingly simple acts such as parking a car along a busy city street or backing out of a crowded parking lot can also be significant sources of stress for many individuals. Not only does stress from such tasks, traffic and other factors impact arousal levels while driving (White and Rotton, 1998), it can also have enduring negative emotional effects that impact post-driving behavior as well (Hennessy, 2008; Van Rooy, 2006). Stress can arise from a variety of sources. One source is the amount of actual effort that has to go into carrying out a task. The greater the amount of physical effort or mental concentration that is required, the greater the total workload on the driver (Brookhuis and de Waard, 2001; Wickens and Hollands, 2000). Another source of stress is the level of uncertainty about one's capability to successfully carry out a task or maneuver and the associated anxiety around the risk of error or failure (Matthews, 2002). As noted by Hancock and Desmond (2001), while the terms *stress* and *workload* arise out of somewhat different traditions, there is a great deal of conceptual overlap in describing demands on the individual arising from both internal and external factors.

In a thought paper, Coughlin et al. (2011) proposed concepts and technologies for detecting heightened driver arousal and suggested approaches that offer the potential to bring an operator from an elevated stress level back to an optimal operational state (see also Byrne and Parasuraman, 1996). While some of the technologies envisioned for actively monitoring and encouraging a state change in the driver will likely take some time to be fully realized in production vehicles, there are advanced driver assistance systems being introduced now that are intended to promote wellbeing by reducing the amount of stress associated with particular tasks and maneuvers by employing autonomous or semi-autonomous technologies to supplement or replace basic human control (see Lindgren and Chen, 2006 and Cottrell and Barton, 2013 for reviews). Examples range from semi-autonomous technologies such as adaptive cruise control that automatically adjusts vehicle speed to maintain a safe headway distance from a lead vehicle to blind spot identification systems that provide operators with warning information on the presence of vehicles hidden from their field of view.

While part of the challenge of developing and implementing such systems is technical, equally important considerations include

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the behavioral aspects of use and acceptance. For example, to what extent is the general public willing and able to learn how to engage with new systems, appropriately trust such technologies, or actually use the systems in ways that produce the intended benefits? This may be particularly the case for older drivers for whom many of these technologies represent significant challenges to their mental models of how to operate a vehicle and who may be less trusting of new technologies per se. Braitman et al. (2010) note that several early reviews of driver assistance technologies found the systems were rated as annoying and drivers turned off the systems. Other work suggests that drivers tend to ignore information presented by such systems (Hurwitz et al., 2010) and adapt driving styles to compensate for the added security (Lindgren and Chen, 2006; Sagberg et al., 1997). Finally, a broad range of literature suggests that human capabilities are not optimally suited for overseeing highly autonomous systems (Sheridan, 1995). It is widely hypothesized that human centered automation (Billings, 1997) is the key to effective implementation of autonomous vehicle systems. Driver state detection systems are envisioned to take a major role in providing the connectivity between the driver, vehicle and operating environment.

Coughlin et al. (2011) and Mehler et al. (2009) have proposed that physiological measures can be used in assessing the relative demand placed on the driver by various comfort, safety systems and in-vehicle interfaces. As suggested in Coughlin et al. (2011), integrating these “assessment methodologies into the development process should help manufacturers select optimized designs with the least demand on the driver, resulting in greater user satisfaction, increased safety, and less stress” (p. 20).

This report details findings of an experiment undertaken to evaluate drivers' reactions to a semi-autonomous system for assisted parallel parking. Parallel parking represents a low-speed maneuvering challenge that most drivers confront on a frequent basis. While many drivers appear quite comfortable with this maneuver, others find it an added source of stress and some individuals will go out of their way to avoid parallel parking. If assistive technologies are able to reduce the stress associated with tasks such as parallel parking and backing out of crowed parking spaces, they not only offer the potential for reducing driver stress but may also increase the mobility of individuals who might otherwise restrict their driving to avoid such situations. This is a particular concern for maintaining the mobility of aging drivers. While new assistive technologies offer potential benefits in safety, mobility and other domains, drivers may be hesitant to try and trust new systems for which they lack a mental model and in which they are asked to give-up partial control to an automated system. This experiment was conceived as a “best case” scenario assessment in which a comprehensive orientation would be provided, followed by an evaluation of drivers' reactions to a semi-autonomous technology for assisted parallel parking.

An important aspect of the evaluation methodology employed was the collection of objective physiological data on the stress levels associated with using the technologies in addition to more traditional self-report ratings and evaluations. Self-report evaluations can be useful sources of information on individuals' perceptions and feelings about their interactions with technologies. At the same time, it is important to keep in mind that participants may be biased toward “helping” research by providing answers they think researchers are attempting to find (Orne, 1962). Depending on the context, this phenomenon can be considered as a form of *response bias* or *social desirability bias*. By monitoring participants' physiological arousal levels while engaged in the parking tasks with and without an assistive technology, data can be obtained that can be used to validate the extent to which self-report information represents a reliable evaluation of their experience. Heart rate was selected as a relatively unobtrusive measure that our group has found to be highly sensitive to incremental increases in cognitive demand in both driving simulation and on-road driving studies (Mehler et al., 2012; Mehler et al., 2009; Reimer and Mehler, 2011). Similarly, an early on-road driving study by Brookhuis et al., (1991) demonstrated that the demands of a task delivered over a cell phone resulted in an increase in heart rate. In a simulation experiment, de Waard, et al., (1999) found heart rate to be lower in an automated platooning condition than when participants served as platoon leaders. A later field study by Brookhuis and de Waard (2001) found heart rate elevations during heightened driving demands such as entering a traffic circle. Vivoli, et al., (1993) employed heart rate as a measure of stress during driving and found that the highest mean levels were during traffic jams and bad weather. Moreover, heart rate has frequently been used as an index of stress in the broader research literature (Forsman and Lindblad, 1983; Kudielka et al., 2004).

In summary, the primary goal of the study was to test whether drivers who were given a comprehensive introduction to a semi-autonomous assistive parallel parking technology under realistic field conditions would become comfortable enough with the system to derive subjective and objective benefit from the technology compared to manually parking. Furthermore, if participants experienced the technology, would this change their willingness to consider using the technology in the future?

2. Methods

2.1. Participants

Participants were required to be active, experienced drivers, defined as driving 3 or more times a week and having held a valid driver's license for 3 + years. Additionally, participants needed to demonstrate a safe operating history by reporting a driving record free of accidents for the past year. They had to report being comfortable driving a full-sized sedan such as a Ford or Lincoln as part of the study and be willing to parallel park the test vehicle. The participant group was considered to be relatively healthy compared to an unscreened community sample based on self-report and specified health exclusion criteria including: a variety of major cardiac conditions, hospitalization in the past 6 months, neurological problems, taking medications that cause drowsiness or suggest safety concerns (e.g. anti-psychotic, anti-convulsant, anti-depressant, anti-anxiety). Participants were drawn from community volunteers in the greater Boston area who responded to online, print advertisements or referrals. The final analysis sample consisted of 42 subjects, half male and half female, equally distributed across three age groups (20s, 40s and 60s). The age range for the 20s group was 20–29 with a mean of 23.2 (SD 3.2), 41 to 48 for the 40s group with a mean of 45.1 (SD 2.3), and 60 to 68 for the 60s group with a mean of 65.4 (SD 2.4).

2.2. Apparatus

A 2010 Lincoln MKS equipped with the manufacturer's forward and reverse proximity sensing systems, rear view camera and Active Park Assist™ (APA) was employed as the test platform. The APA system partially automates the activities involved in parallel parking a vehicle. The system is activated by pressing a button low on the center console near the gear shift. This turns on a set of sensors that measure and identify a feasible parking space as the vehicle is slowly driven past a line of parked cars or other potential parking obstacles. When a feasible space is located, the system sounds a tone and displays the text “SPACE FOUND >> PULL FORWARD” as two lines in a two line message center located