Journal of Safety Research 61 (2017) 129–140

Contents lists available at ScienceDirect

Journal of Safety Research

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

The relationship between cell phone use and management of driver fatigue: It's complicated

Dyani Juanita Saxby, [a,*] Gerald Matthews, [b] Catherine Neubauer [c]

[a] Medical College of Wisconsin, 8701 W Watertown Plank Rd, Milwaukee WI, 53226, United States
[b] Institute for Training and Simulation, University of Central Florida, 3100 Technology Pkwy, Orlando, FL 32826, United States
[c] USC Institute for Creative Technologies, 12015 East Waterfront Dr., Los Angeles, CA 90094, United States

ARTICLE INFO

Article history:
Received 26 February 2016
Received in revised form 23 January 2017
Accepted 23 February 2017
Available online 03 March 2017

Keywords:
Passive fatigue
Countermeasures
Driver insight
Automation
Simulation

ABSTRACT

Introduction: Voice communication may enhance performance during monotonous, potentially fatiguing driving conditions (Atchley & Chan, 2011); however, it is unclear whether safety benefits of conversation are outweighed by costs. The present study tested whether personalized conversations intended to simulate hands-free cell phone conversation may counter objective and subjective fatigue effects elicited by vehicle automation. *Method*: A passive fatigue state (Desmond & Hancock, 2001), characterized by disengagement from the task, was induced using full vehicle automation prior to drivers resuming full control over the driving simulator. A conversation was initiated shortly after reversion to manual control. During the conversation an emergency event occurred. *Results*: The fatigue manipulation produced greater task disengagement and slower response to the emergency event, relative to a control condition. Conversation did not mitigate passive fatigue effects; rather, it added worry about matters unrelated to the driving task. Conversation moderately improved vehicle control, as measured by SDLP, but it failed to counter fatigue-induced slowing of braking in response to an emergency event. Finally, conversation appeared to have a hidden danger in that it reduced drivers' insights into performance impairments when in a state of passive fatigue. *Conclusions*: Automation induced passive fatigue, indicated by loss of task engagement; yet, simulated cell phone conversation did not counter the subjective automation-induced fatigue. Conversation also failed to counter objective loss of performance (slower braking speed) resulting from automation. Cell phone conversation in passive fatigue states may impair drivers' awareness of their performance deficits. *Practical applications*: Results suggest that conversation, even using a hands-free device, may not be a safe way to reduce fatigue and increase alertness during transitions from automated to manual vehicle control.

1. Introduction

The media has suggested that devices allowing for hands-free cell phone communication might serve to improve alertness and performance in monotonous, fatiguing driving situations (Pope, 2009). Anecdotal reports found on driving forums indicate some drivers seem to agree (Weatherson, 2010). Some drivers apparently use cell phone conversation routinely during long, monotonous drives because they perceive it helps reduce fatigue and improve alertness. Yet, this suggestion runs counter to the known dangers of distraction from phoning (Strayer & Drews, 2007), and few studies have investigated costs and benefits of phone conversation in fatigued drivers. Naturalistic driving studies have demonstrated that the risk of cell phone conversation while driving is not completely understood. Victor et al. (2014) analyzed data from The Second Strategic Highway Research Program (SHRP2) and found that talking or listening on a cell phone was likely to decrease crash/near crash risk. Other naturalistic studies (e.g., Fitch et al., 2013; Olson, Hanowski, Hickman, & Bocanegra, 2009) have found that phone conversations do not raise crash risk. Nevertheless, the effects of cell phone use on risk while driving under passive fatigue conditions are often not distinguished from other driving conditions.

In this article, we address the potential efficacy of simulated cell phone conversations as a counter to the fatigue that may be induced by vehicle automation, in relation to subjective and objective outcomes.

1.1. Automation and passive fatigue

Technologies for vehicle automation have advanced to the point where full automation of driving tasks is feasible (Banks, Stanton, & Harvey, 2014), and ‘driverless cars’ are now on certain roads (Payre, Cestac, & Delhomme, 2014). There may be some benefits to high levels of automation (Jamson, Merat, Carsten, & Lai, 2013). Dopart (2015) has pointed out potential benefits including crash avoidance, reduced travel times, improved transportation system efficiency and improved

* Corresponding author at: University of Cincinnati McMicken College of Arts & Sciences, University of Cincinnati, 7148 Edwards One, Cincinnati, OH 45221-0037, United States.
E-mail addresses: dsaxby@mcw.edu (D.J. Saxby), gmatthew@ist.ucf.edu (G. Matthews), catherine.neubauer@gmail.com (C. Neubauer).

http://dx.doi.org/10.1016/j.jsr.2017.02.016
0022-4375/

accessibility, particularly for persons with disabilities and aging adults; however, risks include loss of situational awareness (Young & Stanton, 2007). Attention to tasks may be impaired when the operator's role switches from active management of demands to passive display monitoring, as shown in studies of vigilance decrement (Warm, Parasuraman, & Matthews, 2008).

A special problem in the highly-automated vehicle may be task-related driver fatigue (Neubauer, Matthews, & Saxby, 2012a). In general, driver fatigue may be either active or passive (Desmond & Hancock, 2001; May & Baldwin, 2009; Saxby, Matthews, Warm, Hitchcock, & Neubauer, 2013). Active fatigue is associated with overload and frequent control operations, whereas passive fatigue is elicited by underload and monotony (Desmond & Hancock, 2001). The distinction is important, in part, because the two different types of task fatigue call for different countermeasures (May & Baldwin, 2009). In recent research, Saxby et al. (2013) induced active fatigue during a simulated drive by exposing drivers to wind gusts to increase the required number of steering and acceleration changes. Passive fatigue was elicited by placing the driver in a supervisory role over an automated system in which the only task was to detect a signal of an occasional automation failure. In two studies, subjective fatigue was significantly higher in the passive condition, whereas active fatigue was characterized by increases in distress. Performance was assessed in one study. Passively fatigued drivers had significantly higher brake response times to an unexpected event (a van pulling into the road), and higher crash rates compared to actively fatigued drivers, although the former group actually showed better control of lateral position. A further study showed that allowing drivers voluntary control over use of automation was not effective in alleviating either subjective or objective impacts of full automation (Neubauer, Langheim, Matthews, & Saxby, 2012b).

1.2. Cell phone conversation as a countermeasure to automation-induced fatigue?

It is likely that drivers will retain at least some level of control over the vehicle for the foreseeable future, for a variety of reasons including driver preference (Banks et al., 2014; Khan, Bacchus, & Erwin, 2012). However, vehicles may be operated in a mixed mode in which control shifts between automation and the human driver (Khan et al., 2012). For example, one application for full automation is the close-formation platooning of multiple vehicles to ease highway congestion (Shladover, 2007). In such cases, control would be restored to the driver on exiting the highway. Our previous research suggests that the driver would be vulnerable to passive fatigue and loss of alertness under such circumstances (Neubauer et al., 2012b; Saxby et al., 2013), raising the issue of what countermeasures would be effective. Currently, many drivers are exposed to some levels of automation coupled with minimal task demands such as use of cruise control on long stretches of straight highway; thereby, placing the driver in a largely supervisory role, which may induce passive fatigue.

An intriguing possibility is that cell phone conversations may counter fatigue. Anecdotal reports of drivers commonly suggest that talking on a cell phone helps them feel subjectively more alert and less fatigued in monotonous road environments (Lissy, Cohen, Park & Graham, 2000). Tasks requiring voice interaction may be effective in countering sleepiness (Takayama & Nass, 2008) and fatigue associated with prolonged driving (Gershon, Ronen, Oron-Gilad, & Shinar, 2009; Oron-Gilad, Ronen, & Shinar, 2008). However, the cognitive demands of tasks used in these studies, such as playing trivia games (Oron-Gilad et al., 2008), may differ from those of naturalistic conversation, especially when the topic is personally important or involving. Performance costs of conversation appear to be higher than those of information-processing tasks such as word games (Horrey & Wickens, 2006).

Benefits of conversation for the fatigued driver must outweigh any safety hazards of phone use. Typically, researchers have concluded that phone use is distracting, especially when the driver texts or uses smartphone functions (Strayer, 2015). Caird, Johnston, Willness, and Asbridge (2014) point out that different methodologies suggest different conclusions (although they converge for the most severe threats such as texting). Epidemiological and simulation studies fairly consistently show that phone use is associated with elevated crash risk and performance impairment (Strayer, 2015). However, some naturalistic studies (e.g., Fitch et al., 2013; Olson et al., 2009) found that phone conversations do not raise crash risk. If conversation is actually safe, it is worth considering it as a fatigue countermeasure. However, each methodology used has its own limitations (Caird et al., 2014). It is difficult to determine crash risk (Strayer, 2015), and, in naturalistic studies, to attribute safety critical events to fatigue (Knipling, 2015). Epidemiological and naturalistic studies also tend to neglect moderator factors that would be important in designing an intervention, such as variation in driver workload, the content of the conversation, the driver's level of fatigue and individual difference factors (Matthews, Saxby, Funke, Emo, & Desmond, 2011).

The approach adopted in the current study is to focus on the basic science of the impact of a phone conversation on fatigued driver behavior, using simulation to provide experimental control. Two meta-analyses, covering both simulator and field studies, have investigated conversation effects (Caird, Willness, Steel, & Scialfa, 2008; Horrey & Wickens, 2006). Both analyses concluded that cell phone use has significant performance costs as indicated by delayed reaction times, with minimal impact on lane-keeping performance. Further, Caird et al. (2008) found that effect sizes did not differ significantly across simulator and on-road studies, implying that simulator studies can be informative about real driving. If phone conversation is associated with significantly delayed response times to potentially hazardous events (Strayer, Drews, & Crouch, 2006), then caution is needed in advocating for conversation as a countermeasure for fatigue. Phone use effects may vary with the mental state of the driver, but any claim for benefits of phone use requires rigorous substantiation.

Evidence on interaction between phone use and fatigue is limited. An early study of simulated long distance truck driving (Drory, 1985) did show that voice communication improved braking response time to the appearance of tailgate lights during the simulator run, but also elevated subjective fatigue. By contrast, in a field study conducted on a test track, Jellentrup, Metz, and Rothe (2011) found that 5-min phone calls countered driver subjective fatigue, and had a "vitalizing" effect on their mental state. EEG alpha recordings were in line with their subjective report. Eyelid opening measures indicated a positive effect on alertness, but this effect declined with repeated phone calls. Analyses of performance were not reported.

Two recent simulator studies have investigated performance impacts more systematically. Atchley and Chan (2011) specifically sought to explore whether a verbal task might improve performance (vehicle control and response times) during a monotonous drive. Participants were randomly assigned to one of three "interactive verbal tasks," requiring free association, which included: no verbal task, continuous, verbal task, or late verbal task. Atchley and Chan (2011) found that drivers in the late verbal task condition had better vehicle control than those in the other condition. Control was assessed as standard deviation of lateral position (SDLP). They also tended to make fewer abrupt steering maneuvers. However, there was no significant effect of the task manipulation on brake response times to critical events. A follow-up study using a longer simulated drive (Atchley, Chan, & Gregersen, 2014) replicated the beneficial effects of a late verbal task on SDLP.

However, as Atchley et al. (2014) note, it is arguable whether changes in SDLP reflect changes in alertness. The two studies did not confirm the earlier finding (Drory, 1985) that voice communication improved braking response time. It is also unclear whether findings can be generalized to the specific passive fatigue states induced by automated driving. Atchley and Chan (2011) also used wind gusts to maintain engagement, but this manipulation has been shown to induce active