Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Part F 9 (2006) 387–398

TRANSPORTATION
RESEARCH
PART F

www.elsevier.com/locate/trf

Drivers' attitudes toward imperfect distraction mitigation strategies

Birsen Donmez [a], Linda Ng Boyle [a,b,*], John D. Lee [a,b], Daniel V. McGehee [b]

[a] *Department of Mechanical and Industrial Engineering, University of Iowa, 3131 Seamans Center, Iowa City, IA 52242, United States*
[b] *Public Policy Center, University of Iowa, 3131 Seamans Center, Iowa City, IA 52242, United States*

Received 25 July 2005; received in revised form 4 February 2006; accepted 7 February 2006

Abstract

Studies were conducted to assess driver acceptance of and trust in distraction mitigation strategies. Previous studies have shown that in-vehicle tasks undermine driver safety, and that there is a need for strategies to reduce the effects of in-vehicle distractions. Trust and acceptance of such strategies strongly influence their effectiveness. Different strategies intended to reduce distraction were categorized in a taxonomy. Focus groups were conducted to help refine this taxonomy and explore driver acceptance issues related to these strategies. A driving simulator experiment was then conducted using two of the strategies: an *advising* strategy that warns drivers of potential dangers and a *locking* strategy that prevents the driver from continuing a distracting task. These strategies were presented to 16 middle-aged and 12 older drivers in two modes (auditory, visual) with two levels of adaptation (true, false). Older drivers accepted and trusted the strategies more than middle-aged drivers. Regardless of age, all drivers preferred strategies that provided alerts in a visual mode rather than an auditory mode. When the system falsely adapted to the road situation, trust in the strategies declined. The findings show that display modality has a strong effect on driver acceptance and trust, and that older drivers are more trusting and accepting of distraction mitigation technology even when it operates imperfectly.

Keywords: Driver distraction; Trust; Acceptance; System adaptation; System reliability; Age

1. Introduction

Driver distraction can be defined as the diversion of driver attention away from the driving task and can be characterized in several ways. Both a driver's willingness to engage in a non-driving task and the attentional demands placed on the driver by that task contribute to the potential for distraction. Drivers do not always appropriately divide their attention between potentially conflicting activities, creating hazardous situations. The introduction of advanced technologies (e.g., navigational displays) to the driving domain raises additional

---

[*] Corresponding author. Address: Department of Mechanical and Industrial Engineering, University of Iowa, 3131 Seamans Center, Iowa City, IA 52242, United States. Tel.: +1 319 384 0554; fax: +1 319 335 5669.
E-mail addresses: lnboyle@engineering.uiowa.edu, linda-boyle@uiowa.edu (L.N. Boyle).

1369-8478/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.trf.2006.02.001

concerns, because such systems may reduce driving safety by distracting the driver in critical situations and requiring too much driver attention (Verwey, 2000). It is, therefore, important to develop distraction mitigation strategies that will help reduce driver distraction.

Driver distraction mitigation strategies are diverse. Approaches to mitigating the effects of distraction may consider in-vehicle devices as conversational partners, and use concepts of communication theory to reduce distraction (Wiese & Lee, in press). According to this approach, distraction might be reduced if in-vehicle devices included some of the same conversational mechanisms that people use to coordinate their interactions. Another approach is to consider distraction mitigation strategies as a form of automation. Such automation adapts to the driver or to the roadway situation to encourage drivers to attend to the road and respond to critical roadway demands. Extensive research concerning automation in other domains can provide insights into how drivers may use or rely on distraction mitigation strategies that may or may not adapt appropriately (Sarter, Woods, & Billings, 1997; Sheridan, 2002).

Trust is a particularly important factor influencing the use of and the reliance on automation, and can also impact the effectiveness of different strategies. Miscalibrated trust and the potential for misuse and disuse of automation may result in a failure to provide expected benefits (Parasuraman & Riley, 1997). As distrust may lead to the disuse of the automation, mistrust can lead to a failure to monitor the system's behavior properly and to recognize its limitations, thereby leading to inappropriate reliance on the system (Lee & See, 2004). Over-reliance on the system might amplify risk-taking behavior as the driver places more trust in the automation. In situations of over-reliance, the failure of high levels of automation might lead to more severe safety problems than lower levels of automation. High levels of automation may also lead to lower situation awareness (Endsley, 1995) and greater dependence, thereby generating more opportunities to engage in risk-taking behavior. However, situations with time-critical elements (e.g., impending crash) do require higher levels of automation (Moray & Inagaki, 2003). If the system senses a near-fatal situation, the level of automation should be high enough to take control immediately. That is, if the driver is going to crash, the vehicle should take action.

Appropriate reliance on automation also depends on the performance of the automation and whether or not it is adapting appropriately to the driver state and situational demands. A system that falsely adapts takes action when there is no need, or takes inappropriate or no action when there is a need. False system adaptation undermines drivers' response to and acceptance of the system, which in turn influences overall system effectiveness (Parasuraman, Hancock, & Olofinboba, 1997). False adaptation includes both false positives (an alarm given when no impending collision is present) and false negatives (an alarm not given when an impending collision is present). In these scenarios, distrust and disuse can result from high false-alarm rates. Due to the low base rate of collision events, the probability of a collision when a warning is given can be quite low, while the false-positive alarm rate can be quite high, even if the warning system is highly advanced. High false alarm rates can also lead to driver frustration, which is itself a type of emotional distraction that can undermine traffic safety (Burns & Lansdown, 2000).

False adaptation and diminished trust can undermine driver acceptance. Driver acceptance depends on ease of system use, ease of learning, perceived value, advocacy of the system or willingness to endorse, and driving performance (Stearns, Najm, & Boyle, 2002). Each of these components presents complex behavioral phenomena which impact the joint performance of the driver and in-vehicle technology. Acceptance interacts with trust such that low levels of acceptance lead to disuse. Higher levels of trust, however, do not necessarily lead to greater acceptability of technology (Siegrist, 2000). Therefore, driver acceptance of a distraction mitigation strategy should be assessed before the strategy is implemented.

Driver acceptance can also be influenced by the presentation modality. If the strategy uses an alarm or a display that is perceived as demanding (i.e., ease of use), or non-intuitive (i.e., ease of learning), acceptance will be low. Some of the most common modalities employed in warning systems and displays are visual and auditory (Wickens & Hollands, 1999). Because visual warnings demand the same cognitive resource as the driving task, these strategies may be less effective (Wickens, Lee, Liu, & Gordon, 2003). However, even though auditory warnings are omni-directional, and hence may be more effective, some sounds may be annoying (Berglund, Harder, & Preis, 1994), particularly highly urgent warnings (Wiese & Lee, 2004).

Age is also a factor that affects attitudes towards technology. In general, older adults have less positive attitudes towards technology (Brickfield, 1984; Kantowitz, Hanowski, & Kantowitz, 1997). Other studies have shown that older drivers may also put more trust in technology (Fox & Boehm-Davis, 1998). These findings suggest that older drivers' perceptions are highly dependent on the types of technology assessed. For example, collision warning systems may directly compensate for cognitive impairments in older drivers and hence increase trust, whereas navigational displays may place greater demands on drivers and thus diminish trust.

To further explore the relationship of drivers' attitudes toward imperfect mitigation strategies for different age groups and presentation modalities, a taxonomy was created to systematically identify different mitigation strategies based on different dimensions of automation. This taxonomy, which was initially discussed by Donmez, Boyle, and Lee (2003), embodies a conceptual model and helped guide this research in several ways. First, it provided a classification scheme based on dimensions previously identified as relevant to distraction mitigation; those dimensions are automation level, initiation type, and task relevancy. Second, the classification helped identify gaps in research and areas where additional strategies were needed. Focus groups were then conducted to assess drivers' acceptance of and trust in all the strategies (existing and innovative) as defined in the taxonomy. A driving simulator study was designed to further assess trust and acceptance using two of the more innovative strategies defined there.

The objective of this study is to understand how imperfect distraction mitigation strategies can influence drivers' attitudes toward these strategies. It is hypothesized that differences in trust and acceptance will exist among drivers of different age groups, and that these differences will be influenced by presentation modality and system imperfections. Depending on drivers' perceptions of system benefits, the level of automation may have varying impacts. Older drivers with degraded driving abilities may be more trusting and accepting of high levels of automation compared to younger drivers. Similarly, system imperfections may result in a larger decrement in trust and acceptance for high levels of automation than for low levels.

2. Categories of mitigation strategies

A taxonomy of driver distraction mitigation strategies was developed based on three dimensions: the level of automation, initiation type, and the task being modulated by the strategy. These dimensions were considered critical for the development of mitigation strategies because of their potential influence on drivers' responses and attitudes. Twelve unique mitigation strategies were defined and categorized in terms of these dimensions. Based on recent definitions of automation levels (Parasuraman, Sheridan, & Wickens, 2000; Sheridan, 2002), high (e.g., automation takes control and ignores human), moderate (e.g., automation executes action only if human approves) and low (e.g., automation provides information only) levels of automation were included (Table 1). The taxonomy also defined mitigation strategies according to whether the strategies address driving-related tasks (e.g., steering, braking) or non-driving-related tasks (e.g., tuning the radio, talking on the cell phone) (Ranney, Mazzae, Garrott, & Goodman, 2000; Wierwille, 1993). Strategies that address driving-related tasks focus on the roadway environment and directly support driver control of the vehicle, whereas strategies for non-driving related tasks focus on modulating driver interaction with in-vehicle systems. Within these categories, the mitigation strategies were categorized according to two initiation types: system initiated (i.e., where the system is the locus of control) and driver initiated (i.e., where the driver is the locus of control).

System-initiated strategies, under the category of driving-related tasks, aim to enhance safety by directing driver attention to the roadway and/or by directly controlling the vehicle. *Intervening* is characterized as the highest level of automation in this category, since it refers to the system taking control of the vehicle and

Table 1
Taxonomy of distraction mitigation strategies

Level of automation	Driving related strategies		Non driving related strategies	
	System initiated	Driver initiated	System initiated	Driver initiated
High	Intervening	Delegating	Locking and interrupting	Controls pre-setting
Moderate	Warning	Warning tailoring	Prioritizing and filtering	Place-keeping
Low	Informing	Perception augmenting	Advising	Demand minimizing

performing one or more driving-related tasks during hazardous situations when the driver is too distracted to react in a timely manner. *Warning* alerts the driver to take a necessary action. A collision avoidance system is a *warning* system that can include both visual and audio alerts. *Warning* is considered a moderate level of automation compared to *intervening* as the driver remains in control of the vehicle. *Informing* provides drivers with necessary information that they typically would not observe if distracted. For example, a speed limit indicator might provide information on changes in posted speed limits. This strategy is considered a low level of automation since information is provided in a way that does not require any action from the system.

Driving-related, driver-initiated strategies mitigate distraction by having the driver activate or adjust system controls that relate to the driving task. The driver-initiated strategies that correspond to high, moderate and low levels of automation are classified as: *delegating, warning tailoring* and *perception augmenting*, respectively. *Delegating* is driver initiation of an automatic vehicle control capable of sharing the driving task, such as adaptive cruise control where the system assumes longitudinal control of the vehicle. This strategy distributes the driver workload differently, and therefore may reduce the attentional and biomechanical demands posed by the driving task. The *warning tailoring* strategy refers to driver adjustment of the sensitivity of the warning system depending on the distracting activities the driver expects to perform. This differs from the *warning* strategy described in the previous section because driver input is required. *Perception augmenting* provides driver information at the driver's request. This can help reduce the demands put on the driver to locate necessary information (e.g., driver's speed, posted speed) while driving, thereby decreasing the level of distraction.

Non-driving-related mitigation strategies aim to reduce driver distraction by limiting attention paid to the in-vehicle system, rather than by directly influencing the driving task. Like the driving-related strategies, these strategies can also be subcategorized as system initiated and driver initiated. System-initiated, non-driving-related strategies assume that when the driving performance is or will be significantly deteriorated, the system will take action and change the nature of the non-driving-related task. *Locking* and *interrupting* can be classified as high level automation in this category, since *interrupting* discontinues the non-driving activities and *locking* locks out the system associated with these activities when attention to the primary driving task is required. *Prioritizing and filtering* information presented to the driver minimizes the number of non-driving-related tasks that can be performed in high-load situations; these strategies fit under the moderate level of automation category when compared to *interrupting* and *locking*. For example, under high-demand driving conditions, depending on the criticality of the situation, incoming calls can either be filtered (the phone is not allowed to ring) or prioritized (only calls listed by the driver as highly important are allowed). *Advising* gives drivers feedback regarding the degree to which a non-driving task can distract given a demanding road or traffic situation. A background sound on a cellular telephone conversation could remind both parties that one is driving. This sound could be modulated according to the driving situation. For example, an "*advising*" background sound could become more intense as vehicle speed and traffic density increase. This strategy is considered a low level of automation since it simply informs the driver without taking any action.

The non-driving-related, driver-initiated strategies rely on drivers to modulate their non-driving tasks according to their subjective degree of distraction. *Controls pre-setting* is categorized as the highest level of automation for a driver-initiated option in the non-driving related scenarios. For example, the driver can pre-set the radio or CD player or the destination on navigational devices and then not have to modify it again while driving. *Place keeping* minimizes the demands of switching between the driving and the non-driving-related tasks. Task switching involves directing attention from one task to another (e.g., talking on the cell phone to braking and back to talking on the cell phone). As the number of tasks a person has to simultaneously perform increases, the more difficult it is for the driver to perform these tasks because task switching requires a certain amount of attention. *Demand minimizing* reduces attentional demands associated with non-driving-related tasks by creating low-demand interfaces (e.g., using steering-wheel-mounted controls, voice activation or hands-free devices) and therefore corresponds to a low level of automation.

The dimensions that define this taxonomy reveal general considerations for distraction mitigation strategies. Driver-initiated strategies depend on the driver to recognize the degree of distraction and react appropriately. More importantly, these strategies may be susceptible to behavioral adaptation in which making the system easier to use increases the safety of individual transactions, but leads drivers to increase the number of transactions, diminishing the overall safety of the driver. System-initiated strategies depend on drivers' acceptance of and appropriate reliance on the system. Potentially hazardous situations can occur if the driver relies too much on the system and the system fails to provide the necessary information or take proper action.

Focus groups were conducted to assess drivers' acceptance and trust of different mitigation strategies defined during the development of the taxonomy presented above. Focus groups have previously been used in transportation and other research to gain perspective on and insights into an issue (Lerner, 2005; Rivers, Sarvela, Shannon, & Gast, 1996; Rogers, Meyer, Walker, & Fisk, 1998; Yassuda, Wilson, & von Mering, 1997). Although, the small number of participants in focus groups limits generalization to a larger population (Rogers et al., 1998; Stewart & Shamdasani, 1990), the insight gained from this type of exploratory research is valuable in developing hypotheses and in formulating more precise research questions. The strategies were presented to two sets of focus groups in rural (Iowa City, IA) and urban (Seattle, WA) settings. Participants' ages ranged from 22 to 64 years ($\overline{X} = 37.8$, $\sigma = 11.8$).

The focus group moderators informed the participants about driver distraction and included a brief overview of the different types of distractions. Specifically, illustrations of visual only, visual manual, manual only, and cognitive distraction were presented (Ranney et al., 2000; Wierwille, 1993). In addition, the sources of known distraction were demonstrated, including distractions from in-vehicle technology (e.g., radio), distractions from other passengers, and external distractions (e.g., billboards). Participants also viewed a 12-min video on driver distraction that showed drivers engaged in various distractions. The questions posed to participants assessed (1) the types of distractions in which they had previously been engaged; (2) what had helped to bring their attention back to the driving task; (3) how passengers had mitigated distractions; (4) how passengers had been annoying; (5) given the technology available, what could help them in a distracting situation; and (6) what strategies they would consider helpful.

Although drivers admitted that non-driving-related in-vehicle tasks (e.g., talking on cell phones, changing CDs, tuning the radio) are distracting, most also indicated that they would continue to use in-vehicle devices and perform other types of distracting activities unless there are laws forbidding it. Thus, drivers were interested in systems that would allow them to perform non-driving-related tasks more safely. However, some drivers expressed concern that high levels of automation might not be prepared to handle unexpected situations. Most drivers considered moderate levels of driving-related automation helpful. For non-driving-related automation, most drivers advocated a low level of automation, specifically an *advising* strategy that would enable them to be more aware of their driving behavior and how it might affect others. Some drivers expressed negative attitudes towards interruptions of their non-driving tasks, such as cell phone conversations. On the other hand, many other drivers believed that rather than making the tasks easier to perform, the systems should prevent drivers from engaging in dangerously distracting non-driving activities. Some drivers expressed great interest, while others were skeptical of any intervention. Generally, drivers agreed that the utility of any system would depend on its reliability. Overall, the participants' responses helped the researchers generate ideas that have not been cited in previous literature, to further develop the taxonomy, and to assess how the various strategies might affect acceptance.

3. Assessing acceptance and trust

The focus groups helped us define some key characteristics for mitigation strategies and to determine what types of systems may be more acceptable to drivers. Of the mitigation strategies presented in the taxonomy, the majority of previous research has focused on driving-related strategies. Of the non-driving-related strategies, only *demand minimizing* has been investigated as a potential means of reducing distraction (Lee, Caven, Haake, & Brown, 2001). Because the number of non-driving-related devices is growing, and drivers indicated a preference for continued use of these devices, acceptance of mitigation strategies aimed at adjusting drivers' engagement in non-driving related tasks were further explored. Strategies tested included *advising* and *locking,* which represent the extreme ends of automation (high and low) under the non-driving-related, system-initiated category. Although it would have been useful to explore the mid-levels of automation as well, it was important to initially investigate the extremes to assess the general effect of automation level on trust and acceptance. These two strategies were evaluated under auditory and visual presentation modalities. The system-initiated categories were investigated because they appear to influence acceptance and trust more than the driver-initiated strategies.

3.1. Methodology

A simulator study was designed to assess drivers' acceptance of and trust in non-driving-related mitigation strategies. Given the focus groups' varying opinions on automation, this categorization was further tested based on a high or low level of automation. This study examines *advising* and *locking* strategies when presented in visual and auditory modalities to different age groups. Allocation of attentional resources was controlled for in this study by displaying the same presentation modality for the strategies and the secondary task. That is, the strategies were presented in their respective contexts; visual strategies for visual distractions and auditory strategies for auditory distractions. Previous research has shown that both auditory and visual tasks can distract drivers with a significant degradation in driving performance (Cooper & Zheng, 2002; Cooper et al., 2003; Lee, McGehee, Brown, & Reyes, 2002).

3.1.1. Participants

Twenty-eight drivers participated in this study: 16 middle-aged (range: 35–55; $\overline{X} = 45$, $\sigma = 17.1$) and 12 older drivers (range: 65–75; $\overline{X} = 69$, $\sigma = 11.3$). The participants received a bonus of up to $10 depending on their performance on the task. This enabled the experimental task to more realistically simulate drivers' interaction with in-vehicle systems by ensuring that the secondary task was important to the driver.

3.1.2. Equipment

The experiment was conducted in a fully integrated, fixed-based driving simulator. The simulator has a 1992 Mercury Sable vehicle cab equipped with force feedback steering wheel, actual gauges, and a rich audio environment. Driving scenarios were created using HyperDrive™ Authoring Suite, and were projected onto a screen with a 50° field of view. The fully textured graphics were generated with a 60-Hz frame rate at 1024 × 768 resolution. All graphics for roadway layouts, markings, and signage conform to American Association of State Highway and Transportation Officials (AASHTO) and Manual of Uniform Traffic Control Devices (MUTCD) design standards. Driving data were collected at 60 Hz.

A 7-in. LCD (60-Hz frame rate at 640 × 480 resolution) mounted on the dashboard with a small stand was used to present the visual messages in the secondary task. The viewing angle from the driver's eye point was approximately 18°. Auditory messages used in the secondary task were converted into. wav audio files through the Ultra Hal Text-to-Speech Reader, Version 1.0, created by Zabaware, Inc. An adult, male, North American English native voice was mastered using a Microsoft SAP14 Text-to-Speech Synthesis Machine. Both of the message systems (visual and auditory) were operated on a standard PC in Microsoft Visual Basic.

3.1.3. Procedure

After signing an informed consent, the participants were asked to complete a practice drive. For all driving scenarios, participants were instructed to drive at a comfortable speed that did not exceed the speed limit of 45 mph and to follow a lead vehicle that periodically braked at a mild rate of deceleration (0.2 g) for five seconds. All driving scenarios took place on simulated two-lane rural roads with 12 braking events in each driving scenario. Half of the braking events were on curves and half were on the straight sections of the drive. To make the scenario more realistic, different radius curves were used; half of the curves were 400-meter radius (three left turn, three right turn) and the other half were 200-meter radius (three left turn, three right turn).

Two distraction mitigation strategies were implemented to either advise the driver to discontinue the non-driving-related task (*advising*) or to lock out the interaction with the system completely (*locking*). Both of the strategies were mapped to the driving events that require an appropriate response from the driver. These two events were the lead vehicle braking and the curve entry ahead. Curve entry ahead refers to road sections consisting of the two-seconds-long straight section before a curve together with the initial three-seconds-long drive section of the curve. The participant was told that the strategies would take action when he/she should be attending to the roadway, specifically when the lead vehicle was braking or when there was a curve ahead. The mitigation strategies were implemented between scenarios. That is, each mitigation strategy was tested with a separate experimental drive.

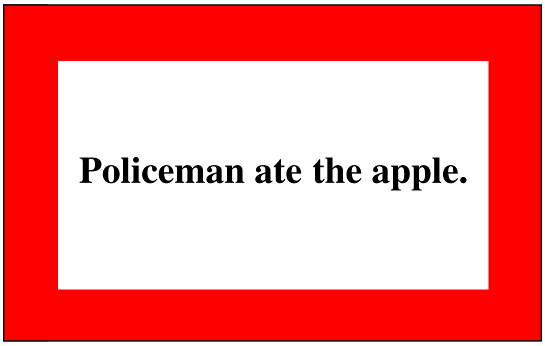
The secondary task was based on the working memory span task defined by Baddeley, Logie, and Nimmo-Smith (1985), and was displayed to the participant on an LCD display for the visual task and by a synthetic voice for the auditory task. The secondary task required the participant to determine if a short sentence was meaningful or not (response by pushing steering wheel buttons) and then to recall the subjects of three consecutive sentences (verbal response). For example "the policeman ate the apple" is meaningful and its subject is "policeman," whereas "the apple ate the policeman" is not meaningful and its subject is "apple." The button-press and verbal recall tasks provided a controlled exposure to the visual, auditory, motor, and cognitive distraction associated with in-vehicle information system interaction and was similar to the tasks used in other driver distraction studies (Radeborg, Briem, & Hedman, 1999). Feedback regarding performance with the secondary task was provided to the participant at the end of each drive.

For the visual secondary task, *advising* was implemented with a red bezel around the screen (Fig. 1). The red bezel illuminated whenever there was a lead vehicle braking or curve entry ahead (five seconds for both conditions). In the *advising* condition, the driver was still able to interact with the system. The *locking* strategy blanked the screen and illuminated the red bezel. The red bezel and the lockout remained in effect until the triggering condition was over (i.e., the lead vehicle braking or curve entry). For the auditory secondary task, *advising* was implemented with a periodic clicking noise (1 Hz) whenever there was a lead vehicle braking or curve entry ahead. Again in the *advising* condition, the driver was still able to interact with the system. The *locking* strategy stopped the task message presentation and presented the periodic clicking noise to the driver. The lockout remained in effect until the triggering condition was over. There were separate experimental drives for each level of the secondary task (visual/auditory).

The system adaptation (true, false) was implemented between days with the order of presentation counterbalanced between two days. That is, a random half of the participants began with the true system adaptation on the first day whereas the other half received the false adaptation on the first day. True system adaptation refers to the system properly adapting to the road condition. False system adaptation occurs when the system fails to adapt appropriately, producing both false alarms (i.e., takes action when it is not supposed to) as well as misses (i.e., does not take action when it is supposed to). These two types of imperfections in false adaptation may affect driver acceptance, trust, and use of the system and needs further exploration. However, for this initial investigation, the effects of the misses and false alarms in the false adaptation condition were not differentiated. For the purpose of creating a faulty system, both of these imperfection types were implemented together under the condition of false system adaptation to form a 50% reliable system in which the number of hits, false alarms and misses were equal. In any given condition, there were 12 braking events and 12 curve entries to which the system had to respond. In the true adaptation condition, there were a total of 24 alarms (*advising* or *locking*) for these braking events and curve entries. In the false adaptation condition, there were 12 false alarms and 12 hits, with an equal number randomly assigned to curves and straight sections. The duration of alarms was equal for each drive. Participants were not told whether or not the drives would involve false or true system adaptation.

3.1.4. Experimental design

The experiment was a 2^4 repeated measures design with two levels for each of the four independent factors: age (middle-aged/old), mitigation strategy (advising/locking), secondary task (visual/auditory), and system



Policeman ate the apple.

Fig. 1. Advising strategy in visual mode.

adaptation (true/false). Each factor and level was tested in a separate drive. Age was the only between-subjects factor. System adaptation was collected over two days (i.e., adaptation was blocked on days) with the order of presentation for each level counterbalanced between subjects. The blocking and the counterbalancing were introduced to eliminate carryover effects of system adaptation. The order of the experimental conditions presented within a day was randomized between subjects.

3.1.5. Acceptance and trust measures

An acceptance questionnaire based on Van Der Laan, Heino, and De Waard (1997) was given to the participants after each drive. The questionnaire was composed of nine questions investigating two dimensions of acceptance: usefulness and satisfying. Before analysis, the acceptance questionnaire was recoded to fall along a scale of −2 to +2 (−2 representing the lowest level of acceptance and +2 the highest level). These numbers were then averaged to obtain a metric for usefulness and satisfying as defined in Van Der Laan et al. (1997). Participants completed additional questionnaires to assess acceptance of the *advising* and *locking* strategies if they were embedded in current in-vehicle system features (radio, cell phone, e-mail).

A system trust questionnaire based on Wiese (2003) and Bisantz and Seong (2001) was also given to participants. Two statements used from the questionnaire were ‘I trust the safety system’ and ‘The performance of the safety system enhanced my driving.’ A −2 (strongly disagree) to +2 (strongly agree) Likert scale was used to code the responses. The overall trust metric was obtained by averaging the responses for these two questions.

3.2. Results

The mixed procedure in SAS 9.0 with Sattherwaitte’s approximation for unequal variance was used to analyze the data. This approximation will result in degrees of freedoms for the error term reported in decimals. Our results show that middle-aged and older participants differed in their response to the strategies. Older participants perceived the strategies to be more useful ($F(1,26.5) = 9.43$, $p < 0.005$, Δ (mean difference) = 0.56, 95% CI (confidence interval) for Δ: 0.18–0.93) and more satisfying ($F(1,26.7) = 11.43$, $p < 0.005$, $\Delta = 0.68$, 95% CI: 0.27–1.10) compared to the middle-aged group (Fig. 2). Older drivers also tended to accept non-driving-related, system-initiated mitigation strategies more than middle-aged drivers. However, regardless of age group, visual strategies were perceived to be more satisfying ($F(1,160) = 40.3$, $p < 0.0001$, $\Delta = 0.53$, 95% CI: 0.37–0.70) and more useful ($F(1,158) = 21.66$, $p < 0.0001$, $\Delta = 0.35$, 95% CI: 0.20–0.50) than auditory strategies. These findings confirm the focus group results regarding the preferred display modality. Focus group participants preferred visual compared to auditory-based strategies.

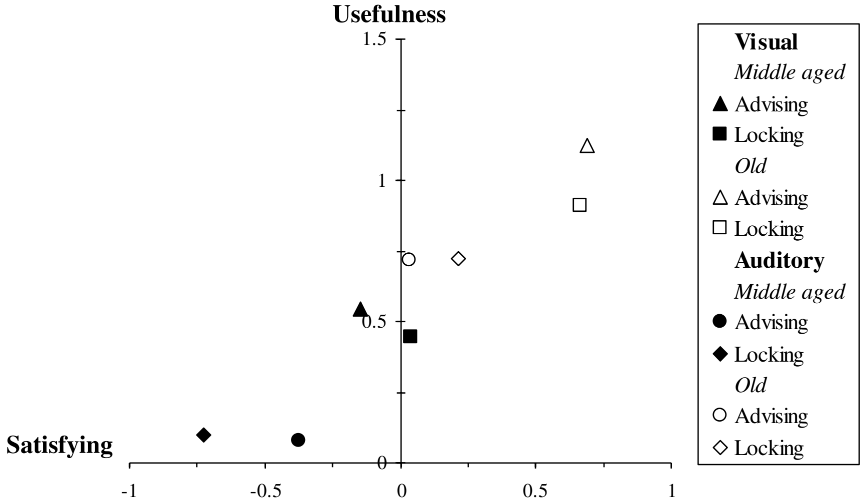


Fig. 2. Acceptance of mitigation strategies by age group and presentation modality.

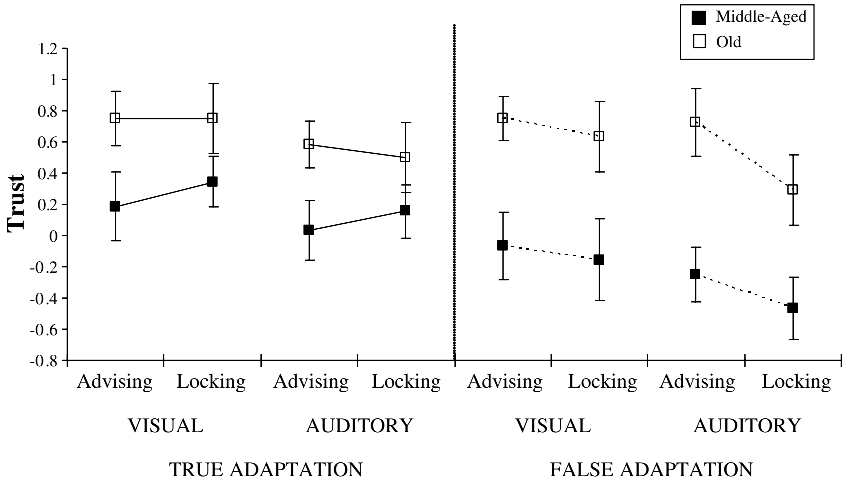


Fig. 3. Trust on mitigation strategies by system adaptation, age group, and presentation modality.

The older participants trusted the systems more than the middle-aged participants ($F(1,26.8) = 9.84$, $p < 0.005$, $\Delta = 0.63$, 95% CI: 0.22–1.04) (Fig. 3). System adaptation, which emerged as an important issue from the focus group findings, are also supported by the experimental data. As expected, the accurate systems resulted in higher trust than the imperfect systems ($F(1,27.2) = 6.21$, $p < 0.05$, $\Delta = 0.27$, 95% CI: 0.05–0.49). Participants also trusted the visual strategies more than the auditory strategies ($F(1,160) = 10.07$, $p < 0.005$, $\Delta = 0.22$, 95% CI: 0.08–0.36). There were no significant differences between the *advising* and *locking* strategies for acceptance ($p > 0.05$), and for trust ($p > 0.05$).

Pearson correlation coefficients for three variables—level of trust in the driver distraction mitigation strategy, usefulness, and satisfying—were also investigated. As the level of usefulness increased, so did the driver's level of trust ($\rho = 0.731$, $p < 0.0001$). Likewise, as satisfaction increased, so did the level of trust ($\rho = 0.629$, $p < 0.0001$).

After driving in the simulator and experiencing the various mitigation strategies, drivers rated their acceptance of these same strategies as applied to existing in-vehicle information systems, such as cellular phones, voice activated e-mail messages, and radio controls. These in-vehicle systems were evaluated so that drivers' experiences in the simulator could be extrapolated to other in-vehicle technologies. There were significant

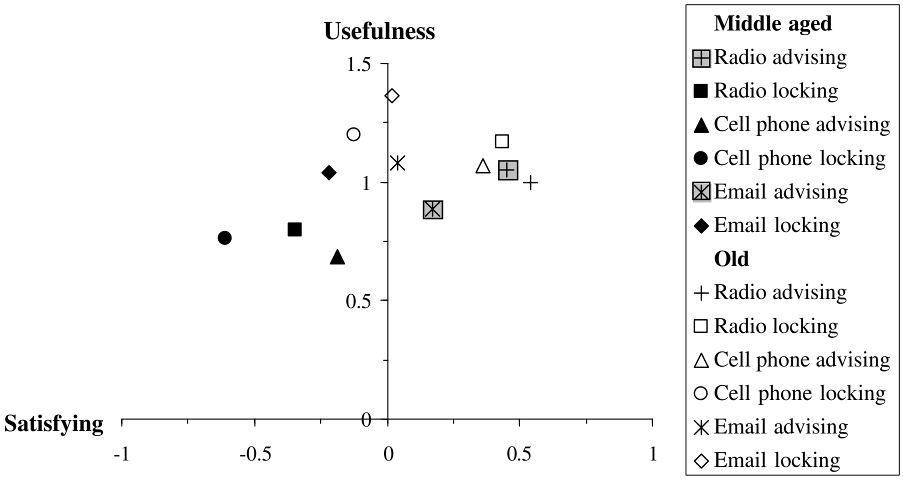


Fig. 4. Acceptance of mitigation strategies embedded in current in-vehicle systems.

differences between different systems in terms of satisfaction ($F(5,160) = 2.42$, $p < 0.05$) (Fig. 4). In general, participants were more satisfied with a visual *advising* strategy (such as a red bezel) on their radio when compared to an auditory *locking* strategy for their cell phone ($t(160) = -3.35$, $p < 0.001$, $\Delta = 0.89$, 95% CI: 0.37–1.42) or e-mail ($t(160) = -2.28$, $p < 0.05$, $\Delta = 0.61$, 95% CI: 0.08–1.13). Therefore, a visually-based alert which does not lock the in-vehicle task appears to be more acceptable than an auditory *locking* alert. There was also an age difference, with older participants perceiving the strategies embedded in in-vehicle systems to be more useful ($F(1,160) = 4.63$, $p < 0.05$, $\Delta = 0.28$, 95% CI: 0.02–0.53) and more satisfying ($F(1,160) = 4.58$, $p < 0.05$, $\Delta = 0.33$, 95% CI: 0.03–0.64) than middle-aged drivers.

3.3. Discussion

The experiment revealed that older drivers accepted the distraction mitigation strategies more than middle-aged drivers. Older drivers generally have decrements in their driving, task switching and divided attention performance (Ball & Owsley, 1991; Kray & Lindenberger, 2000; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). These decrements in performance may lead to greater workload and less self-confidence, which may in turn lead to higher acceptance and trust of strategies that can help older drivers maintain safer driving. Other studies have also shown that this age group tends to trust in-vehicle systems more than other driver age groups (Fox & Boehm-Davis, 1998). Middle-aged drivers may accept such strategies less because they get fewer benefits in terms of safer driving and are annoyed with the interventions in their own non-driving-related activities.

Auditory strategies were less accepted than the visual strategies, and false adaptation resulted in lower levels of trust. Trust was also found to be positively correlated with the acceptance measures: usefulness and satisfaction. This is important because trust in a system is likely to guide drivers' reliance on it. Information from systems with imperfections may be best conveyed to drivers using visual displays rather than auditory displays because auditory displays tend to be trusted less and perceived as generally less useful.

4. General discussion

Focus group and driving simulator studies were conducted to investigate whether adaptive in-vehicle systems designed to mitigate distraction will be accepted by drivers and could thereby reduce the number of crashes and fatalities that occur each year. Because many focus group participants indicated that they have been distracted while driving and did not want to give up their in-vehicle devices unless required to by law, investigating strategies that help reduce the distraction from these devices were of great importance.

The simulator study showed that drivers clearly will put more trust in a system that adapts appropriately to the situational demands than in one that does not. However, the effectiveness of the strategies can have an influence on this outcome. In previous findings by Donmez, Boyle, and Lee (in press), where only the true adaptation was investigated, strategy did indeed influence driver performance, with effectiveness being highly dependent on the presentation modality and the type of distractions encountered by the driver. In their study, for the auditory condition, both *advising* and *locking* strategies resulted in enhanced response to the lead vehicle braking event and better speed maintenance entering curves. The *advising* strategy was more beneficial to older drivers when compared to the *locking* strategy. Under the visual condition, the *locking* strategy was particularly beneficial to middle-aged drivers' braking response under visual distractions. In the current study, violations of the *advising* strategy recommendations were not assessed since there was no eye-tracking or video data collected. However, there are clear benefits in assessing drivers' engagement in distracting activities and their compliance with an *advising* strategy, and this should be examined in future studies.

Little research has addressed trust in and acceptance of in-vehicle systems as they relate to driver age. The results of the driving simulator study showed that older drivers accept and trust strategies that autonomously modulate their in-vehicle system interactions (e.g., cell phone conversations) more than middle-aged drivers. Therefore, when designing systems for middle-aged drivers, preserving driver control of the in-vehicle system interactions may be necessary if the strategy is to be accepted. For older drivers, a concern revealed by this study is that older drivers may trust and accept mitigation strategies too much. This may lead to over-dependence on strategies by older drivers. More specifically, the pressures of being a good driver combined with age-related cognitive impairments may lead older drivers to accept any safety information offered to enhance their driving performance, whether true or false. The middle-aged drivers, on the other hand, seemed to be more cautious in accepting or trusting the alerts.

The results indicate that mitigation strategies presented in an auditory format can be very annoying. The auditory mitigation strategies were accepted less than the visual-based strategies. Therefore, when appropriate, warnings should be conveyed visually. However, when drivers are cognitively distracted, an auditory warning may be more effective than a visual one, and the design of any particular system must consider the tradeoff between effectiveness and acceptance. In situations that pose an imminent danger, the system should aim for the highest effectiveness.

This study provides a framework describing the strategies to mitigate driver distraction. It also demonstrated that differences in driver age can affect the trust and acceptance of the non-driving-related strategies. More research is needed to assess how other levels of automation affect the effectiveness of distraction mitigation strategies. For example, differences between automation levels of driving-related strategies, or strategies that directly influence vehicle control should be the focus of future research to provide additional information on acceptance and trust and help guide us on the design of adaptive in-vehicle systems.

Acknowledgements

This research was conducted as part of the SAVE-IT program under contract by Delphi Corporation and sponsored by the National Highway Traffic Safety Administration—Office of Vehicle Safety Research. The authors acknowledge the technical support and comments provided by Mike Perel of NHTSA and Mary Stearns of the Volpe Center. Additional assistance in the review and preparation of the manuscript was also provided by two anonymous reviewers and individuals at the University of Iowa from the Human Factors and Statistical Modeling Laboratory, and Teresa Lopes of the Public Policy Center.

References

Ball, K., & Owsley, C. (1991). Identifying correlates of accident involvement for the older driver. *Human Factors, 33*(5), 583–595.

Baddeley, A., Logie, R., & Nimmo-Smith, I. (1985). Components of fluent reading. *Journal of Memory and Language, 24*, 119–131.

Berglund, B., Harder, K., & Preis, A. (1994). Annoyance perception of sound and information extraction. *Journal of the Acoustical Society of America, 95*, 1501–1509.

Bisantz, A. M., & Seong, Y. (2001). Assessment of operator trust in and utilization of automated decision-aids under different framing conditions. *International Journal of Industrial Ergonomics, 28*(2), 85–97.

Brickfield, C. F. (1984). Attitudes and perceptions of older people toward technology. In J. Livingston & J. E. Birren (Eds.), *Aging and technological advances* (pp. 31–38). New York: Plenum Press.

Burns, P. C., & Lansdown, T. C. (2000). E-distraction: The challenges for safe and usable internet services in vehicles. www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics043100029.htm [Retrieved: July 2004].

Cooper, P. J., & Zheng, Y. (2002). Turning gap acceptance decision-making: The impact of driver distraction. *Journal of Safety Research, 33*, 321–335.

Cooper, P. J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., & Siegmund, G. (2003). The impact of hands-free message reception/response on driving task performance. *Accident Analysis and Prevention, 35*, 23–35.

Donmez, B., Boyle, L., & Lee, J. D. (2003). Taxonomy of mitigation strategies for driver distraction. In *Human factors and ergonomics society 47th annual meeting* Denver, CO (pp. 1865–1869).

Donmez, B., Boyle, L., & Lee, J. D. (in press). The impact of distraction mitigation strategies on driving performance. *Human Factors*.

Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. *Human Factors, 37*(1), 65–84.

Fox, J. E., & Boehm-Davis, D. (1998). Effects of age and congestion information accuracy of advanced traveler information systems on user trust and compliance. *Transportation Research Record, 1621*, 43–49.

Kantowitz, B. H., Hanowski, R. J., & Kantowitz, S. C. (1997). Driver acceptance of unreliable traffic information in familiar and unfamiliar settings. *Human Factors, 39*(2), 164–176.

Kray, J., & Lindenberger, U. (2000). Adult age differences in task switching. *Psychology and Aging, 15*(1), 126–147.

Lee, J. D., Caven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effect of speech-based e-mail on drivers' attention to the road. *Human Factors, 43*, 631–640.

Lee, J. D., McGehee, D., Brown, T. L., & Reyes, M. (2002). Collision warning timing, driver distraction, and driver response to imminent rear end collision in a high fidelity driving simulator. *Human Factors, 44*(2), 314–334.

Lee, J. D., & See, K. A. (2004). Trust in technology: Designing for appropriate reliance. *Human Factors, 46*(1), 50–80.

Lerner, N. (2005). Deciding to be distracted. Paper presented at the Driving Assessment Conference, Maine.

Moray, N., & Inagaki, T. (2003). Attention and complacency. *Theoretical Issues in Ergonomics, 1*(4), 354–365.

Parasuraman, R., Hancock, P. A., & Olofinboba, O. (1997). Alarm effectiveness in driver centered collision warning systems. *Ergonomics, 39*, 390–399.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 230–253.

Parasuraman, R., Sheridan, T., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man and Cybernetics—Part A: Systems and Humans, 30*(3), 286–297.

Radeborg, K., Briem, V., & Hedman, L. R. (1999). The effect of concurrent task difficulty on working memory during simulated driving. *Ergonomics, 42*(5), 767–777.

Ranney, T., Mazzae, E., Garrott, R., & Goodman, M. (2000). *NHTSA driver distraction research: Past, present, and future*. NHTSA.

Rivers, K., Sarvela, P. D., Shannon, D. V., & Gast, J. (1996). Youth and young adult perceptions of drinking and driving prevention programs: A focus group study. *Journal of Alcohol and Drug Education, 41*(2), 80–91.

Rogers, W. A., Meyer, B., Walker, N., & Fisk, A. D. (1998). Functional limitations to daily living tasks in the aged: A focus group analysis. *Human Factors, 40*(1), 111–125.

Sarter, N. B., Woods, D. D., & Billings, C. E. (1997). Automation surprises. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 1926–1943). New York: Wiley.

Sheridan, T. (2002). *Humans and automation: System design and research issues*. New York: Wiley.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195–203.

Stearns, M., Najm, W., & Boyle, L. (2002). A methodology to evaluate driver acceptance. Paper presented at the Transportation Research Board, 81st Annual TRB Meeting, Washington, DC.

Stewart, D. W., & Shamdasani, P. N. (1990). *Focus groups: Theory and practice*. London: Sage.

Van Der Laan, J., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C, 5*(1), 1–10.

Verhaeghen, P., Steitz, D. W., Sliwinski, M. J., & Cerella, J. (2003). Aging and dual-task performance: A meta-analysis. *Psychology and Aging, 18*(3), 443–460.

Verwey, W. (2000). Evaluating safety effects of in-vehicle information systems. In P. A. Hancock & P. A. Desmond (Eds.), *Stress, workload and fatigue* (pp. 409–425). New Jersey: Lawrence Erlbaum Associates.

Wickens, C. D., & Hollands, J. G. (1999). *Engineering psychology and human performance* (3rd ed.). New Jersey: Prentice Hall.

Wickens, C. D., Lee, J. D., Liu, Y., & Gordon, S. E. (2003). *An introduction to human factors engineering* (2nd ed.). New York: Longman.

Wierwille, W. W. (1993). Visual and manual demands of in-car controls and displays. In B. Peacock & W. Karwoski (Eds.), *Automotive ergonomics* (pp. 299–320). Bristol, PA: Taylor and Francis.

Wiese, E. E. (2003). Attention grounding: A new approach to IVIS implementation. Unpublished master's thesis, University of Iowa.

Wiese, E. E., & Lee, J. D. (in press). Attention grounding: A new approach to IVIS implementation. *Theoretical issues in Ergonomics Science*.

Wiese, E. E., & Lee, J. D. (2004). Effects of multiple auditory alerts for in-vehicle information systems on driver attitudes and performance. *Ergonomics, 47*(9), 965–986.

Yassuda, M. S., Wilson, J. J., & von Mering, O. (1997). Driving cessation: The perspective of senior drivers. *Educational Gerontology, 23*, 525–538.