# Assessing the Effectiveness of Interactive Media in Improving Drowsy Driver Safety

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**ABSTRACT**

**Objective:** This study investigated the possibility of using interactive media to help drowsy drivers wake up, thereby enabling them to drive more safely. **Background:** Many studies have investigated the negative impacts of driver drowsiness and distraction in cars, separately. However, none have studied the potentially positive effects of slightly interactive media for rousing drowsy drivers to drive more safely. **Method:** In a 2 (drowsy vs. non-drowsy drivers) x 2 (passive vs. slightly interactive voice-based media) x 2 (monotonous vs. varied driving courses) study, participants (N=80) used a driving simulator while interacting with a language learning system that was either passive (i.e., drivers merely listen to phrases in another language) or slightly interactive (i.e., drivers verbally repeat those phrases). **Results:** (1) Drowsy drivers drove more safely with and preferred slightly interactive media rather than passive media. (2) Interactive media did not harm non-drowsy driver safety. (3) Drivers drove more safely on varied driving courses than monotonous ones. **Conclusion:** Slightly interactive media hold the potential to improve the performance drowsy drivers on the primary task of driving safely. **Application:** Applications include the design of interactive systems that increase user alertness, safety, and engagement on primary tasks as opposed to take away attentional resources from the primary task of driving.

**Keywords:** drowsy driving, driving simulator, interactive media, interactivity

**DROWSY DRIVING AND INTERACTIVE MEDIA**

With the many benefits of driving cars come the many risks of traveling at high speeds with large, metal bodies. The inherent risks of driving are notably compounded by drivers who go out on the road while drowsy (Beirness, Simpson, & Desmond, 2004; Nguyen, Jauregui, & Dinges, 1998; Stutts, Wilkins, & Vaughn, 1999). Unfortunately, drowsy driving is not an uncommon activity: 56 percent of the general population drives while drowsy (Beirness et al., 2004; Dement, 1997). Sleepiness is cited as the second most frequent cause of driving accidents unrelated to excessive speed. Drowsy driving results in four- to six-times higher near-crash/crash risk as compared to alert driving (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Despite efforts to impress upon the public the dangers of drowsy driving (Beirness et al., 2004; Stutts et al., 1999), people seem to insist upon driving while drowsy. Hence, we must understand how to make drowsy drivers less of a threat to themselves and others.

Existing research tends to discuss drowsiness in terms of medical causes of sleepiness rather than sleepiness by itself (Dement, 1997). We treat *sleepiness* and *drowsiness* as synonymous terms that fall under the broader category of *fatigue* (Brown, 1994), which refers to the combination of consciously experienced sleepiness and decrease in performance (Shinar, 2007, p. 566). Drowsy driving is not only the result of *chronic* predisposing factors such as sleep apnea, but also the result of acute *situational* factors such as sleep loss or the use of sedating medications (NHTSA, 2005).

There is much research progress on the subject of detecting drowsy drivers using sensors for detecting eye closure (Dinges, 1998; Grace et al., 2001), head nods (2001), and image tracking (Horberry, Hartley, Krueger, & Mabbott, 2001; von Jan, Karnahl, Seifert, Hilgenstock, & Zobel, 2006). Many institutions and driving systems employ preventative approaches to drowsy driving, e.g., setting maximum drive times and minimum rest times for professional drivers. However, relatively little is said about what to *do* once a system detects drowsiness (Ayoob, Grace, & Steinfeld, 2003). The safest option would be to persuade the driver to pull over to rest (Bonneford, Tassi, & Muzet, 2004; Horne & Rener, 1996), but this message is not often heeded by drivers (Shinar, 2007, p. 593).Thus, it is critical for systems to help drivers stay awake and drive safely.

**Preventing Drowsiness**

Some methods that drowsy drivers currently employ include napping, chewing gum, drinking caffeinated beverages, opening a window, and conversing (Nguyen et al., 1998; Strayer, Drews, & Crouch, 2003; Stutts et al., 2003). A frequent technique of relevance to the current study is the use of media (Nguyen et al., 1998; Strayer, Drews, & Crouch, 2003; Stutts et al., 2003). One-way media, such as listening to the radio, CD player, or iPod, have not been empirically shown to be efficacious in reducing drowsy driving (Strohl et al., 2004; Stutts et al., 2003).

People frequently employ the highly interactive medium of phone conversations as a means of staying awake while driving (Verwey & Zaidel, 1999). In the current study, more drowsy drivers self-reported that they use cell phones while driving (71%) than non-drowsy drivers (38%), $X^2$=8.03, $p$<.05. This may not be a safe solution to the problem: A study of 699 drivers who owned cell phones and had been in driving collisions found that using a cell phone while driving quadrupled the risk of accidents (Redelmeier & Tibshirani, 1997; Strayer, Drews, & Crouch, 2003, 2006). Neither hands-free nor voice controlled interfaces prevent these (Lamble, Kauranen, Laakso, & Summala, 1999; Strayer & Johnston, 2001). Given that regular drivers have difficulty driving while talking on cell phones, we surmise that drowsy drivers will also be negatively affected by this behavior. On the other hand, a naturalistic 100-car study data did not show a statistically significant rise in relative risk of crash or near-crash events for "listening/talking on a handheld device" as compared to "just driving" (Klauer, et al. 2006). An extensive analysis of field operational test data (from 36 drivers observed for four weeks each) found little difference in lane position variability or speed maintenance during cell phone use as compared to just driving, and evidence of prudent judgment regarding when to engage in secondary tasks (Sayer, Devonshire, & Flannagan, 2005). Such findings suggest that controlled studies may not capture important effects of driver discretion and compensatory strategies in the face of perceived risks.

In this study, we focus on a form of media that has not been previously explored for its efficacy for drowsy driver safety: *slightly interactive media*. At first glance, the insertion of intensively interactive media into the driver cabin is an obvious cause for concern, considering the distracting effects observed with interactive media in cars (Ranney et al., 2003; Stevens & Minton, 2001; Stutts & Hunter, 2003). The idea that interactivity will reduce attention is grounded in the assumption that a normal driver's cognitive (typically, attentional) resources are *fixed*. Thus, primary and secondary tasks vie for a single fixed resource (Wickens, 1991). In contrast to this assumption, the Malleable Attentional Resources Theory states that "attentional capacity can change size in response to changes in task demands," a notion supported by eye-tracking data from vehicle automation and mental workload studies (Young & Stanton, 2002). Consistent with this theory that attentional resources vary by task demands, environmental stressor factors, the physiological adaptation to those stressors, and the individual's goal-directed psychological responses can also affect stress and sustained attention (Hancock & Warm, 1989).

When in a drowsy state, people have an overall decrease in cognitive resources as compared to when they are awake and alert (Alchanatis et al., 2005; Dinges & Kribbs, 1991; Durmer & Dinges, 2005; Holingworth, 1911; Horowitz, Cade, Wolfe, & Czeisler, 2003; Nilsson et al., 2005). However, if the drowsy driver becomes more awake, new cognitive resources can be directed to *both* primary and secondary tasks (Kahneman, 1973; Shinar, 2007, p. 568). Thus, if engaging with interactive media can wake up drowsy drivers, then such interactive media may provide *more* cognitive resources for the primary task of driving.

Previous work regarding drowsy drivers has found results consistent with this hypothesis. One study found that drowsy drivers using a gamebox had slightly more than half as many accidents as those who did not have a gamebox (Verwey & Zaidel, 1999). In contrast to this work, we did not tell participants that using the interactive system might improve their safe driving behaviors, thus decreasing chances for a placebo effect, and we varied the degree of system interactivity rather than making a comparison of having the system vs. not having the system. Another study of professional truck drivers found some alertness-maintaining tasks such as a trivia game helped to delay performance deterioration over time while the less interactive task of choice reaction time were not effective (Oron-Gilad, Ronen, Cassuto, & Shinar, 2002). Building upon this work, the current study focuses upon everyday drivers as opposed to professional ones, explicitly manipulating the degree of media interactivity.

**Driver Distraction**

Of primary concern for driver safety is driver distraction. Many years of research on the dangers of mobile phone use in cars (McKnight & McKnight, 1993; Poysti, Rajalin, & Summala, 2005; Recarte & Nunes, 2003; Redelmeier & Tibshirani, 1997; Strayer, Drews, & Crouch, 2003) attests to the importance of maintaining safe driving environments in the face of the temptation to load information technologies in the car. A critical review of mobile phone studies in the driving context specifically recommends comparing these types of distractions to other types of media use in cars (Haigney & Westerman, 2001). The current study addresses a different type of conversational partner: a voice in the car that would speak to the user and (in the interactive conditions) invited the driver to respond  While mobile phone use in cars is typically confined to a few minutes of interaction (Rothman, Loughlin, Funch, & Dreyer, 1996), interacting with car-based voices may involve much longer durations of time, particularly those for helping with navigation or keeping drivers entertained on road trips. This could make interacting with these voices more akin to continuous conversations with collocated passengers rather than to distant people on mobile phones (e.g., Manalavan, Samar, Schneider, Kiesler, & Siewiorek, 2002; Recarte & Nunes, 2003). Conversations with collocated passengers is not necessarily an effective strategy for dealing with driver drowsiness  (Stutts & Hunter, 2003), but they are less detrimental to driving safety than talking on mobile phones (Manalavan et al., 2002).

**Research Questions**

The goal of the current experiment was to empirically evaluate how driver drowsiness, media interactivity, and driving conditions affect safe driving performance and feelings about the driving experience.  Via a driving simulator, we approached the research questions: Do passive media (e.g., listening to a voice-based media system) differ from slightly interactive media (e.g., speaking back to a voice-based media system) with respect to how they affect driver attitudes and behaviors? Does the answer to this question differ depending on whether the driver is drowsy or not and/or whether the driving course is monotonous or varied?

The comparison of *drowsy vs. non-drowsy* drivers is an important variable because the ways in which interactive media and course monotony affect safety and attention may vary with level of drowsiness. Because drowsy people have unfocused attention (Blagrove, Alexander, & Horne, 1995; Harrison & Horne, 2000; Norton, 1970) and sleep deprivation strongly impairs human functioning (Pilcher & Huffcutt, 1996), safe driving behavior is very likely to be worse among drowsy drivers than non-drowsy drivers. However, because people are often able to overcome detrimental effects of sleep deprivation when engaging in complex, interesting tasks (Harrison & Horne, 2000), it is possible that drowsy drivers might be helped by more engaging media (e.g., more interactive media) and more engaging driving courses (e.g., more varied driving courses).

The variable of *media interactivity* (e.g., slightly interactive vs. passive) relates to previous work in acquisition (i.e., attending to audio messages) vs. production (i.e., verbally reproducing the audio messages) types of secondary tasks performed while driving (Recarte & Nunes, 2003; Recarte, Nunes, & Conchillo, 1999). As in this previous work, participants were informed that they would be tested for language learning at the end of the driving session. Drivers subjectively reported that talking rather than simply listening takes more effort (Recarte & Nunes, 2003), which is consistent with behavioral observations of pupil dilation measures as an indicator of visual attention to the situation on the road. There is controversy about whether audio-verbal cognitive processes generally interfere with visual-spatial processes or not (Just et al., 2001; Wickens, 1992) though it has been shown that talking on cell phones while driving sometimes impairs attention to visual inputs (Strayer, Drews, & Johnston, 2003).

Different *driving course types* also affect attentional demand upon drivers, suggesting that drivers might strategically select routes according to their drowsiness (when this option is available). Driving along a straight, boring route with plain, repetitive scenery and a limited amount of traffic can be soporific (Contardi, Pizza, Sancisi, Mondini, & Cirignotta, 2004;

Nguyen et al., 1998). Conversely, driving that involves heavy traffic, many cars and pedestrians, and a number of reasons to change speeds can make people more alert. That is, although drowsy drivers might not initially have the cognitive capacity to handle variable driving situations, dynamic situations might also awaken drivers, making them more alert (however, see Klauer et al., 2006).

# METHOD

An expert panel on drowsy driving and automobile crashes identified three research needs: (1) quantification of the problem, (2) risks, and (3) countermeasures (Strohl et al., 2004). The current study follows this framework. Drowsiness is measured using standard scales from existing sleep research. Driving performance is accounted for via a set of unsafe driving indicators that represent risks to the driver and others. Finally, we determine whether limited interactivity is a more effective countermeasure to drowsiness than passive media consumption and whether this countermeasure will be deleterious for non-drowsy drivers. The research incorporated a 2 (drowsy vs. non-drowsy drivers) x 2 (slightly interactive vs. passive media) x 2 (monotonous vs. varied driving course) between-participants experiment that balanced gender across conditions. All procedures were approved and conducted according to this institution's human subjects review board.

## Participants

Participants were recruited by local mailing lists. Each potential participant was required to fill out an online version of the Epworth Sleepiness Scale to measure chronic or usual daytime sleepiness (Johns, 1991). Eighty people (40 women and 40 men) who scored particularly low or particularly high on this scale were invited to participate in the study. Participants were each paid with a $15 gift certificate for contributing to this 90-minute experiment.

Participant ages ranged from 18 to 44 years (*M*=21.53, *SD*=3.87) with between 0.5 and 14 years of driving experience (*M*=4.39, *SD*=2.72). Young people are particularly prone to drowsy driving (Strohl et al., 2004). However, neither age ($F(1,73)=.03$, $p=.86$) nor years of driving experience ($F(1,70)=.10$, $p=.76$) significantly predicted drowsiness levels in this study.

**Stimulus and Apparatus**

*Driving context.* We used the STISIM driving simulator in this study. The visuals of the simulator were projected on to a 1.83-meter front-projection screen. The audio of the simulator was played through a three-speaker system. The hardware interface of the system included a gas pedal, brake pedal, and a force-feedback steering wheel. The STISIM system allowed us to pre-program all events along the driving course, including the placement of buildings, scenery, attributes of the road, behavior of cars and pedestrians, and the timing of traffic lights at intersections.

Studies have shown that key characteristics of drowsy driving crashes include driving during late-night hours, driving alone, and driving on higher speed roads in non-urban areas (NHTSA, 2005). We attempted to model these conditions within the context of the simulator. The room in which the participants used the simulator was darkened and relatively soundproof, simulating nighttime driving and thereby maximizing the probability of drowsiness.

Half of the participants drove on a “monotonous course,” meaning its objective stimulus situation was repetitive and predictable (McBain, 1970). The monotonous course consisted of primarily straight roads and very plain scenery on a mostly one-lane highway with no passing cars; there were a few urban and suburban areas to pass through. The other half of the participants drove a “varied course,” consisting of the same number of turns as the monotonous course, but incorporating heavier traffic, more aggressive drivers, more crowded streets with people and dogs crossing, more town and cities, and more intersections.

*Media.* This study required content that was reasonable for use both interactively and non-interactively, so we opted for a language learning system. Drawing from several commercial Swedish language instructional systems, we designed language-teaching content, recorded by a native Swedish speaker, that would require minimal alterations to change from a non-interactive to an interactive system. Half of the participants received the “interactive” version and were instructed to “listen carefully, repeat, and try to learn to each phrase”; the other half of the participants, in the “passive” media condition, were simply instructed to “listen and try to learn each phrase.” All other content in the language lesson was held constant across conditions.

The Swedish language learning system included words and phrases for travelers going to Sweden as well as tourist information about Swedish history and culture. The following list includes some excerpts from the section on greetings:

How do you do? *Goddag. Goddag.*

How are you? Hur mar ni/du? Hur mar ni/du?

The words/phrases ranged from single word items to longer sentences. After each line, there was a pause in the recording such that the participants could either repeat the word or phrase (in the “interactive” conditions) or could wait for the next line to begin (in the “passive” conditions).

**Measures**

*Driver drowsiness.* Consistent with previous work in drowsy driving (Arnedt, Wilde, Munt, & Maclean, 2000; Connor et al., 2002; Suhner et al., 1998), the Stanford Sleepiness Scale was used to measure in-the-moment need for sleep (Connor et al., 2002; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973; NHTSA, 2005). The Stanford Sleep Scale, which ranges from 1 ("Feeling active, vital, alert, or wide awake") to 7 ("No longer fighting sleep, sleep onset soon; having dream-like thoughts"), has proven to be a valid and reliable measure of drowsiness (Hoddes et al., 1973) and was simpler and more reliable than forcing half of the participants to be drowsy and half to be non-drowsy. Participants with sleepiness rating of 3 ("Awake, but relaxed; responsive but not fully alert") or less were labeled non-drowsy; participants with ratings of 4 ("Somewhat foggy, let down," or higher) or greater were labeled as drowsy. The Epworth Sleepiness Scale was not an appropriate indicator here because it describes a general tendency for sleepiness rather than in-the-moment drowsiness (Sayed, 2005).

*Unsafe driving.* The driving simulator collected summary data about many aspects of the driver's behavior on the course. Using Principal Component Analysis, we created a single weighted factor score (*eigenvalue*=2.53; $R^2$=.63) based on behavioral measures of poor driving with factor loadings greater than 0.4 (Kim & Mueller, 1978): road edge excursions (loading=.85), center line crossings (loading=.80), road accidents (loading=.79), and traffic light tickets (loading=.74).

*Attitudes: Liking the media system.* The language learning system was assessed based on the question, "How well do the following adjectives describe the language learning system?", and ten-point Likert scales ranging from strongly disagree (=1) to strongly agree (=10). Liking of the media system was defined, using Principal Component Analysis, as a factor score (*eigenvalue*=4.33; $R^2$=.54) consisting of the following items: interesting (loading=.80), useful (loading=.79), effective (loading=.76), organized (loading=.75), "would like to spend more time with it" (loading=.75), fun (loading=.71), easy to use (loading=.69), and annoying (loading=-.64).

*Learning: Recognition memory for content presented.* Language learning performance served as another method to determine the cognitive effects of drowsiness, interactivity, and driving conditions. Each participant's language learning score was calculated as the average of the individual's scores on 15 quiz questions given to the participant immediately after completing the driving course. Two items were true or false questions; three questions involved identifying audio clips of Swedish with English terms; and ten questions were questions about Swedish and Sweden. The language learning questions included items such as:

*Goddag means...*

Good bye  Good morning  How do you do?  Thank you  You're welcome

**Procedure**

After a brief training session with the simulator, involving driving down a 4700-foot long suburban road with traffic, pedestrians, and interactions, participants sat quietly in the dark simulator room for ten minutes. Given appropriate environmental and situational factors employed in this procedure — a dark room, tedious task, and the hum of white noise — it was possible to unveil hidden sleepiness (Contardi et al., 2004). After ten minutes, participants then filled out the Stanford Sleepiness Scale. The distribution of participants across experiment conditions is presented in Table 1.

Immediately after filling out the scale, participants drove the simulator for 40 minutes while the experimenter sat outside of the driving simulator room. The maximum speed allowed by the simulator was 105 kph. After ten minutes of driving, participants heard the language learning media system begin playing through speakers placed in front of the driver; this lasted through the end of the driving course.

Immediately after the driving exercise, participants filled out the questionnaire which included demographic information. Participants were then debriefed and paid.

## RESULTS

There were more non-drowsy participants ($n$=57) than drowsy participants ($n$=22) in our study. Because of the unequal sample sizes across conditions, we first examined the main effects model and then tested each of the two-way interactions via increment to $R^2$; it was impossible to examine the three-way interaction given the distribution. One driver was removed from the dataset for driving extremely recklessly.

### Safe driving behavior

We used regression to analyze unsafe driving behavior scores as predicted by driver drowsiness, type of driving course, and media interactivity level. (See Table 2.) Consistent with the previous literature (e.g., Fairclough & Graham, 1999), drowsy participants drove less safely than people who were not drowsy. This is also consistent with the definition of fatigue that includes both conscious perception of drowsiness and decrease in performance (Shinar, 2007, p. 566). Similarly, the limited interactivity of the media system improved driving performance.

Participants drove more safely on the varied course than the monotonous course. On the one hand, one might have guessed that the more challenging driving courses would result in more lane deviations and other unsafe driving behaviors than the more monotonous course. However, the complex course led drivers to drive more slowly, as demonstrated by a regression analysis of the time on the course, $t(37)=19.82$, $\beta=.91$, $p<.001$. Drowsiness and interactivity were not significantly related (both $p>.18$) to run length.

There was a significant interaction between the drowsiness of the driver and media interactivity level. To interpret the interaction, we ran separate analyses for interactive vs. non-interactive media participants. For interactive media participants, there was clearly no difference between drowsy and non-drowsy drivers, $t(37)=0.48$, $\beta=.08$, $p>.63$, while for non-interactive media participants, drowsiness negatively affected drivers, $t(38)=3.31$, $\beta=.44$, $p<.002$.

**Attitudes toward the media system**

There were no main effects for liking of the learning system (all $p<.7$). However, there was once again a significant interaction for drowsiness and interactivity, $t(71)=3.06$, $\beta=.59$, $p<.01$. For the interactive media participants, there was no effect of drowsiness, $p>.08$. For the non-interactive media participants, drowsiness clearly impeded liking, $t(37)=2.46$, $\beta=.38$, $p<.02$.

**Learning of media system content**

There were no main effects for learning (all $p>.19$). There was a significant interaction between drowsiness and difficulty of the driving situation, $t(37)=2.56$, $p<.02$. Consistent with the idea that in difficult driving situations, drowsy drivers can find additional cognitive resources, drowsiness was a significant impediment to learning when driving was simple, $t(36)=2.13$, $\beta=.33$, $p<.04$. Drowsiness did not have an effect on learning during the difficult driving course, $p>.09$. The other interactions were not significant.

## DISCUSSION

While the majority of literature regarding various information technologies and interactive media in cars demonstrates negative effects on driver safety, the current study offers hope that interactive media in cars can improve driving safety.

**Effects on drowsy drivers**

The most interesting finding of the current study is that engaging drowsy drivers with more interactive media can help them to drive more safely. Drowsy drivers liked interactive media more than passive media, possibly because they felt more engaged in the driving session.

These findings support the idea that secondary task stimulation for drowsy drivers can increase cognitive availability for the primary task of safe driving.

**Effects on non- drowsy drivers**

Non-drowsy drivers behaved as psychological theories of normal attention would predict: because they were already functioning with normal amounts of cognitive resources, they chose to focus on the primary task of driving when the driving course was more exciting and chose to focus on the secondary task of learning Swedish when the driving course was boring.

There were no discernible negative effects of interactivity for non-drowsy drivers. This is consistent with previous work that found driving performance was not hindered by books on tape or radio broadcasts (Strayer & Johnston, 2001). Whereas a phone call requires the driver to engage in a truly two-way joint activity with a person on the other end of the line, thereby disrupting driving performance (Strayer & Johnston, 2001), the limited interaction between the system and the driver minimized the complexity of the exchange.

**Implications for Theory and Design**

*Theory.* Contrary to the notion that interactive media necessarily causes unsafe driving, our results suggests that interactive media may be *helpful* for drowsy drivers while not being harmful to non-drowsy drivers. These findings present a more nuanced view of the situation of interactive media in cars, extending existing research to include levels of media interactivity in cars. While talking with people via mobile phones can have detrimental effects upon safe driving behavior (Haigney & Westerman, 2001; McKnight & McKnight, 1993; Poysti et al., 2005; Recarte & Nunes, 2003; Redelmeier & Tibshirani, 1997; Strayer, Drews, & Crouch, 2003), talking with car-based voices involves a different sort of interaction. Whereas a far-end human caller might demand immediate responses from the driver, a car-based voice does not possess the same human needs and desires that demand the attention of the driver.

The conceptualization of cognitive resources as limited and secondary activities as taking away cognitive resources from primary activities is not supported for drowsy drivers. Drowsy people initially have a small pool of cognitive resources available, but those dormant resources might be regained through engaging in secondary tasks. In this case, the secondary task of verbally responding to the learning system helped drowsy drivers to improve performance on their primary task of driving safely. There is also evidence that complex driving may free up cognitive resources for learning as well as driving.

*Design.* While it is important for researchers to empirically investigate the risks of interactive media in cars (e.g., Lee, Caven, Haake, & Brown, 2000; Manalavan et al., 2002), it is also important to see if and how interactive media might *improve* driver safety. The utility of interactive media in cars is typically argued from the perspective of the secondary task, e.g., helping the driver to navigate. While such benefits may be important, driver safety benefits ultimately trump secondary activities. This study's findings have implications for the design of context-aware computing interfaces in cars. Computing systems can sense driver drowsiness and/or the features of upcoming driving conditions to decide when to change the degree of media interactivity to encourage safer driving behavior. Of course, interactive media are merely remedial measures and not adequate substitutes for a healthy amount of sleep. At best, short-term countermeasures can help a sleepy driver stay awake and alert enough to find a resting stop or call for a ride (NHTSA, 2005).

**Limitations and Future Work**

The current study aims to open investigations regarding the ways that interactive media can help people to perform better on primary activities rather than taking away cognitive resources from them. This single study cannot address all issues at play in complex situations such as unsafe drowsy driving behaviors. Future work should take into account other important factors that relate to drowsy driving, including: different participant populations (e.g., different ages, cultures, geographical regions), more fine-grained and/or moment-to-moment measures of drowsiness, measures of cognitive load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003), real-world driving contexts, and time of day (Horne & Reyner, 1995; NHTSA, 2005).

## CONCLUSIONS

This study opens investigations into the ways that media technologies may be used to improve safe driving behaviors and effective responses to interactive media in cars. Using a driving simulator experiment, we found that interactive media actually helped drowsy drivers to drive more safely without hindering non-drowsy drivers. This improvement in driving safety for drowsy drivers was coupled with more positive feelings toward the interactive media system. Our study contributes to theories of cognitive resources in drowsy vs. non-drowsy individuals and provides design implications for future interactive media systems in cars.

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Table 1

*Distribution of participants across experiment conditions*

| Driver drowsiness | Inactivity Level | Driving Course Type | *Count* |
|---|---|---|---|
| Drowsy (D) | Interactive (I) | Varied (V) | 8 |
| | | Monotonous (M) | 6 |
| | Passive (P) | Varied (V) | 4 |
| | | Monotonous (M) | 4 |
| Non-drowsy (ND) | Interactive (I) | Varied (V) | 10 |
| | | Monotonous (M) | 14 |
| | Passive (P) | Varied (V) | 17 |
| | | Monotonous (M) | 16 |
| TOTAL | | | 79 |

Table 2

*Regression Analyses with Unsafe Driving as the Dependent Variable in a Main Effects Model and Models Including Each of the Two-Way Interaction Terms, Respectively*

| Variables | $\beta$ | $t$ | $p$ | $R^2$ | $adjR^2$ | $\Delta R^2$ | $F$ | $p$ |
|---|---|---|---|---|---|---|---|---|
| Main Effects Model | | | | .20 | .17 | .20 | 6.13 | .001 |
| Driver drowsiness (DD) | .296 | 2.80 | .01 | | | | | |
| Media interactivity (MI) | -.314 | 3.02 | .01 | | | | | |
| Course difficulty (CD) | -.236 | 2.23 | .03 | | | | | |
| Interaction Terms (Each term is independently entered after the main effects model) | | | | | | | | |
| DD*MI | -.452 | 2.57 | .01 | .26 | .22 | .06 | 6.61 | .01 |
| DD*CD | -.097 | 0.674 | .82 | .20 | .15 | .00 | 0.45 | .82 |
| MI*CD | 0.212 | 1.22 | .23 | .21 | .17 | .01 | 1.48 | .23 |

## Biographies

Leila Takayama (PhD, Stanford University, Communication, 2008) is a recent alumna of Stanford University. Her research focuses on ubiquitous computing, the ways people interact with agentic objects, and the psychological implications of computational tools that become incorporated into everyday experience.

Clifford Nass (PhD, Princeton University, Sociology, 1986) is the Thomas M. Storke Professor of Communication at Stanford University with appointments by courtesy in Computer Science; Education; Science, Technology, & Society; Sociology; and Symbolic Systems. His research focuses on social psychological aspects of human-technology interaction and statistical methodology.