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Bringing Design Considerations to the Mobile Phone and Driving Debate

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ABSTRACT

Though legislation is increasingly discouraging drivers from holding on to their mobile phones while talking, hands-free devices do not improve driver safety. We offer two design alternatives to improve driver safety in the contexts of voice-based user interfaces and mobile phone conversations in cars—side tones (auditory feedback used in landline phones) and location of speakers. In a 2 (side tone: present vs. not) x 2 (location of speakers: headphones vs. dashboard) between-participants experiment (N=48), we investigated the impact of these features upon driver experience and performance on a simulated mobile phone conversation while driving. Participants became more verbally engaged in the conversation when side tones were present, but also experienced more cognitive load. Participants drove more safely when voices were projected from the dashboard rather than from headphones. Implications for driver user interface design are discussed.

Author Keywords

Driver user interfaces, driver safety, voice user interfaces, side tones, speaker location.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

The days of hand-held mobile phone usage in the vehicle are numbered, as states such as California and New York have enacted legislation banning the use of mobile phones unless used with a hands-free headset or phone kit. In anticipation of this change, many automotive manufacturers have begun to include Bluetooth compatible phone kits as a standard feature. In these cases, the microphone is located in front of the driver and the phone audio is projected from the car's speakers. To comply with the new hands-free phone use laws, drivers without this option in their cars will have to use their mobile phones with a headset composed of a microphone and earpiece.

While the use of hands-free phone kits helps to ensure that drivers' hands stay on the steering wheel, neither hands-free nor voice controlled interfaces prevent accidents [5]. Driving while talking on mobile phones distracts drivers from the primary task of driving safely [8, 11, 13, 14], but drivers do it anyway [13]. A comprehensive meta-analysis of the effects of cell phones on driver performance found that cell phones increase reaction times of responses to events and stimuli with both hand-held and hands-free phones [2]. One method of mitigating risk in voice interactions in cars leverages the signaling of remote cell-phone callers when drivers are cognitively busy [7]. Another way to mitigate risk is to use more general acoustic qualities of conversation to decrease the cognitive load that results from engaging in mobile phone calls while driving.

Spatial Location of Voices

One such factor is the location that the audio of the conversation is projected from. People naturally orient toward voices [10]. Spatially-presented audio has been demonstrated to improve memory and listening comprehension for speakers in a teleconference [1]. Also, the addition of so-called 3D sound helps visually impaired people to orient spatially around a virtual environment [12]. Having the phone conversation projected from the front of the vehicle might orient the driver's attention in that direction, toward that point of interaction, which could promote in safer driving. Therefore, one of the questions this study aims to address is if the location of audio presentation has differential effects on driving behaviors.

Side tones

In addition to the location of the audio presentation, another factor that might affect the cognitive load mobile phone calls is the inclusion of a side tone in the audio stream. A

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side tone is the sound that is picked up by the phone's microphone and is returned to the user (at low levels) in the phone's earpiece [3]. Without the feedback of side tones, the user might feel that the phone is not active and that the conversation has stopped.

Previous work in the psychoacoustics of side tones focused on perceived loudness and adaptation of vocal loudness [4, 6]. For example, altering the intensity of side tones can produce effects such that decreasing the volume of the side tone makes speakers talk louder, and vice versa [3]. Research in speech therapy has examined the effect of manipulating side tones to improve speech production for people with speech impediments such as stuttering [8].

Given that side tone parameters affect the ease with which people produce speech, drivers who are using hands-free phone kits should have side tones optimized for maximum ease of speaking. Since side tones seem to ease landline phone conversations, we aimed to evaluate their utility in mobile phone conversations in cars. Therefore, in this study, another goal was to examine the effects of side tones on driving behavior.

Hypotheses

Based upon the existing literature, we approached this study with several working hypotheses. (H1) If speaker location in the dashboard draws attention toward the screen, then drivers will drive more safely when the speakers are placed in the dashboard than when the speakers are in headphones. (H2a) If side tones decrease cognitive load in people, then drivers will experience less cognitive load with side tones and drive more safely with side tones. (H2b) Conversely, if side tones get people more engaged in the conversation than in the driving task, then drivers will talk more with side tones, experience more cognitive load with side tones, and drive less safely with side tones.

EXPERIMENT DESIGN

In a 2 (side tones: present vs. not) x 2 (location of speakers: headphones vs. dashboard) between-participants experiment (N=48), we investigated the impact of voice communication system features upon driver experience and performance on a simulated mobile phone conversation while driving. For safety reasons, we ran the study in a driving simulator, STISIM. Side tones presence was manipulated by mixing the participants' microphone audio stream into the outputted audio stream.

METHODS

Participants

Forty-eight adults (24 female and 24 male), who had valid drivers' licenses, volunteered to participate in this study. Their ages ranged from 18 to 34 years (M=21.4, SE=0.44). People were granted credits for experiment participation. Those who did not consent to being audio recorded were not included in verbal engagement data analyses.

Procedure

Each participant first drove a short introductory course to practice using the driving simulator. Then the participant drove the full course that was 52,000 feet (15,850 meters) in length. It typically took 20 minutes to complete the drive. All participants experienced the same vehicle characteristics, driving course, and environmental conditions, driving a virtual car down a rural and urban roads populated with other dynamic vehicles, pedestrians, and traffic signals. The simulation was viewed on a front projection screen that measured six feet along the diagonal.

During the drive, the participant engaged in a mock phone interview. Pre-recorded voice prompts simulated the phone interview, which began with standard questions such as, "What is your major, and why did you decide to study it?" The questions progressed towards more experience and creativity-oriented questions. Voice prompts were triggered automatically with distance markers on the simulated driving course. Voice prompts were either played from speakers in front of the driver (dashboard condition) or from headphones (headphones condition); road noises from the simulator were played from separate speakers.

After completing the course, the participant filled out a questionnaire that assessed their perceived cognitive load, emotions, and other aspects of their experience of the drive. The participant then was debriefed about the study.

Materials

Practice interview questions included modified interview questions from university career center booklets and modified creativity questions from previous creativity research [16], such as: "List as many creative uses for a toothpick as you can think of," "Give a short, fictional biography that you think would describe someone named Florence Pattersen," and, "List several headlines you would most want to read in the newspaper tomorrow."

The voice agent prompts were recordings from two female and two male voice acting volunteers. The voice agent genders were matched to driver genders with the voice agents balanced across conditions. Their voice prompts were programmed into the driving simulation to play at certain points throughout the driving course.

Measures

Behaviors and perceptions were measured. All questionnaire items were ten-point Likert scales. Indices were created via Principal Components Analysis.

There were two manipulation checks. *Hearing one's own voice* was based on the rating of the statement: "I could hear my own voice through the speakers." *How much the experience was like a mobile phone conversation* was an index of two items—"Speaking with the voice agent was like having a mobile phone conversation," and "To what degree did the voice interaction feel like a mobile phone conversation"—(Cronbach's α=.72).

Unsafe driving behavior was an index based on data gathered from the driving simulator: number of off-road incidents, collisions, speeding incidents, and centerline crossings. We used principle components analysis to combine these correlated driving metrics because it better addresses the underlying processes that created the correlations among these variables [15 p. 582]. Because the data ranged widely and did not have normal distributions, we calculated median splits on each item (0=below the median, 1=equal to or above the median) before creating the summed index (α=.59).

Verbal engagement in the communication task was measured by calculating the average number of words uttered per creativity question (α=.87), derived from transcripts of audio recordings of participant utterances. The number of words uttered was used for this measure because more talking suggests more verbal engagement, which is consistent with previous work [16].

Cognitive load was measured by an abbreviated version of the NASA-TLX questionnaire [9]. We created a weighted index of cognitive load based on perceptions of mental load, physical load, time pressure, and overall work load. The index was highly reliable (α=.79).

Data Analyses

Analysis of variance (ANOVA) was used to analyze all of the data collected in this study, with side tone presence (side tones vs. no side tones) and location of voices (headphones vs. dashboard) as independent variables.

RESULTS

Manipulation Checks

Side tone participants felt that they heard their own voices more than non-side tone participants, $F(1,44)=10.13$, $p<.01$. Consistent with how mobile phones currently work, there was an interaction such that side tone+headphones participants perceived the interaction to be more like a mobile phone conversation than any other participants, $F(1,44)=11.00$, $p<.01$. (See Figure 1.)

Behaviors: Unsafe Driving and Verbal Engagement

Headphone participants drove more safely than dashboard participants, $F(1,44)=4.85$, $p<.05$. (See Figure 2.) Side tone participants were more verbally engaged in the conversation than non-side tone participants, $F(1,44)=19.86$, $p<.001$. (See Figure 3.)

Cognitive Load

Side tone participants experienced higher cognitive load than no-side tone participants, $F(1,44)=8.44$, $p<.01$. (See Figure 4.)

DISCUSSION

While mobile phones have been shown to be clearly deleterious to driving [8, 13, 14], it is unclear whether hands-free mobile phones are actually safer than hand-held phones [2, 13]. For example, the current has shown that having the other person's voice come from the dashboard, which is often a suggested alternative to using a mobile phone, may be less safe than having the other person's voice come directly into the listener's ears, which is more similar to the way voice is delivered via a handheld mobile phone. This surprising result directly negated our original

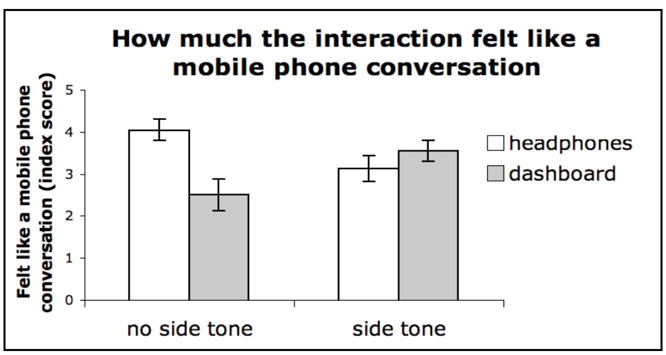

Figure 1. Mean and SEs for how much the interaction felt like a mobile phone conversation

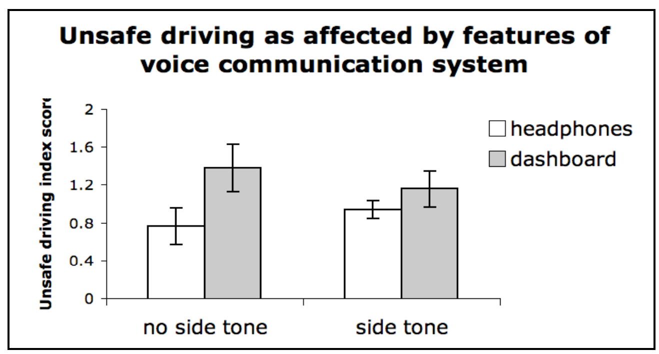

Figure 2. Mean and SEs for unsafe driving behavior

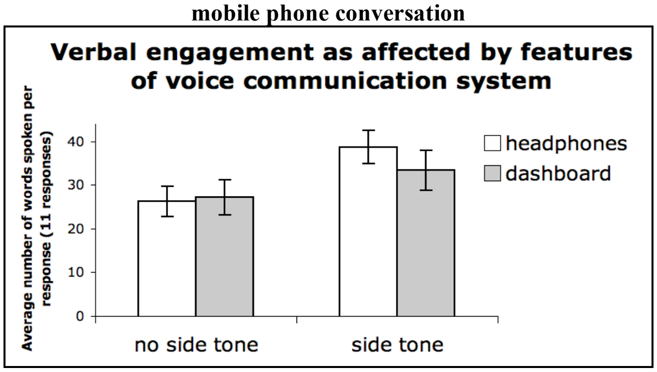

Figure 3. Means and SEs for verbal engagement

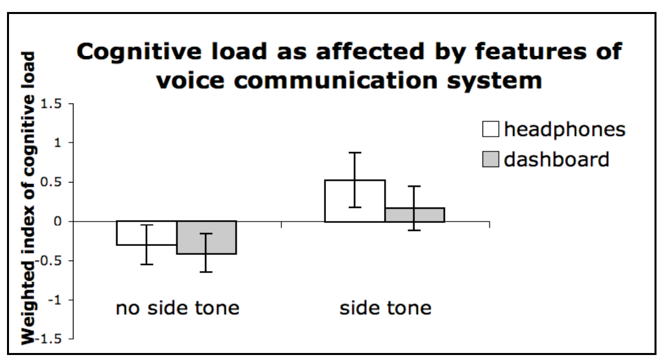

Figure 4. Means and SEs for cognitive load

hypothesis (H1) that projecting voices from the dashboard would be safer than through headphones. Future research should explore the various ways of providing telephone conversations to assess which methods are safest.

Regarding side tones, the current study results also negated H2a, and found partial support for H2b. As in landline phone and speech therapy studies, the presence of side tones seems to increase the ease with which people engage in phone conversations, thereby increasing verbal engagement. The combination of increased verbal engagement (word count) and increased perceived cognitive load in the presence of side tones suggests that the word count measure was an indicator of verbal engagement rather than spare cognitive capacity. Despite this higher level of cognitive load, the current study did not find a significant effect of side tone presence upon driving performance. One possible interpretation of this result is that side tones may make the conversation feel more like a conversation with a passenger, which is known to have less negative effects on driving performance than a conversation with a distant interaction partner.

Drivers seem to demand the right to communicate with remote others. The design community, addressing questions such as where to locate the voice of the remote speaker and whether to use side tones are not, can play a key role in ensuring that the debate about handheld mobile phones is not framed erroneously as a simple “yes” or “no.”

LIMITATIONS AND FUTURE WORK

The current study provides empirical findings that raise more theoretical questions about the underlying mechanisms and design implications for how to improve driver safety. Are there mediating factors at play in the relationship between voice projection location and safe driving behavior? Psychologically, how do side tones increase verbal engagement and cognitive load? Future work could use more fine-grained driving metrics (e.g., centerline crossings vs. reaction times), more measures of verbal engagement (e.g., triangulated metrics), and more realistic driving contexts (e.g., not simulated) to improve the robustness of the metrics and further explicate the implications of projected voice location and side tone presence upon driver safety.

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