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Tactile-Acoustic Devices for Automotive Safety Applications

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ABSTRACT

Tactile-acoustic devices represent a class of sensory augmentation technology that is typically considered as an assistive device for increasing access to movie or music soundtracks when hearing is limited or unavailable to an individual. However, the use of the skin as an input channel for critical information when the visual and auditory channels are engaged represents a new area of research for this technology. The paper presents preliminary arguments and motivation for expanding research into sensory augmentation with tactile-audio devices into automotive applications as a means to increase safety and awareness for drivers.

Categories and Subject Descriptors

B [**Hardware**]: B.4 Input/Output and Data Communications—*B.4.2 Input/Output Devices*

Keywords

Tactile-acoustic devices, driver engagement, attention, distraction reduction, multi-sensory interactions

1. INTRODUCTION

Computers have enabled researchers to explore the concept of sensory substitution or cross-modal interactions for many interesting and creative applications to assist people with disabilities access, navigate and interact with the environment using an alternative sensory modality to augment or replace vision and sound. But these technologies can also enhance perceptions and awareness for everyone, especially when our eyes and ears are overloaded with information while operating a vehicle. The sense of touch opens up a new form of sensory display that can provide increased access to environmental information in general, offering an novel form of extra-sensory information that can improve awareness and safety. This work introduces a new research initiative that explores the use of multi-modal tactile interfaces to increase awareness and reduce driver distraction.

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Driver distraction and attention

Driving represents one of the most attention-intensive everyday activities we all engage in, and the technology we can now use to improve safety and awareness, like GPS displays, and ubiquitous access to email and phone calls actually place additional demands on our limited visual and auditory attention resources. Though these devices help us better navigate and keep connected while on the road, they serve to further distract us from the critical attention levels needed just to maintain our basic driving skills, and represent a growing problem for all drivers. Sensory augmentation of visual and audio information through the tactile senses represents an excellent opportunity to begin exploring ways to support this increasing influx of information that is presented to drivers. By leveraging the ability of the skin to receive and process information that is intended for our eyes and ears, we can start to offload some demands placed in our eyes and ears to the body.

2. BACKGROUND

Several years of research into sensory augmentation of sound to the tactile senses have revealed benefits worth exploring that can increase driver awareness and safety. A tactile acoustic device (TAD) transfers audio information directly to the body in an effort to emulate the human cochlea on the skin, and has demonstrated effective results in communicating characteristics of sound to the tactile senses for deaf and hard of hearing people [2]. Research into TADs also suggest that hearing people can just as effectively process sound information through the skin, which may have valuable applications in providing an alternative means of receiving information that is intended for the eyes and ears [3]. TADs present sound to the body using multiple audio-transducers in a similar way that our ears process audio signals. For example, most existing tactile systems tend to process signals within the low frequency spectrum, ranging from 60Hz to 200Hz [1]. However, these signals are already easily detected simply by placing your hand on a speaker, or along the door of a car when loud music is playing. TAD has shown that the skin has a much higher capacity for processing audio signals, and includes the entire range of the audio spectrum to provide a potential for creating a much higher resolution form of tactile-acoustic display format using the body. This, coupled with the available surface area of the skin provides the potential to create an exceptional alternative to delivering safety critical information to the driver without placing additional demands on our eyes and ears.

Motivation

Over the past 5 years, TADs have been explored as an assistive device, in addition to an entertainment enhancement system to augment sound from film, music, and gaming with tactile-sound. Studies suggest that augmenting audio-visual experiences with tactile-sound can increase awareness, emotional connections, immersion, and enjoyment for users, with the added benefit of providing accurate and important information about sound through the skin alone [4]. However, it is the gaming research that has led to this move towards automotive applications as a safety critical device. Early results from an ongoing series of usability studies involving the game GranTurismo 5 (GT5) and TADs suggest many significant benefits to driver performance, engagement, and commitment to the game with the addition of the tactile-sound. Although gaming is not the same as driving, the added attention, immersion, and information that drivers reported experiencing with the tactile-sound could be transferrable to the driving safety enhancement system. The TAD system presents the sounds from the game through chairs that are used by a driver and passenger in our gaming scenario. The study presents sound from the car engine, the road noise, and game music through the TAD, using different combinations for the study. Each of these sound sources can be clearly identified by users, and even slight changes or disruptions to the sound can have a profound impact on the users attention to that signal. This occurs even when all three sources of sound are presented through the TAD concurrently. All of our gaming participants preferred the TAD-enabled condition, with drivers reporting feeling increased heart rates and perceived improved scores in race times and precision in handling the vehicle. It is anticipated that similar effects will be transferrable to actual driver scenarios, and the goal is to evaluate these effects in an actual driving scenario to expand on the gaming research.

Research Goals

Results of previous research that show that the body can interpret a significant amount of information about sound through vibrations, including detecting emotional content of music [3], musical timbre [4] as well as the gender and intentionality of speech. Other forms of audio cues that are not directly based on sound have also been shown to be effective for providing critical information to drivers [1]. Using the TAD system as a tool for investigating and implementing tactile audio and audio-cues together in combinations and configurations that will potentially reduce driver distraction and increase awareness of their environment. Additional factors that will be explored and validated include determining optimal size and placement of transducers, effects of the integration of audio and non-audio signals, quantitative measures on driver attention and distraction, and optimal combinations of the multiple sources of audio signals.

Methodology

A combination of ethnography and empirical methods will be applied to support the hypotheses being proposed in this research, which focus on the use of multi-sensory stimulus as a means of increasing driver awareness, while reducing distraction. The TAD systems will be refined and adapted for use in automotive vehicles as a low cost, adaptable multi-sensory integration tool for investigating the nuances of tactile-audio and audio-cues for automotive applications. Biometrics, response times, and performance measures of drivers in the different sensory conditions will be considered, as well as driver perception, preference, and enjoyment reports, towards understanding the relationships and factors of the multi-sensory feedback system being proposed, and to explore tactile-sound as a new mode of information that can offer many distinct ways of providing vehicle operators with a new channel for receiving meaningful information from the environment, and from the automobile itself.

Prototype Development

A flexible and adaptable model of current TAD system will be developed based on early research results towards determining the critical factors of installation and integration into the automotive system. While a plug-and-play version is currently in use, the aim is to develop an integrated system that can be adapted to integrate seamlessly with the current and existing audio sources and automobile information systems including surround sound, road noise, driver alerts, communication, and other feedback sources. The hardware that drives the signal processing to the TAD can be powered using a 12V power outlet, the system comes with a suite of audio cables, splitters, and connecters to support access to different and multiple sources of audio signals to make experimental design more efficient and flexible.

3. NEXT STEPS

The auto-TAD is being used in actual driving scenarios now, and has begun to take shape as a robust experimental device that will be used in the upcoming research projects. In addition to testing and modifying the prototype, signal-processing studies will be conducted independently to provide a broader understanding of the combined sound and audio-cue signals that can support the hypotheses that tactile displays can improve driver safety, increase attention, and reduce distraction.

4. REFERENCES

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