PROTOTYPE AUDITORY DISPLAYS FOR A FUEL EFFICIENCY DRIVER INTERFACE

Michael A. Nees[1], Thom Gable[2], Myounghoon Jeon[3], & Bruce N. Walker[2]

[1]Lafayette College
Easton, PA, USA
neesm@lafayette.edu

[2]Georgia Institute of Technology
Atlanta, GA, USA
{thomas.gable, bruce.walker}@gatech.edu

[3]Michigan Technological University
Houghton, MI, USA
mjeon@mtu.edu

ABSTRACT

We describe work-in-progress prototypes of auditory displays for fuel efficiency driver interfaces (FEDIs). Although research has established that feedback from FEDIs can have a positive impact on driver behaviors associated with fuel economy, the impact of FEDIs on driver distraction has not been established. Visual displays may be problematic for providing this feedback; it is precisely during fuel-consuming behaviors that drivers should not divert attention away from the driving task. Auditory displays offer a viable alternative to visual displays for communicating information about fuel economy to the driver without introducing visual distraction.

1. INTRODUCTION

Changes in driver behavior could appreciably reduce the environmental impact of vehicle emissions, and feedback on the impact of driving behaviors on fuel economy for the driver is an important component of behavioral change [1]. Fuel efficiency driver interfaces (FEDIs)—displays for fuel economy information—have become increasingly common elements of vehicle cockpits and appear poised to become standard in most vehicles [2]. Although research has established that FEDIs can have a positive impact on driver behaviors associated with fuel economy, the impact of FEDIs on driver distraction has not been established [3]. Researchers have acknowledged the need for multimodal FEDIs to be developed in the interest of avoiding visual distraction [3], but displays for current FEDIs remain almost exclusively visual [2][4].

Current FEDI designs have taken a variety of approaches to display information about fuel economy to drivers (for reviews, see [2][4]). Broadly speaking, FEDIs display either: 1) instantaneous information about the vehicle's current fuel efficiency; or 2) cumulative information about fuel efficiency over a recent period of time (i.e., during the current trip, in between vehicle stoppages, etc.). In their simplest form, instantaneous displays use dynamic text that shows the vehicle's moment-to-moment fuel efficiency, usually expressed in miles-per-gallon in cars in the United States. Other instantaneous FEDIs have reduced the information in the display to an ordinal scale of representation by coding the moment-to-moment fuel economy by color (e.g., a green element in the display for best economy, a yellow element for average economy, and a red element for worse economy). Still other approaches use a simple warning such as a flashing light that only becomes active during times of non-optimal fuel consumption. Cumulative FEDI displays also use a range of strategies for communicating the effects of driving behaviors on fuel economy. Simple cumulative FEDIs may display the average fuel consumption over a recent epoch, but many FEDIs use more complex graphs and iconic displays to communicate patterns of fuel consumption over time [for a recent design, see, e.g., 5].

Research has suggested that driving behaviors such as hard acceleration, heavy braking, and frequent stopping decrease fuel economy (for a review, see [3]). As such, these driving behaviors will be triggers to initiate driver feedback with instantaneous FEDIs, and this feedback will be delivered with visual displays in nearly all current FEDI designs. Visual displays may be problematic for providing this feedback; it is precisely during acceleration, braking, and stopping that drivers should not divert attention away from the driving task. Auditory displays offer a viable alternative to visual displays for communicating information about fuel economy to the driver without introducing visual distraction. Auditory displays also offer a practical advantage over tactile displays [e.g., 6] in that they do not require additional hardware beyond the speakers already present in most vehicle cockpits.

2. PROTOTYPE AUDITORY DISPLAY DESIGNS

Nees and Walker [7] reviewed the use of auditory displays for in-vehicle technologies including FEDIs. Research has shown that well-designed auditory displays for in-vehicle technologies, through increased primary task performance [8] and decreased gaze time [9], can help people to move through menu lists as compared to visual-only displays. While these auditory displays were used within a menu-searching context, there are a number of existing forms of auditory displays that could be used in FEDIs to communicate information about the effects of driving behaviors on fuel efficiency.

2.1. Verbal Auditory Displays

Verbal auditory displays have been prototyped for use in FEDIs; the system offered spoken alerts and advice to improve fuel economy [4]. Speech offers an advantage in that the intended message requires no explanation and the system does not require a learning phase. The primary drawbacks of speech, however, are its potential to: 1) interfere with concurrent conversation; and 2) create annoyance in the form of a virtual version of the colloquial backseat driver.

2.2. Earcons

Earcons—brief, abstract melodic sounds whose acoustic attributes [see, e.g., 10] are systematically correlated with fuel economy parameters—could be deployed in FEDIs. Earcons are generally associated with considerable learning costs, but a limited catalog of earcons could be used to adequately convey enough information to affect driver behavior.

2.3. Auditory Icons

Auditory icons—for example, an exaggerated sound of a car engine or the sound of gas guzzling—could be used to indicate heavy fuel consumption to drivers. Auditory icons are generally easier than earcons to learn in interfaces. The specific sounds used would need to be distinct enough so as not to be confused with actual ambient driving noises.

2.4. Spearcons

Spearcons, or speech earcons, are speech accelerated or compressed such that users may no longer recognize the sound as speech. Spearcons combine the advantages of speech with greater brevity and thus, they could more efficiently deliver the same amount of fuel consumption information as speech.

2.5. Sonifications

Sonifications of real time gas consumption data could be effective for conveying continuous fuel consumption information with audio.

2.6. Soundscapes

Sonification from fuel consumption information could also be orchestrated with sonification based on other information (e.g., stability of driving performance, a driver's states, etc.), which could provide an overview of the driving status as in-vehicle soundscapes.

3. RESEARCH IN PROGRESS

Our research collaboration in progress will explore a holistic approach to the exploration of auditory displays for FEDIs. We plan to compare multimodal FEDI systems including the auditory display designs described above against visual-only FEDI and no FEDI control conditions. Research will focus on drivers' fuel economy, the aesthetics/acceptability and annoyance of the interfaces, and driving performance. A recent review [3] suggested considerable overlap between safe and environmentally-friendly driving behaviors, but little is known about the extent to which FEDIs have the potential to result in driver distraction despite their documented benefits for improving fuel economy. Measuring and decreasing this distraction by examining visual scanning patterns and workload will also be a major focus of this research. We will use a combination of basic laboratory experiments in conjunction with simulator studies.

A wealth of research in cognitive psychology (see [11]) has suggested that immediate as opposed to delayed feedback may be most effective for supporting learning new behaviors during a cognitive and procedural task such as driving. We initially plan to investigate auditory displays for feedback in instantaneous FEDIs, but research is also needed to determine whether instantaneous or delayed feedback about fuel economy is more effective for altering driver behaviors toward eco-friendly driving.

4. CONCLUSIONS

Acceleration, braking, and stopping can negatively impact fuel economy. During these same activities, drivers should be vigilant about keeping visual attention directed toward potential road hazards, yet current FEDI designs use visual displays to communicate instantaneous fuel economy to drivers. Auditory displays of the same information may allow drivers to adjust their behaviors for more eco-friendly driving and also allow them to keep their eyes on the road. The potential for auditory displays for FEDIs to introduce annoyance is real. Our research program seeks to provide evidence for best use of auditory displays in FEDIs by examining their effectiveness in terms of performance and aesthetics.

5. REFERENCES

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