Celerometer and Idling Reminder: Persuasive Technology for School Bus Eco-driving

Tyler Pace
Indiana University
School of Informatics
Bloomington, IN 47406
tympace@indiana.edu

Shruti Ramalingam
Indiana University
School of Informatics
Bloomington, IN 47406
sramalin@indiana.edu

David Roedl
Indiana University
School of Informatics
Bloomington, IN 47406
droedl@indiana.edu

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Abstract
We are designing a feedback system to encourage more fuel-efficient driving habits among school-bus drivers. We chose to design for the school bus because as one of the largest public transport systems in the U.S., it is a major contributor to the country's total fuel consumption and pollutant emissions. Our design uses persuasive technology to discourage excessive idling and aggressive driving by providing real-time in-vehicle feedback for self-monitoring.

Keywords
Persuasive Technology, Captology, Automobile Interfaces, Automobile Cockpit Design, Designing for Eco-Driving, Mission-Critical Systems

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous, Ergonomics, User-centered design

Introduction
As noted in the competition problem statement, petroleum fuel costs have recently risen and the trend is predicted to continue due to ever-increasing demand and concerns over diminishingly supply. It has been estimated that automobile emissions account for 27% of all U.S. greenhouse gases [11]. One European study

found air-borne pollution to lower life-expectancy by almost 9 months on average [1]. In order to mitigate these risks of disease, economic strain, and global climate change, the overall goal of our design project is to reduce petroleum fuel consumption.

Why School Buses

Public school buses serve as one of the largest public transportation systems in the U.S. with over 500,000 school buses traveling more than 4 billion miles a year [10]. School buses have an average fuel economy of only 5-7 miles per gallon [7]. Using a conservative estimate this means school buses annually consume around 600 million gallons of fuel, costing $1.5 billion and emitting 6.6 million tons of carbon dioxide. In addition, exhaust from diesel fuel (which powers 95% of school buses) contributes to serious health problems, including heart disease, cancer and premature death. The 24 million children who ride school buses daily are especially vulnerable to these effects [10].

Current Situation

While safety remains their primary concern, from our field study we learned that school bus administrators have recently been paying more attention to fuel economy. So far major initiatives have been technical in nature (e.g. proper vehicle maintenance) and little emphasis has been placed on the influence of driver behavior.

It has been known for several decades that driving style and habits have an impact on fuel consumption. Driving strategies that seek to maximize economy have been developed and are often referred to as 'eco-driving'. When driving automatic transmission vehicles (which include most school buses) the primary recommended behaviors are to reduce excessive idling time and to minimize aggressive driving behaviors, such as rapid acceleration and braking [4].

As recommended by the Environmental Protection Agency (EPA), many school districts have anti-idling policies [10]. However, our field study indicates that enforcement and compliance are low. In addition, virtually no measures have been implemented to discourage against aggressive driving.

Persuasive Technology

In recent years attention has grown within HCI for the potential of computers to change the way users think or behave. BJ Fogg has written extensively about the design of such persuasive technologies. Some of the powerful design principles he has identified are to make suggestions at opportune moments for action, present contextualized information, and to allow users to self-monitor their progress towards a goal [2].

Applying such strategies to the context of driving behavior, researchers from Stanford University have designed a dynamic speedometer to discourage speeding. The display shows the current speed limit in comparison to the vehicles speed, making an implicit suggestion to stay within the limit [5].

Research Goals

Our research is concerned with how persuasive technology can change behavior, in particular how real-time feedback can be used to improve performance of complex tasks such as driving. More specifically, we want to determine if an in-vehicle interface can be successful in persuading school bus drivers to reduce their idling and aggressive driving, while remaining safe and unobtrusive.

Design Process

Concept Formation

Our user-centered design process started with exploring the problem space. We conducted a focus group on car drivers in an effort to understand the negative attitudes that constitute the use of public transportation. We also conducted a contextual inquiry on bus commuters to try and understand problems faced while traveling. Our major insight from the above research was that people were resistant to making huge changes in lifestyle. Any change induced needed to be small enough that it fit in to their existing activities with least effort. Our second insight was with regards to the problem itself. We started to see the problem as part of the bigger problem of increased carbon emissions, of which motivating people to use public transportation was just one possible solution.

This led us towards examining ways in which we could promote changes in other areas such as driving behavior as a move towards reducing carbon emissions. Our research indicated that while a common myth exists that it is better to leave a diesel engine running than to start and stop, the behavior actually wastes fuel, pollutes and causes greater wear and tear on the engine. The EPA estimates that a typical school bus will burn 1/2 gallon of fuel for every hour spent idling. In addition to this, growing concern for the health damage caused by diesel exhaust during idling has led the EPA to strongly promote anti-idling campaigns for school buses [10]. We also found that while many factors combine to affect fuel efficiency, probably the greatest impact is achieved through proper acceleration and deceleration patterns. Estimates suggest that changing driving style can reduce fuel consumption up to 15-20% [4].

As part of our design process, we interviewed Mr. Mike Clark, Transportation Director of Monroe County Community Schools Corporation (MCCSC). We found that he was constantly in search of new ways to reduce fuel consumption. At present this is done by performing regular maintenance checks and implementing anti-idling policies. We found that 8% of all buses in the school system were equipped with a GPS tracking system and that there was a five year plan in place to convert all the buses in the school system. We also learned that all MCCSC drivers are required to pass a series of rigorous tests on general driving knowledge, passenger safety, and school bus safety. From our interview, we learned that in spite of the training and existence of anti-idling policies, idling continues to happen due to lack of resources to survey the drivers in real time as they execute their routes.

Mr. Clark also stated that driver recruitment and retention is one of the most difficult problems faced by the transportation administration. Additionally, bus drivers are the only employees on the bus and are responsible for children and driving. Our design should require minimum cognitive effort on the driver’s part to understand and respond, ensuring that both passenger safety and job satisfaction levels not be affected.

Concept

Our concept involves a real time feedback system for school bus drivers coupled with a social incentives program. The real time feedback system serves to remind the driver of his driving behavior. The design is

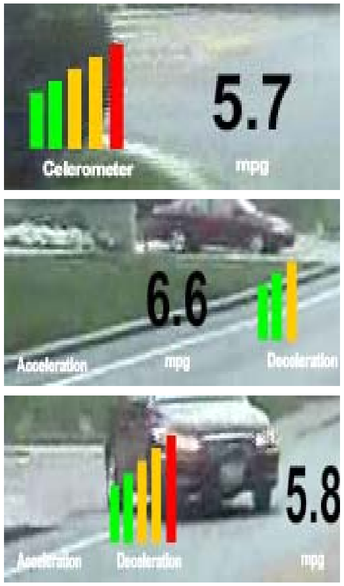

Figure 1. HUD designs (A), (B), and (C) respectively.

Figure 2. Idling timer.

built around the concept of allowing the driver control over his behavior in real time rather than having to correct it only after it has come to the notice of the management. The concept is complemented by a monthly report, delivered as a hard copy, which allows the driver to monitor their performance over longer periods of time. These reports would show comparative data in relation to the fleet average in order to create added social influence. In addition, administrators might choose to offer rewards to top-performing drivers to increase motivation.

The real time feedback system will allow the driver to monitor his acceleration/braking as well as idling time. We choose to provide this display on a heads-up-display (HUD) projected onto the vehicle windshield. Research demonstrates that driver response time is reduced with windshield displays when compared to an in-vehicle display [8]. Additionally, the projected interface remains in the driver's visual periphery to minimize cognitive overload. It has also been found that drivers spend most of their driving time monitoring the forward field of view and rear view mirror. It is in between these two activities that they glance at in-vehicle displays and controls. In general, a driver spends a mean glance time of 1.2 to 1.5 seconds looking at in-vehicle controls and displays. However, it has been found that for drivers to feel safe, the total glance time should not exceed five to ten seconds [3]. The HUD can be broken down into two primary components: idling timer and *celerometer*.

The idling timer serves as a constant, visual reminder of the bus' current amount of engine idle time. Providing a display of current idle time enables the driver to become aware of their idling habits and make informed choices about why and when their engines should remain running. Feedback from the idling timer appears only when the bus is parked and is graduated, beginning with a simple timer and progressing to more noticeable color feedback as established idling thresholds are reached (Figure 2).

The *celerometer* serves as a measure of aggressive driving by displaying the current rate of bus 'celeration' (acceleration or deceleration). This takes the form of a spectrum of colored bars, moving from small, green to large, red bars. In addition to the celeration spectrums, the HUD displays the current miles per gallon to reinforce the relationship between celeration and fuel economy. The specific feedback being displayed is relative to the action at hand and thus we expect that it will not confuse the user as to what is being monitored.

Evaluation

Inspired by the study *Getting the Right Design and the Design Right: Testing Many is Better Than One* [9], we conducted a pilot study of three different HUD concepts on drivers (n=5) with varying levels of driving experience. Each concept (Figure 1) was demonstrated with a video prototype while subjects were asked to think aloud about the displays and fill out post-test questionnaires discussing their reactions to each display. The prototypes were shown in counterbalanced order. The results of the pilot study (Figure 3) were used to design a hi-fidelity simulation prototype used for further testing.

Method

To evaluate the persuasive efficacy of the HUD, we conducted a user test with a fully functional, hi-fidelity prototype (Figure 4). The prototype was used in

1. All users preferred Celerometer (B).

Separate displays for acceleration and braking increase learnability.

2. 80% of users thought the display may be annoying if always visible.

Phasing display in and out during active and inactive periods will limit over-exposure.

3. All users understood the idling timer without explanation.

Figure 3. Results and recommendations from pilot test.

tandem with a free, cross-platform 3D driving simulation environment, as was used in [5].

A group of drivers (n=5) with varying levels of driving experience were recruited to participate in our study. Human Subjects Committee approval was obtained and consent secured for each participant. The drivers were asked to participate in multiple, consecutive tests.

A course with realistic driving conditions (traffic signs, stop lights, various road shapes, etc) was selected for the test. Subjects were given time to practice in the simulated environment using the provided steering wheel and pedal controls. After practicing, subjects were given the scenario of a bus driver who needed to get students to school as soon as possible without violating the speed limit. This scenario was used as the baseline driving behavior for each user.

Figure 4. Testing setup.

After the baseline lap, each subject was asked to drive for fuel efficiency using eco-driving strategies of smooth acceleration and braking, while again remaining within the speed limit. For this scenario, subjects were asked to drive two laps, one using a car that was equipped with the HUD and one car that was without the HUD. Participants were informed of the differences between the two vehicles. The cars were introduced to the subjects in counter-balanced order to control for the effect of extra time in the simulated environment on driving behavior.

Results

For each driving test, the celeration (absolute value of change in speed in kph) was measured at 1 second intervals for the duration of each lap around the test course. Average baseline celeration was 2.46 kph/s, average eco-driving celeration was 1.99 kph/s, and average eco-driving with the HUD was 1.57 kph/s (Figures 5&6).

The HUD had a significant effect on persuading participants to drive less aggressively. Comparing the driving behavior of subjects between the baseline, eco-driving, and eco-driving with celerometer scenarios, the average celeration decreased for all subjects.

Our future plans are to create an actual vehicle HUD to be tested in real world driving conditions. Additional research will be conducted on audio and kinesthetic feedback systems, as multi-modal feedback has been found to improve performance in similar systems [6].

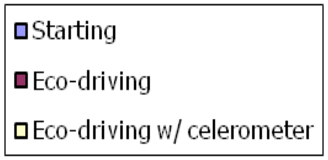

Figure 6. Chart legend.

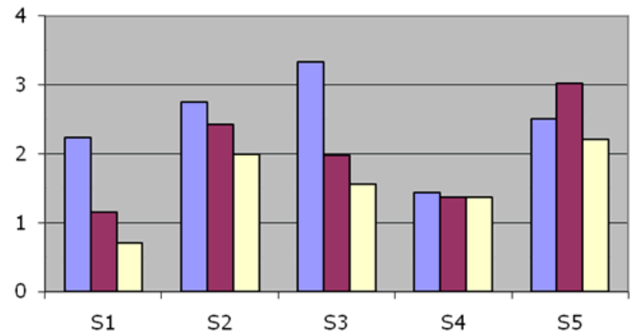

Figure 5. Average celeration by subject (kph/s).

Conclusion

Our heads-up-display offers meaningful feedback at opportune moments to promote eco-driving among school bus drivers. Testing shows that the feedback is easily understood and has a positive effect on driving behavior and hence a decrease in fuel emissions.

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