A User-Centered Drowsy-Driver Detection and Warning System

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Abstract

This work is a culmination of years of research to develop an effective in-vehicle countermeasure to drowsy driving. Previous work resulted in an independently validated measure of drowsiness that was then incorporated into a drowsy-driver prototype monitor. The goal of this project was to develop an associated drowsy-driver interface that enabled effective, user-centered interactions with the underlying system.

A multidisciplinary team designed a new drowsy-driver interface and introduced smart user interactions through a careful participatory design process that included both design experts and commercial motor vehicle drivers. It is hoped that this effort and subsequent field trials will result in a reliable, smart system that convinces drivers that they are driving in an unsafe condition and to make a wise choiceóstop and rest.

Keywords

User-Centered Design / Human-Centered Design, Multidisciplinary Design / Interdisciplinary Design, Product Design, User Experience, Safety, Alertness.

Industry/category

Transportation, trucking, intelligent vehicle initiative

Twenty-four hour operations, high annual mileage, exposure to demanding environmental conditions, and demanding work schedules make drowsiness a major cause of combination-unit truck (CUT) crashes.

Fatigued drivers are often unaware of their condition, frequently driving for 3 to 30 seconds with their eyes closed.

PERCLOS
The proportion of time that the driver's eyes are 80 to 100% closed over a specified interval.

Figure 1: Camera view

Figure 2: Truck dashboard location for monitor

Project statement

The National Highway Traffic and Safety Administration (NHTSA) has been working for years toward developing an effective, validated drowsy-driver detection and warning system for use by commercial motor vehicle drivers (CMVs). Considerable progress has been made in measuring drowsiness and understanding its effects upon human performance in the laboratory and in simulated and operational driving conditions.

A measure of drowsiness, PERCLOS, was generated and associated with degradation in driving performance in a simulated roadway environment [1]. Its validity was tested, along with other new technologies, and it was shown to be an accurate drowsiness detector [2]. Studies of overnight commercial trucking operations resulted in a proof-of-concept prototype containing an infrared camera system and software capable of detecting drowsiness and issuing a warning real time in an operational setting [3].

The challenge is to translate these findings into a fully functional prototype whose system design minimizes false alarms (PERCLOS logic), addresses issues of effectiveness (accuracy, reliability, behavioral change), and reflects a user-centered approach to the interaction and interface. This prototype will then be tested in a large-scale, over-the-road study.

Project participants

Ellen M. Ayoob, Lead Designer
Richard Grace, Senior Systems Scientist
Aaron Steinfeld, Senior Research Psychologist
Lisa Carvajal, Industrial Design Consultant
John Thackery, Electronics Engineer
Rob Engel, Electronics Technician

Project dates and duration

The project began in July of 2001 and the draft report was presented in September 2002, with work still ongoing.

Process

Much is known and documented about the effects of drowsiness [4] and the short-term [5] and long-term countermeasures [6] drivers use to manage fatigue.

Many studies have already focused on warning-sound qualities, driver annoyance with alarms and alerts, tonal preferences, and safe glance durations for a visual display in a vehicle.

Design options for the displays and controls are bounded by technological limitations and design and human-factor principles that have been extensively tested for in-vehicle environments (illumination and glare issues, ambient noise levels, temperature, and so on).

Surprisingly, despite all of this research, very few multidisciplinary teams have been assembled, and a user-centered, participatory design process has been practically nonexistent.

Overview of the Design Process
The design process was organized around humanistic themes (human connection, choice, engagement, integration, driver awareness, and association) that emerged from gaps identified in past approaches. These themes set the tone for the designs.

With user-centered design principles [7] central to the development, the team undertook a series of activities

Figure 3: Experts reviewing interaction flows

Expert Activities
- Short context-setting film
- Tour of a truck cab
- High-level briefing of goals
- Interaction flow model
- Exercise and design review
- Random spot signaling exploration
- Sound exploration

Figure 4: Driver design exercise

User Activities
- Questionnaire
- Action-sequence model [8]
- exercise to understand a typical night shift
- Critical drowsy-driving incident interviews
- Design exercise and discussion

to enhance their understanding of the problem space and assist in the development of an appropriate design. These included literature reviews, brainstorming sessions, field visits, and thematic explorations that culminated in an expert/advisor focus group and a user focus group.

By talking with design and usability experts first, less usable or conceptually flawed ideas were eliminated and valuable knowledge was gained. By speaking with a representative group of drivers, their perceptions, preferences, issues, and attitudes became known. Unfortunately, constraints did not permit more than one user focus group.

Results
The experts connected the design of the warning interaction and interface with user perceptions about intended use. The driver focus group provided insight into the task of driving a commercial vehicle, the nature of drowsiness episodes, a list of the features they desire in a drowsy-driver interface, and potential resistance/acceptability issues.

A perceptual conflict arose, however, between the drivers and the scientific community. The drivers viewed the system as a loyal servant that would alert them and avert danger, while the scientific community viewed the system as a trusted advisor that would encourage them to stop and rest. The final design had to incorporate features that address these views.

Solution
The interaction and interface design incorporates the drivers' desire for a stimulating and alerting response with the researchers' desire to encourage safe behavior. Promoting driver acceptance through driver control is a theme throughout the design.

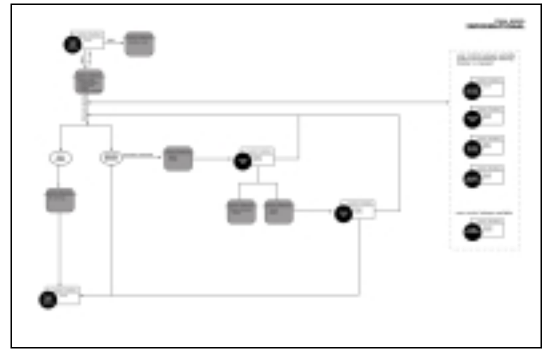

Figure 5: Interaction flow model for final design

The interaction model allows the driver to:

- Adjust the sensitivity of the drowsiness warning to minimize false alarms
- Select sounds that range from a robust, alerting sound to a gentle advisory tone
- Adjust the volume to match the ambient sound environment
- Disable the warning system should the driver find it bothersome

The warning sound occurs simultaneously with an informational warning display. The informational display is a horizontal bar graph that displays the time the driver's eyes were closed (up to four seconds) and the distance traveled (up to 120 yards at an average speed of 61 mph). These metrics were chosen over PERCLOS as being less abstract, more believable, and more relevant to the drivers' experiences, after many

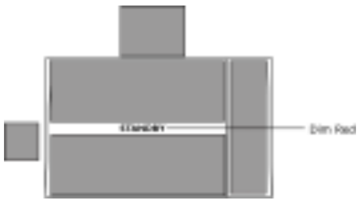

Figure 7: Interaction sketch

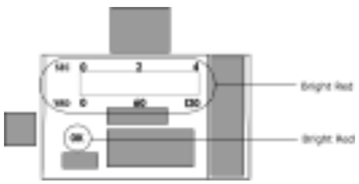

Figure 8: Interaction sketch

Figure 9: Prototype model sketch

Figure 10: Prototype model

discussions between design and engineering team members.

A secondary display shows time lapses between warnings, and total warnings received during a drive. Both are preceded by an auditory alert.

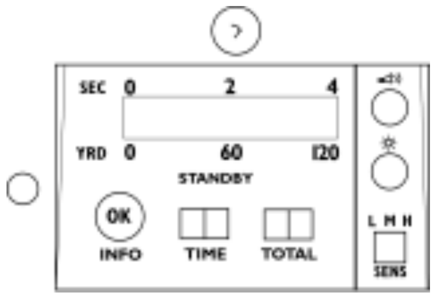

Figure 6: Interface diagrammatic sketch

Next Steps

Until drivers experience the new design in a real setting, a gap exists between professed want and actual use. The plan is to pilot the system with several drivers, then deliver fully functioning prototypes and specifications for use in the over-the-road test.

Acknowledgements

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