TechBrief

Programs of the Federal Motor Carrier Safety Administration (FMCSA) encompass a range of issues and disciplines, all related to motor carrier safety and security. FMCSA s Office of Analysis, Research and Technology defines a “research program” as any systematic study directed toward fuller scientific discovery, knowledge, or understand-ing that will improve safety, and reduce the number and severity of commercial motor vehicle crashes. Similarly, a “technology program” is a program that adopts, develops, tests, and/or deploys innovative driver and/or vehicle best safety practices and technologies that will improve safety and reduce the number and severity of commercial motor vehicle crashes. An “analysis program” is defined as economic and environmental analyses done for the agencys rulemakings, as well as program effectiveness studies, state-reported data quality initiatives, and special crash and other motor carrier safety performance-related analyses. A “large truck” is any truck with a Gross Vehicle Weight rating or Gross Combination Weight rating of 10,001 pounds or greater.

Currently, FMCSA s Office of Analysis, Research and Technology is conducting programs in order to produce safer drivers, improve safety of commercial motor vehicles, produce safer carriers, advance safety through information-based initiatives, and improve security through safety initiatives. The study described in this Tech Brief was designed and developed to support the strategic objective to produce safer drivers. The primary goals of this initiative are to ensure that commercial drivers are physically qualified, trained to perform safely, and mentally alert.

U.S. Department of Transportation
Federal Motor Carrier Safety Administration
Office of Analysis, Research and Technology
1200 New Jersey Ave. SE
Washington, DC 20590

FMCSA Contact: Robert Carroll, MC-RRR, 202-385-2388

An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies

This Tech Brief summarizes the findings of the “An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies” study that was done in order to evaluate emerging driver alertness detection measures, models, and technologies that can be used to provide 24-hour fatigue monitoring capability. The study ties into an important element in meeting the strategic safety objectives of the Federal Motor Carrier Safety Administration (FMCSA)—that is, an emphasis on the safety performance of commercial drivers to ensure they are physically qualified to operate commercial motor vehicles (CMVs) safely while staying mentally alert. The full report (Document No. FMCSA-RRR-09-005) provides a comprehensive discussion of unobtrusive, in-vehicle, real-time drowsy driver detection and fatigue monitoring and alerting systems.

An onboard device that monitors a driver’s level of fatigue and drowsiness in real time could be a significant enhancement to a comprehensive and effective fatigue management program. People suffering from fatigue exhibit certain behaviors that are easily observable from facial features, including eyelid, pupil, and head movement, as well as facial expression. To make use of these cues of sleepiness, a considerable amount of research is aimed at developing non-invasive techniques for assessing a driver’s alertness, often based on visual observation of his/her physical condition using a remote camera and state-of-the-art technologies in computer vision. Recent progress in machine vision research and computer hardware have made it possible to measure head pose, eye gaze, and eyelid movement with a high degree of accuracy using video cameras.

Background

FMCSA, the trucking industry, safety advocates, and transportation researchers have all identified driver fatigue as a high priority CMV safety issue. Fatigue affects mental alertness, decreasing an individual’s ability to operate a vehicle safely and increasing the risk of human error that could lead to fatalities and injuries. Sleepiness slows reaction time, decreases awareness, and impairs judgment.

Incidence of fatigue is underestimated because it is so difficult to quantify and measure. Obtaining reliable data on fatigue-related crashes is challenging because it is difficult to determine the degree to which fatigue plays a role in crashes. For instance, if a motorist is unharmed in a crash, the increased arousal following the incident usually masks the impairment that could assist investigating officers in attributing the crash to drowsiness. As a result, sleepiness as a contributing factor in motor vehicle crashes is underreported in databases of police accident reports. Moreover, because sleep deprivation increases the likelihood of attention lapses, drowsiness or fatigue may play a role in crashes attributed to other causes. An investigator may report that a crash was caused by a driver running a red light, whereas in reality the crash occurred because the driver was not appropriately vigilant due to his or her state of sleepiness and fatigue. Lastly, drivers tend to be poor judges of their own level of drowsiness since they cannot reliably predict when they are impaired to the point of falling asleep at the wheel.

Challenges

Three challenges were identified in successfully addressing the issue of fatigue in the motor carrier industry. First, operational requirements are diverse since the trucking industry covers a wide range of driving requirements. Factors such as work schedules, duty times, rest periods, recovery opportunities, and response to customer needs can vary widely. Second, there are considerable individual differences among operators. For example, age can have a significant effect on the quality and quantity of sleep an individual might obtain, a person's ability to cope with rotating shift schedules or night work, and the risk for sleep disorders. Finally, the interaction of the principal physiological factors that underlie fatigue, namely the homeostatic drive for sleep and circadian rhythms, are complex. These challenges preclude a single, simple solution, but fatigue may be managed, resulting in a significant reduction in risks and potential improvement in safety.

Technology Approaches

Successfully reducing fatigue-related risks in transportation will require innovative concepts and evolving approaches. Technologies have great potential to address fatigue are available and emerging. Four categories of operator-centered alertness monitoring and fatigue detection and prediction technologies were identified:

- **Mathematical models/algorithm technologies**—This approach involves the application of mathematical models that predict operator alertness and performance at different times based on interactions of the amount of sleep obtained or missed, circadian factors, present workload, and related temporal antecedents of fatigue.
- **Vehicle-based operator alertness/drowsiness/vigilance monitoring technologies**—These technologies exemplify the most common approaches currently used to monitor driver fatigue, and they monitor some bio-behavioral aspect of the operator such as eye gaze, eye closure, pupil occlusion, head position and movement, brain wave activity, heart rate, and other measures.
- **Readiness-to-perform and fitness-for-duty technologies**—These systems attempt to assess reaction time, psychomotor tracking, or the vigilance and alertness capacity of an operator before work is performed (i.e., prior to the start of the work shift).
- **Vehicle-based performance technologies**—These technologies measure vehicle performance parameters (e.g., steering movements, vehicle speed, or the movements of the vehicle within the lane markers on the roadway), and they infer driver behavior by monitoring the continuity of steering wheel movements and/or vehicle speed or by examining the driver's ability to maintain adequate lane-tracking movements while steering the vehicle.

Mathematical models/algorithm technologies

Biomathematical models that quantify the effects of circadian and sleep/wake processes on the regulation of alertness and performance have been developed; theypredict the magnitude and timing of fatigue-related responses in transportation operations. These models of alertness and performance typically use input information about sleep history, duration of wakefulness, work and rest patterns, and circadian phase to predict sleepiness, performance capability, and/or fatigue risk. Highly complex algorithms then produce outputs describing how levels of performance will be affected by the individual's sleep/work history. Vulnerability to fatigue and performance degradation as a function of time of day are assessed, and the information is used to: 1) design and evaluate work/rest schedules, 2) plan work and sleep in operational missions, 3) assist in determining the timing of countermeasures to anticipated performance deficits, and 4) assess accidents and facilitate policy-making (e.g., hours-of-service regulations). These models make up the subclass of operator-centered technologies that includes devices that monitor sources of fatigue, such as how much sleep an operator has obtained, and combine this information with a mathematical model designed to predict performance capability and when future periods of increased sleepiness will occur.

Table 1. Description of Technologies Reviewed

DD850 Driver Fatigue Monitor ATTENTION TECHNOLOGY, INC.	Video-based drowsiness detection system for measuring slow eyelid closure. It is designed to mount on the vehicle's dashboard to provide a continuous real-time measurement of eye position and eyelid
Driver State Monitor DELPHI ELECTRONICS AND SAFETY	Computer vision system that uses a single camera mounted on the dashboard directly in front of the driver and two infrared illumination sources. It evaluates eye closures and the forward attention level of the driver over time using a single high-fidelity
faceLab® SEEING MACHINES	Flexible and mobile tracking system that provides head and face tracking as well as eye, eyelid, and gaze tracking for human subjects using a non-contact, video-based sensor. A wide field of view enables analysis of naturalistic behavior in real time under real-world conditions without the use of wires, magnets, or headgear.
Smart Eye Pro 3.0 SMART EYE AB	Computer vision-based software that enables computers and machines to detect human face/head movement, eye movement, and gaze direction
InSight™ SENSOMOTORIC INSTRUMENTS GMBH	Advanced, non-invasive, computer-vision based operator monitoring system that measures head position and orientation, gaze direction, eyelid opening, and pupil position and diameter.
ETS-PC II APPLIED SCIENCE LABORATORIES	Video eye tracker that provides a horizontal and vertical field of view for accurate measurement of the driver's eye movement and line of sight.
Eyegaze Analysis System LC TECHNOLOGIES, INC.	Hands-off, unobtrusive, remote human-computer interface used to track a driver's gaze point or allow an operator to interact with their environment.
Drowsy Driver Detection System JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LAB	Drowsiness detector containing a transceiver similar to those used in automatic door entry systems that operate at safe microwave frequency and power levels.
Prototype computer vision system for monitoring driver vigilance RENSSELAER POLYTECHNIC INSTITUTE	A prototype computer vision system that can simultaneously monitor in real time several visual behaviors, including eyelid and gaze movement, pupil movement, head movement, and facial expression to characterize the driver's state of alertness.
Artificial Neural Network GEORGE WASHINGTON UNIVERSITY	A network that observes the steering angle patterns and classifies them into drowsy and non-drowsy driving intervals.

Full report title:
An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies (Document No. FMCSA-RRR-09-005)

Performed by:
The Volpe National Transportation Systems Center,
55 Broadway, Kendall Square,
Cambridge, MA 02142

Authored by:
Lawrence Barr, Stephen Popkin, and Heidi Howarth.

Key Words:
Alertness, Carrier Safety, Circadian, Commercial Motor Vehicle, Drowsiness Detection, Drowsy, Fatigue, Lane Tracking, Motorcoach, On-Board Monioring, Truck, Vigilance, CMV

Web Site:
All FMCSA Tech and Analysis Briefs may be accessed at www.fmcsa.dot.gov.

Technical Editor:
Karen Robin
C² Technologies, Inc.

June 2009
Publication No. FMCSA-RRR-09-006

Vehicle-based operator alertness/drowsiness/vigilance monitoring technologies

While some enduring systems and devices have been available as prototypes for a decade or more, many of these technologies are now in the development, validation testing, or early implementation stages. Previous studies have reviewed available fatigue detection and prediction technologies and methodologies. This study builds on previous work by providing updated information on state-of-the-art fatigue detection and alertness monitoring technologies, which are briefly listed in Table 1. Significant advances in video camera and computer processing technologies coupled with robust, non-invasive eye detection and tracking systems have made it possible to characterize and monitor a driver's state of alertness in real time under all types of driving conditions.

Conclusion

Driver drowsiness poses a threat to highway safety, and the problem is particularly urgent for CMV operators. Twenty-four hour operations, high annual mileage, exposure to challenging environmental conditions, and demanding work schedules all make this a serious safety issue. Monitoring drivers' drowsiness and vigilance, and providing feedback on their condition so that they can take appropriate action are crucial steps in a series of preventive measures necessary to address this problem.

Technological approaches have continued to emerge in recent years that hold promise for real-time detecting and monitoring driver drowsiness. These devices check everything from eye closure to head movement to steering inputs. To be practical and useful to drivers, these devices must acquire, interpret, and provide information in real world driving environments; a significant amount of work is underway in this area.

Several promising state-of-the-art devices and technologies were identified in the study and evaluated against a set of proposed design guidelines. Technological advances in electronics, optics, sensory arrays, data acquisition systems, algorithm development, and machine vision have brought the goal of providing unobtrusive, real time, affordable, 24-hour driver alertness monitoring capability much closer to reality. Considerable development effort is taking place to demonstrate the scientific validity and reliability of these technologies, but more work is required before they can be fully implemented as an integral component of an overall fatigue management program