TECH BRIEF: Pilot Test of Fatigue Management Technologies

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The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the large truck fatality rate by 41 percent from 1996 to 2008. This reduction translates into a rate of 1.65 fatalities in truck crashes per 100 million miles of truck travel.

FMCSA's Research and Technology programs encompass a range of issues and disciplines, all related to motor carrier and bus safety and security. FMCSA defines a "research program" as any systematic study directed toward fuller scientific discovery, knowledge, or understanding that will improve safety, and reduce the number and severity of commercial motor vehicle crashes. Similarly, a "technology program" defines those programs that adopt, develop, test, and/or deploy innovative driver and/or vehicle best practices, and technologies that will improve safety and reduce the number and severity of commercial motor vehicle crashes.

Currently, FMCSA's Office of 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 FMCSA Research & Technology 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.

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Background

Fatigue management technologies (FMTs) were recently pilot-tested in a field trial with commercial truck drivers. Reactions of these drivers, all volunteers, to the technologies were evaluated to ascertain whether or not these devices were seen as either beneficial or intrusive. The FMTs were evaluated in order to see if feedback from these devices improved driver alertness, especially during night driving, and if feedback increased driver sleep time on either workdays or non-workdays. The pilot test consisted of the development of an experimental design and an instrumentation plan, and was conducted under Federally-mandated hours-of-service rules in both the U.S. and Canada.

Fatigue Management Technologies Tested

Four different FMTs were tested concurrently during this pilot test.

SleepWatch® with Sleep Management Model Software

The SleepWatch® (developed by Precision Control Design, Inc.) is a wrist-worn device, containing an algorithm (developed by Walter Reed Army Institute of Research) for monitoring and providing feedback to drivers on personal sleep needs and performance readiness. Wrist-worn actigraphic monitoring of drivers' rest-activity patterns, with feedback regarding drivers' estimated sleep need, was judged to be a promising, objective way to inform drivers of the development of cumulative sleep debt and the need to obtain more sleep and/or take additional alertness-promoting countermeasures. A button is pressed to view "Performance-Readiness," which is displayed as a percentage (P) from 0–99 percent.

CoPilot® System using PERCLOS

The CoPilot® System (Attention Technologies, Inc.) is used for infrared monitoring of slow eyelid closures (PERCLOS), a sign of driver drowsiness. This real-time detection and feedback of driver drowsiness provides drivers with immediate information on their drowsiness levels when driving, which is especially important during driving in the late-night and early morning hours, when drowsiness is typically more present.

SafeTRAC® Lane Tracking System

The SafeTRAC® lane tracker system (Applied Perception and AssistWare Technology, Inc.) provides online monitoring of driver lane tracking performance. This technology estimated "Driver Alertness" by a proprietary algorithm involving stable lane tracking. Alertness was measured on a scale from 0 to 99—99 expressing maximum alertness.

Howard Power Center Steering® System

The Howard Power Center Steering® system (River City Products, Inc.) is used to eliminate most of the work involved in driver correction of vehicle instability and control problems. It involves a hydraulic device attached to a truck's tie rod and steering system, which reduces the physical demands of driving. The driver has the ability to control the desirable hydraulic pressure on a panel by adjusting air pressure, which increases or decreases effectiveness of the system.

Other Instruments and Tasks

The trucks of volunteer drivers were also instrumented with the Accident Prevention Plus (AP+) on-board recording device ("black box") to continuously record a range of truck motion variables (such as speed and lateral acceleration), as well as information from the FMT devices (including PERCLOS, lane tracking variability, and steering). Drivers also completed a daily diary on their work-rest activities, which included questions about different variables such as traffic delays, weather problems, and impressions of FMT devices. They performed a "Psychomotor Vigilance Task" (PVT) test twice daily. The PVT is a well-validated 10-minute laboratory test of behavioral alertness that is widely used to obtain an estimate of performance limits in alert and drowsy subjects, developed by D.F. Dinges and colleagues. This test was performed midway, and at the end of each trip, as an independent validation of drivers' behavioral alertness level.

Before driving the instrumented trucks, drivers received training in the use of all of the technologies listed above, and attended a course entitled "Education on Alertness and Fatigue Management." The education module encouraged drivers to be responsible for their alertness levels at all times throughout the study. Following completion of the study, drivers were debriefed, and completed the "Human Factors Structured Interview Questionnaire," in which they reported their reactions to all interventions, measures, and technologies used in the study.

Study Design

A "within-subjects cross-over design," using subjects as their own controls, was the most efficient way to compare the two conditions in this study: the FEEDBACK condition and the NO FEEDBACK control

condition. The FMT intervention and data collection were applied to existing trucking operations, and did not require manipulation of scheduling or any other actions of participating companies and drivers. Drivers first drove for 2 weeks in the NO FEEDBACK condition, in which data were recorded, but no feedback on alertness/sleepiness, performance or sleep need was provided to drivers. In the subsequent 2 weeks, drivers operated with FEEDBACK from the SleepWatch®, the CoPilot® System for monitoring PERCLOS, and the SafeTRAC® lane tracker. The Howard Power Center Steering® System was also available to use during these 2 weeks of FEEDBACK.

Since it was neither cost-effective nor practical to conduct a separate study of each individual technology, the selected representative four FMTs were combined and tested as a set within a single field trial that had two phases. Study Phase 1 took place under Canadian hours-of-service, and involved a Canadian trucking company in which drivers operated single tractor-trailer units with sleeper berths, and approximately 74 percent of their driving was conducted during daytime hours. Study Phase 2 took place under U.S. hours-of-service, and involved a U.S. trucking company in which drivers operated tandem tractor-trailer units without sleeper berths, and approximately 93 percent of their driving was conducted during nighttime hours. The difference between the Canadian and U.S. trucking companies were in part a function of which companies agreed to be part of the study, as well as the goal to expressly study companies in which night driving was both a minority (Study Phase 1) and a majority (Study Phase 2) of trucking operations.

Results

Two main hypotheses were tested in the study.

Hypothesis One: FMT FEEDBACK will improve driver alertness and/or reduce driver drowsiness at night.

Canada Study - Phase 1

There was modest evidence to support the hypothesis in this phase, where 26 percent of the driving was done at night. Driver drowsiness as measured by the CoPilot® index of PERCLOS during night driving tended to be reduced under the FEEDBACK condition compared to the NO FEEDBACK condition. This effect was significant in drivers' subjective sleepiness ratings taken before and after PVT performance tests at night. However, the SafeTRAC® index of driver "alertness" and PVT reaction times showed slight reductions in alertness during day driving in the FEEDBACK condition.

United States Study - Phase 2

There was clear evidence in support of the hypothesis in Study Phase 2, where 93 percent of the driving was done at night. The SafeTRAC® index of driver "alertness" and the CoPilot® index of PERCLOS both provided evidence of greater alertness in the FEEDBACK condition than in the NO FEEDBACK condition. Lane tracking variability also tended to improve with FMT FEEDBACK during night driving in the U.S. phase. In contrast, PVT performance was worse at night in the FEEDBACK condition, and subjective sleepiness was higher.

Combined Canada and United States Data

Composite results from pooling data from the two study phases yielded support for the hypothesis that "FMT FEEDBACK will improve driver alertness and/or reduce driver drowsiness at night." During night driving, FMT FEEDBACK significantly reduced slow eyelid closures (PERCLOS) as measured by CoPilot®, increased the SafeTRAC® estimate of driver "alertness," and decreased lane tracking variability. However, PVT lapses were elevated in each study phase in the FEEDBACK condition, relative to the NO FEEDBACK condition, and the increase occurred during the portion of the 24-hour day in which drivers most often were driving (daytime for the Canadian drivers and nighttime for the U.S. drivers). This finding suggests that there may be a fatigue-related "cost" to the added effort (inattention and compensatory behaviors) required to respond to the FEEDBACK from the FMT devices.

Hypothesis Two: FMT FEEDBACK will increase driver sleep time.

Canada Study - Phase 1

None of the SleepWatch® actigraphy outcomes demonstrated systematic differences between the NO FEEDBACK and FEEDBACK conditions for all days combined—both workdays and non-workdays. There was also no evidence from drivers' daily diaries to support the hypothesis that FMT FEEDBACK resulted in increased sleep time on workdays relative to NO FEEDBACK.

United States Study - Phase 2

There was a significant increase in the number of SleepWatch® actigraphically identified sleep episodes, but not an increase in sleep duration in the FMT FEEDBACK condition relative to the NO FEEDBACK condition for all days combined. There was no evidence from drivers' daily diaries to support the

hypothesis that the FMT FEEDBACK condition resulted in increased sleep time on workdays relative to the NO FEEDBACK condition.

Combined Canada and United States Data

When SleepWatch® actigraphically identified sleep duration per 24 hours was analyzed for both study phases, separating workdays and non-workdays, there was clear evidence in support of the hypothesis. In contrast to workdays, where FMT FEEDBACK had no effect on sleep time, there was a significant increase in mean sleep duration during non-workdays in the FEEDBACK condition relative to the NO FEEDBACK condition. Drivers in both study phases increased their non-workday sleep durations in the FEEDBACK condition by an average of 26 minutes per day over sleep duration on days off in the NO FEEDBACK condition.

Conclusions

The pilot test results led to specific questions and recommendations regarding fatigue management technologies.

Is there a "cost" to being more alert with FMT FEEDBACK?

A composite of results from both phases of the study showed support for the hypothesis that alertness improved in the FMT FEEDBACK condition, especially during the U.S. study phase, which predominantly involved night driving. However, there was also consistent evidence that performance of the Psychomotor Vigilance Task (PVT) worsened, and subjective sleepiness ratings increased during the FEEDBACK period relative to the NO FEEDBACK period, once again, especially during the U.S. study phase. This suggests the possibility that FMT FEEDBACK in drivers who operate primarily at night may have alertness-promoting benefits during driving, but such feedback may also create a modest "cost" to the added effort (inattention and compensatory behaviors) required to respond to information from the devices, and that "cost" may manifest itself as slightly worse performance and greater subjective sleepiness when performing a demanding vigilance-based reaction time task while not driving, such as the PVT.

Do drivers prefer vehicle-based measures of alertness?

Descriptive analyses of drivers' responses to the Human Factors Structured Interview Questionnaire at the end of the 2-week NO FEEDBACK condition, and again at the end of the 2-week FEEDBACK condition, revealed clear preferences of both Canadian and American drivers for certain fatigue management technologies. Drivers were uniformly positive about the Education on Alertness and Fatigue Management course given at the beginning of each study phase. Among technologies designed to detect alertness or drowsiness, drivers gave higher ratings to SafeTRAC®, medium ratings to the SleepWatch®, and low ratings to the CoPilot®. Among all FMTs deployed, however, drivers were significantly more enthusiastic about the benefits of the Howard Power Center Steering® system and SafeTRAC®, than they were about SleepWatch® and CoPilot®. It is noteworthy that Howard Power Center Steering® and SafeTRAC® both interface with the vehicle, while SleepWatch® and CoPilot® interface with the driver. It may be that truck drivers prefer fatigue management be carried out by way of vehicle monitoring, more so than driver monitoring.

A future for FMT technologies?

Overall, participant drivers were positive toward the FMT approach in general and felt that if such technologies could be further improved, they would be a benefit in management of fatigue and alertness.

Recommendations for Future Work Outside the Scope of this Project

Continue development of fatigue management technologies. There is enough evidence to support the case for continued development of FMTs. These developments, however, should not solely be in the area of driver monitors. Vehicle-based monitoring should also get increased attention, as truck drivers appear to have some preference for this mode of fatigue management.

Drivers need and want Alertness and Fatigue Management courses. Despite differences in country of operation, hours-of-service, type of trucks, and a host of other factors, American and Canadian drivers had surprisingly similar views toward the FMT project. They enthusiastically endorsed the "Alertness and Fatigue Management Training" course provided in the study. Drivers indicated they benefited from the course and wanted more of this type of didactic to help teach them how to manage their fatigue. This is impressive, given that these were largely seasoned long-haul drivers, who appeared not to be inhibited about reporting that they can still learn about fatigue and ways to manage it. These positive views towards fatigue management training suggest that some segments of the trucking industry are likely to welcome fatigue management programs.

PVT should be developed as a fitness-for-duty test. Although the Psychomotor Vigilance Task was not discussed with drivers as either an FMT or a "fitness-for-duty" test, a majority of drivers in both countries

indicated when asked that the PVT could be used as a personal checking analysis on driver fitness-for-duty system, if it could be reduced in duration. Drivers' generally positive view of the PVT as a potential fitness-for-duty device suggests that efforts should be made to attempt to validate the sensitivity, as well as the positive and negative predictability of a shorter duration PVT test relative to truck driver fatigue.

Barriers to drivers obtaining adequate sleep during workdays need to be identified. One of the more striking outcomes of the project was the finding that drivers in both countries were routinely averaging between 5 hours and 6 and a quarter hours of sleep per day during workdays, despite very different work schedules. Recent scientific work, some of it by DOT on volunteer truck drivers, shows that severe sleep debt and deficits in behavioral alertness can develop within a few days at these sleep durations. The fact that project participants markedly increased their sleep durations on non-workdays also supports the view that they were suffering sleep debts. Much more needs to be understood about the factors that determine when and where drivers obtain sleep on workdays and non-workdays, the barriers to obtaining adequate sleep on workdays, and the factors that convince them to get more recovery sleep on non-workdays.

Researchers

This study was performed at the University of Pennsylvania, Philadelphia, PA, by David F. Dinges, Adrian Ecker, Donald Terry, and John W. Powell; Greg Maislin and Robert Hachadoorian (University of Pennsylvania Biomedical Statistical Consulting, Inc.); Gerald P. Krueger (Krueger Ergonomics Consultants); Col. Daniel P. Redmond, Greg Lounsberry, Thomas Balkin, and Col. Gregory L. Belenky (Walter Reed Army Institute of Research); and Rebecca Brewster (American Transportation Research Institute). Contract No. DTFH61-96-X-00022.

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Availability

The study final report will be made available from USDOT's Information Services Online Publishing at http://isddc.dot.gov.

Key Words

Commercial motor vehicle, crash risk, fatigue management technology, fatigue management technologies, sleep disorder, truck driver.

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