FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

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An Assessment of Driver Drowsiness, Distraction, and Performance in a Naturalistic Setting

Driver drowsiness is a safety issue of special concern to commercial motor vehicle (CMV) transportation. The Federal Motor Carrier Safety Administration, CMV industry, highway safety advocates and researchers, and the general public have all identified driver drowsiness as a high priority CMV safety issue. Because of their greater mileage exposure and other factors, CMV drivers face far greater risk of being involved in a drowsiness-related crash than non-commercial drivers, even though CMV drivers represent a relatively small proportion of all drivers involved in drowsiness-related crashes and their rate of involvement per mile traveled is no greater than that of non-commercial drivers.

The study summarized herein characterizes episodes of driver drowsiness and assesses the impact of driver drowsiness on driving performance using the naturalistic data of local/short haul (L/SH) truck drivers. The results of the study help to provide a better understanding of the relationship between drowsiness and the safety of driver behavior and performance. It is hoped that this information will be useful in identifying effective countermeasures for drowsy driving.

The primary objectives of the study were to:

- Investigate drowsiness as a naturally occurring phenomenon by characterizing episodes of drowsiness that occurred during all periods of driving for the study.
- Characterize the natural occurrence of drowsiness, and determine if episodes of drowsiness are associated with operational or driving environment factors.
- Explore the effects of drowsiness on safe driving performance.
- Identify relationships between drowsiness, distraction, and safe driver behavior and performance.

Research Methodology

The data used in this study were collected as part of a naturalistic field study of driver drowsiness among L/SH truck operators. L/SH operations can be defined as those that primarily involve trips of 100 miles or less from the home base. Thus, L/SH drivers typically start and end their workday at their home base. A total of 42 drivers from 2 L/SH trucking companies participated in the field study in which in-service L/SH trucks were instrumented with data collection equipment. Each driver drove an instrumented truck for approximately 2 weeks. The onboard instrumentation consisted of sensors to monitor such vehicle performance parameters as velocity, lateral and longitudinal acceleration, steering position, and brake pedal activation. Each truck also was equipped with video cameras that provided exterior views of the driving environment as

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 understanding 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 agency's 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 more than 10,000 pounds.

The primary goal of the report described in this TechBrief is to document the results of a study undertaken to characterize episodes of driver drowsiness and to assess the impact of driver drowsiness on driving performance. This data mining effort performed additional analyses on the data collected in an earlier FMCSA study of the effects of fatigue on drivers in local/short-haul operations.

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well as interior images of the driver's face. The video cameras were activated upon engine ignition; video data were recorded continuously while the trucks were in operation rather than being recorded only when triggered by pre-defined critical events or near-crash situations. Thus, the L/SH data set is a very rich source of naturalistic data for analyzing driving behavior and human factors issues.

The study consisted of the following four major tasks:

- Process continuous video data to identify all episodes of fatigue/drowsiness.
- Characterize drowsiness and its relationship to driver and external factors.
- Relate driver drowsiness to driver performance.
- Relate driver drowsiness to driver distraction.

All incidents of driver drowsiness were identified, and relationships between driver drowsiness and operational/external factors, driver performance, and driver distraction were investigated. Predictive models were developed to determine the driver characteristics and external or environmental factors that influence the likelihood of driver drowsiness occurring on the job. Driver characteristics included age, years of commercial driving experience, and sleep quality and quantity, while external or environmental factors included time of day, weather, and traffic density. Several analytical techniques, including analysis of variance, contingency table analysis, multiple linear regression, and logistic regression, were applied, and these methodologies produced generally consistent results.

Study analysts recorded the duration of each drowsy event and assigned each event an Observer Rating of Drowsiness (ORD). This scale, shown in Table 1, started with a baseline ORD value of one (not drowsy), and increased stepwise from two (slightly drowsy) to five (extremely drowsy). An event was judged to have commenced when a drowsiness behavior was observed (for example, a yawn), and ended with an alerting event. The video sync number of the initial drowsiness behavior was noted as the event start time. In some cases, the event would end shortly thereafter; for example, the driver would scan the environment before making a lane change maneuver. Other times, the driver's level of drowsiness would build until an alerting event occurred to reduce the driver's level of drowsiness.

A simple frequency count of drowsy events does not include the severity of drowsiness (e.g., a short

Table 1. Observer Rating of Drowsiness (ORD) Scale

Value	Description
1	Not Drowsy. Driver shows no signs of being drowsy (baseline).
2	Slightly Drowsy. Driver shows minor signs of being drowsy (single yawn, single stretch, droopy eyes for a short period of time), but quickly recovers; the event does not have any impact on the driver's ability to drive.
3	Moderately Drowsy. Driver shows signs of being drowsy (yawns, stretches, moves around in seat, droopy eyes for a slightly longer period of time, minor blinking), and takes slightly longer to recover, but the event does not have any impact on the driver's ability to drive.
4	Very Drowsy. Driver shows signs of being drowsy (yawns often, has very heavy/droopy eyes, frequent blinking), and the duration lasts much longer, but the event does not have any impact on the driver's ability to drive.
5	Extremely Drowsy. Driver shows extreme signs of being drowsy (yawns often, has very heavy/droopy eyes, has trouble keeping eyes open, very frequent blinking), the duration lasts much longer, and the event has an impact on the driver's ability to drive.

yawn vs. multiple complete eye closures) nor does it take into account the amount of driving done by each driver. Therefore, a measure of drowsiness called the Fatigue Index was developed for each driver in this study. The Fatigue Index accounts for the frequency of occurrence of drowsy episodes, normalized by total driving time, as well as the severity of the drowsy event. It is defined as the sum of the ORD rating for each drowsy event divided by the total number of hours of driving data analyzed. The Fatigue Index was used to classify drivers into one of two categories, a "High Fatigue" group and a "Low Fatigue" group.

Results

A total of 2,745 fatigue or drowsy events were identified in approximately 900 total hours of driving by 41 drivers. (Although 42 drivers participated, there were no usable data for one subject due to a data acquisition malfunction; thus, the pool was made up of 41 drivers.) The rate of drowsy occurrences for the 41 drivers combined was 3.1 events per hour of driving. On a per driver basis, the drowsiness rate varied from 0 to 9.3 events per hour. Generally speaking, the longer a drowsy event lasted, the more severe it was in terms of ORD. After assignment of ORD numbers, the breakdown of drowsy events by severity was as follows:

- 1,636 ORD 2 events (slightly drowsy).
- 824 ORD 3 events (moderately drowsy).
- 160 ORD 4 events (very drowsy).
- 125 ORD 5 events (extremely drowsy).

There was considerable subject-to-subject variation in drowsy behavior among the 41 drivers. While 5 drivers never, or almost never, exhibited signs of drowsiness while driving their trucks, one driver had 224 incidences of drowsiness—70 more than any other driver. The average event duration ranged from 5 seconds to nearly 2 minutes. Another interesting descriptive measure of driver drowsiness is the percentage of total driving hours that each driver was drowsy. For all drivers collectively, almost 31 hours, or 3.5 percent of overall driving time, were spent being drowsy.

The lowest values of drivers' Fatigue Index are 0 and 0.11, and they range up to the highest values of 24.09 and 19.71. All other drivers have Fatigue Index values of less than 15. The median value of the Fatigue Index for all 41 drivers is 7.35. Drivers with a Fatigue Index higher than the median value were categorized as "High Fatigue" drivers, while those with a Fatigue Index less than or equal to the median value were designated "Low Fatigue" drivers. More than half of the drivers were assessed to be in the "High Fatigue" category.

In addition to establishing the frequency, duration, and severity of all drowsy events, video analysts also determined the alerting activity that appeared to bring the driver out of a drowsy state and restore full attention to the driving task.

Major Findings

Naturalistic driving data is a valuable source of information for exploring driving behaviors and human factors issues such as drowsiness and driver distraction, and many new realizations were gained from this study:

- Every analysis provided evidence of a strong association between drowsiness and time of day. The early morning time period between 6 a.m. and 9 a.m. was especially problematic for the L/SH drivers. Conversely, increased alertness was associated with the time period between 12 p.m. and 3 p.m.
- Drowsiness was also found to be associated with younger and less experienced drivers.

Drivers in the 19–25-year-old age group were nine times more likely to be classified in a "High Fatigue" group than older drivers. Similarly, inexperienced drivers with less than 1 year of commercial driving experience were about seven times more likely to be "High Fatigue" drivers than those with more driving experience.

- Drivers who averaged more than 3 hours of driving during their daily shifts over their entire period of participation in the L/SH field test were nearly four times more likely to experience higher levels of on-the-job drowsiness than those who averaged less than 3 hours of driving per day.
- Quantitative evidence was obtained to verify the hypothesis that drivers suffering from drowsiness experience "tunnel vision." When a driver becomes drowsy, the rate of eye transitions and the proportion of time his eyes are off the forward roadway were both found to decrease. Therefore, a drowsy driver is less aware of the driving environment around him, and his ability to recognize potential hazards from other vehicles or objects outside the vehicle is compromised.
- Observation of driver behavior from the continuous video data revealed that in the majority of cases drowsiness occurred during periods of extremely low driver workload brought on by boredom and monotony.

This study provided an analytical framework for quantitatively assessing driver drowsiness as a function of driver characteristics and the driving environment. The authors recommend that this work be the basis for a follow-on study to develop a more robust and comprehensive predictor of drowsiness using a combination of physiological data with other driver and vehicle performance data. The authors recommend further research to set up equations to predict PERCLOS, the primary measure of drowsiness used in this study (defined as the proportion of time over the 3-minute event interval that the driver's eyes were closed or nearly closed), on the basis of performance measures (lane position, speed variation, and relative position to forward vehicles), and to develop an algorithm that incorporates physiological data as well as vehicle/driver performance data into a drowsy driver warning system.

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