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An analysis of driving and working hour on commercial motor vehicle driver safety using naturalistic data collection

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ABSTRACT

Current hours-of-service (HOS) regulations prescribe limits to commercial motor vehicle (CMV) drivers' operating hours. By using naturalistic-data-collection, researchers were able to assess activities performed in the 14-h workday and the relationship between safety-critical events (SCEs) and driving hours, work hours, and breaks. The data used in the analyses were collected in the Naturalistic Truck Driving Study and included 97 drivers and about 735,000 miles of continuous driving data. An assessment of the drivers' workday determined that, on average, drivers spent 66% of their shift driving, 23% in non-driving work, and 11% resting. Analyses evaluating the relationship between driving hours (i.e., driving only) and SCE risk found a time-on-task effect across hours, with no significant difference in safety outcomes between 11th driving hour and driving hours 8, 9 or 10. Analyses on work hours (i.e., driving in addition to non-driving work) found that risk of being involved in an SCE generally increased as work hours increased. This suggests that time-on-task effects may not be related to driving hours alone, but implies an interaction between driving hours and work hours: if a driver begins the day with several hours of non-driving work, followed by driving that goes deep into the 14-h workday, SCE risk was found to increase. Breaks from driving were found to be beneficial in reducing SCEs (during 1-h window after a break) and were effective in counteracting the negative effects of time-on-task.

1. Introduction

The first United States (U.S.) government issued hours-of-service (HOS) regulations addressing how long a commercial motor vehicle (CMV) driver may drive and work over days and work weeks went into effect in 1938. Since 1938, the U.S. HOS regulations have been revised three times. In the 2005 regulations CMV drivers may drive a maximum 11 h after 10 h off duty and may not drive beyond the 14th hour after coming on duty (Federal Motor Carrier Safety Administration, 2008). Drivers may also use the sleeper berth provision to take breaks; the sleeper berth provision allows drivers to use the sleeper berth for at least 8 h, plus an additional off duty period of at least 2 h, to restart their work day calculations. The 2005 HOS regulations also regulate the total driving time over 7 or 8 days to 60 or 70 h, respectively.

The majority of the research dealing with crash risk and HOS regulations has examined time-on-task. In a study by the American Transportation Research Institute (ATRI) to evaluate the safety impacts of the 2005 HOS regulations, incidents and reportable crashes occurring in 2009 (per vehicle mile of travel [VMT]) as reported by the fleets surveyed were collected and compared to similar data collected from 2004 (American Transportation Research Institute, 2006, 2010). Results indicated that total crashes per million VMT (11.7% reduction), preventable crashes per million VMT (30.6% reduction), and driver injuries per million VMT (1.6% reduction) all experienced a significant reduction in 2009 as compared to 2004. The ATRI-conducted analysis of crashes per driving hour used data collected in October 2009 and January 2010. These results indicate that the majority (approximately 87%) of reportable crashes occurred in the first 8 driving hours (American Transportation Research Institute, 2010). While this analysis did not account for driving exposure, it does provide a useful overview of crash frequency per hour. The ATRI study also examined the use of driving hours 9–11. The majority (more than 60%) of drivers used the 9–10 driving hour and 10–11 driving hour epochs. Slightly more than 50% of drivers used the entire 10–11 driving hour (American Transportation Research Institute, 2010).

A study by the Virginia Tech Transportation Institute evaluated the effect of time-on-task on SCE risk in CMV drivers (Hanowski et al., 2008). This research utilized naturalistically collected driving data gathered from 103 drivers (102 males, 1 female) between May 2004 and September 2005. Key safety analyses conducted included examining SCEs as a function of driving hours, SCEs as a function of driving hour for drivers who drove into the 11th hour, and SCEs

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as a function of time of day. Results indicated that there were significantly more SCEs during the first driving hour as compared to all other driving hours. However, comparisons of all other driving hours failed to reach statistical significance. Similar findings were present for the analysis of SCEs as a function of driving hour for drivers who drove into the 11th hour. The first driving hour represented an increase in SCE risk, but the comparison of all other driving hours (including the 11th hour) did not reach significance. The time-of-day analysis suggested there was a significant time-of-day effect on SCE risk. However, Hanowski and colleagues note that other explanatory factors (primarily traffic density) may have influenced the findings.

Research from non-driving domains indicate that time-on-task is highly associated with fatigue (Williamson et al., 1996). The topic of time-on-task is also highly related to shift duration, which has been widely studied in both medical and industrial domains. Research in the medical domain has indicated that for shifts longer than 12.5 h, self-reported frequency of errors is three times greater than for shorter shift durations, and working more than 40 h per week is associated with a significant increase in self-reported errors among nurses (Dembe et al., 2005). When these extended schedules lead medical personnel into working during nighttime shifts, errors can become more frequent. One study of trainee physicians found that lapses in attention (a precursor to errors) occur between 1.5 times (during the day) and twice as often (during the night) under a 30-h physician trainee duty schedule as opposed to a 16-h duty schedule (Lockley et al., 2004). Industrial workers on a rotating shift (12 h in a 16-day rotation period) got less sleep during the initial days of the shift. During the night-shift period, workers reported lower perceived alertness levels and increased difficulty working (Budnick et al., 1994). This is an important finding, as other research has indicated that sleep debts (including self-perceived sleep debts) are associated with both driving and non-driving accidents (Carter et al., 2003). Furthermore, impaired or shortened sleep is noted as a major cause of workplace accidents in industrial settings (Philip and Akerstedt, 2006).

Unsafe driving is assessed by the presence of a safety-critical event, defined as a crash, near-crash, crash-relevant conflict, or unintentional lane deviation. Although crashes and near-crashes are the typical variables of interest in a safety evaluation such as the present study, less severe events can also provide valuable information. For example, unintentional lane deviations present additional safety concerns and have been shown to be a valid measure of performance decrement in prior research on HOS regulations and fatigue (Van Dongen et al., 2010). Additionally, unintentional lane deviations represent "driver errors." While much less serious than crashes, these may reflect potential time-on-task issues. Previous research by Wylie et al. (1996) and Hanowski et al. (2008) has suggested that there are no differences in safety events across driving hours. If similar findings are present in this analysis, which includes minor events that are sensitive to time-on-task, then this would provide strong evidence for the veracity of previous findings.

In naturalistic data collection, drivers operate vehicles with integrated data collection equipment as they would normally operate a vehicle. The sensors and cameras continuously record data when the vehicles are on and in motion, allowing researchers to assess driving behaviors and accurately determine the number of hours a participant has been driving a CMV at any point in time. Without naturalistic driving data, the knowledge of driver work day, driving hours, working hours, and breaks would be extremely limited and likely inaccurate in some areas. The current study used naturalistic-data-collection methods to evaluate several issues regarding the 2005 HOS regulations for CMV drivers. Researchers wanted to characterize the average workday for long-haul and line-haul drivers and investigate whether a relationship exists between workday characteristics and risk of safety-critical events (SCEs). Specifically, researchers considered workday characteristics of time-on-task, as defined by driving hour or working hour, and breaks from the driving task, including breaks used to perform work-related tasks and breaks used for rest.

2. Material and methods

The data used in this report was collected in the Naturalistic Truck Driving Study (NTDS) and reduced by Blanco et al. (2011, 2012). Blanco et al. (2012) collected and analyzed more than 14,500 h of naturalistically collected CMV driving data as well as sleep data collected via Actigraph watches. The NTDS driving data was augmented with previously collected activity register data in Blanco et al. (2011), which investigated the relationship between driving hours, work hours, and breaks on SCE occurrence. The data collection and reduction is outlined in this section.

2.1. Participants

Data collection for the NTDS took place from November 2005 to March 2007. A total of 100 drivers were involved in the study, however three drivers were removed due to missing data that were necessary for analyses. This left 97 drivers for analyses. Of these 97 drivers, 96 provided demographic information. Of the 96 drivers that provided demographic information, 91 were male and 5 were female. The average age was 44 years old (range: 21–73 years), and the drivers had an average of 9.13 years experience driving CMVs (range: 4 weeks to 54 years). Four for-hire trucking companies participated in the study. Long-haul (on the road for an extended period of time) and line-haul (usually out for a day or day/night) trucking operations were both represented in the study: 75 drivers were primarily long-haul and 21 drivers were primarily line-haul. All drivers and companies were volunteers and recruited for the study. Virginia Tech served as the Institutional Review Board of record. Drivers signed an Informed Consent prior to participation, and a Certificate of Confidentiality (from the National Institutes of Health) was in place. As with any study that uses volunteers, there is a chance the sample of participating drivers may not be representative of the general population of commercial drivers.

2.2. Procedure

2.2.1. Data collection

A naturalistic-data-collection approach was used to collect data. Study participants drove instrumented company trucks during their normal revenue-producing runs. The instrumented trucks were fitted with unobtrusive data-collection equipment consisting of a data acquisition system (DAS), sensors to measure driver performance, and video cameras that recorded the driver's face, steering wheel, and three views outside of the truck (Fig. 1). The data-collection equipment recorded data when the vehicle was on and in-motion. Each driver was assigned to one of nine instrumented trucks and drove the truck for approximately 4 weeks. After a driver completed their time in the study, a different driver was assigned to the instrumented truck until data collection was complete for all participants. Drivers assigned to the same truck did not have overlapping time in the truck. The resultant data set consisted of approximately 735,000 miles of driving data (comprised of both video and dynamic sensor data).

In addition to the vehicle data, each participant was asked to fill out an activity register (including both during-duty and off-duty periods) for the entire 4 weeks he or she participated in the study. A sample page of the activity register is shown below in Fig. 2. The top part of the daily activity register was a 24-h timeline, which began at midnight and ended at 11:59 p.m., scaled with 15-min