A Comparison of Drowsiness Measures in Truck and Bus Naturalistic Driving Data: Streamlining Drowsiness Reduction

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DDI 2024 MICHIGAN

Introduction

Every year, drowsy and fatigued driving contributes to thousands of crashes and their resulting injuries and fatalities.(1) Drowsy driving prevalence in truck-involved crashes has been estimated at 13%.(2) However, these estimates likely underestimate how often drowsiness contributes to crashes.

Naturalistic driving data allows researchers an opportunity to better understand drowsy driving, through review of driver-facing video capturing the driver's behavior and eyes as it occurs in the real world. In a recently completed naturalistic driving study, reduction of a subset of events included two drowsiness measures successfully used in naturalistic driving data: Observer Rating of Drowsiness (ORD) and manual percentage of eye closure (PERCLOS).(3,4)

Objectives

The reduction of both ORD and PERCLOS 3 in Hammond et al. (2021),(5) a recently completed naturalistic driving study featuring trucks and buses, provided a unique opportunity to:

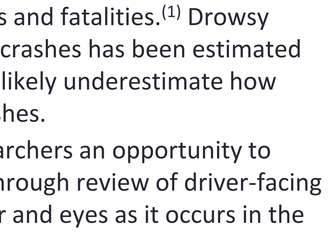
- compare drowsiness measures for strengths, weaknesses, similarities, and differences;
- explore how drowsiness measures impact study estimates of fatigue prevalence and risk for truck and motorcoach drivers; and
- identify ways to obtain the most valuable drowsiness reduction dataset at the lowest cost to time and budget.

Methods

Data Source

The current study utilized naturalistic driving data collected during the Onboard Monitoring System Field Operational Test (OBMS FOT) study and further reduced during the Naturalistic Driving Study.(5,6) The study included 172 truck driver and 73 motorcoach driver participants.

Images from captured from five cameras used during naturalistic driving data collection.(5)



Safety-critical events (SCEs) and baseline driving epochs (BLs) underwent reduction for secondary task engagement, driver drowsiness, and more.

Methods

Drowsiness Measures

Driver drowsiness reduction performed in the studies included ORD, PERCLOS 3, and PERCLOS 1.

- **ORD** measures drowsy driving over one minute of data with a subjective assessment of the driver *(summary below):*

Three reductionists review the video and each rates driver drowsiness on a scale from 0 to 100.	The range between the minimum and maximum ORD ratings is calculated. If the range between ratings > 30, additional review is performed.	If the range between ratings <= 30, the ORD Score is calculated as the average of all three reductionist ORD ratings.

- **PERCLOS** measures the percentage of time when driver's eyes are at least 80% closed and was scored over one (PERCLOS 1) and three (PERCLOS 3) minutes of data *(summary below):*

One reductionist reviews the video sync by sync.	For each sync, if the driver's eyes are closed at least 80% of the way, the sync is marked as "eyes closed."	The total time with eyes closed is divided by the total sample time to calculate the PERCLOS score. Blinks are excluded from the calculation.

Analysis Methods

- Generalized linear mixed-effect models were used to estimate the risk of SCE involvement during fatigued driving.
- To investigate how a multifaceted drowsiness reduction approach could maximize data collection and reduce reduction costs, an ORD rating threshold that the PERCLOS fatigued events met or exceeded was identified. Estimates of reduction time and cost were calculated for several drowsiness reduction approaches, including performing ORD on all events and targeted PERCLOS reduction on events meeting or exceeding the ORD rating threshold.

Results

Investigating Prevalence and Risk of Fatigue using PERCLOS 1

Table 1 *Prevalence of PERCLOS 1 fatigue in motorcoach and truck driving data.*

Vehicle Type	Driving Epoch Type	Prevalence of Fatigue using PERCLOS 1
Motorcoach	BL	0.52%
Motorcoach	SCE	1.42%
Truck	BL	3.95%
Truck	SCE	12.69%

Results

- Driving while fatigued was found to *increase* risk by 2.31 times compared to driving without fatigue for truck drivers [95% CI = (1.69, 3.15)]- a finding consistent with the PERCLOS 3 finding in Hammond et al. (2021).(5)
- Motorcoach drivers showed no significant change in SCE risk when driving while fatigued, a result inconsistent with the Hammond et al. (2021) finding based on PERCLOS 3 data.(5)

Comparing Fatigue Reduction Options for Time and Cost

- If an ORD rating score of at least 25 was set as a cutoff for performing PERCLOS reduction, 62% of events in the current study would receive PERCLOS reduction.
- Table 2 compares the reduction costs for ORD and targeted PERCLOS options to the approach of ORD and PERCLOS for all events. A targeted approach using PERCLOS 1 (the most cost-efficient option) is 55% of the cost of all events receiving ORD and PERCLOS 3 reduction (the highest cost option).

Table 2 *Proportion of reduction cost for ORD and targeted PERCLOS option compared to all ORD and PERCLOS option.*

Proposed Fatigue Reduction Option	Comparison Option	Proportion of Cost
All ORD + Targeted PERCLOS 3 at ORD Threshold 25	All ORD + All PERCLOS 3	78.23%
All ORD + Targeted PERCLOS 1 at ORD Threshold 25	All ORD + All PERCLOS 1	87.83%
All ORD + Targeted PERCLOS 1 at ORD Threshold 25	All ORD + All PERCLOS 3	55.31%

Acknowledgement

The authors would like to acknowledge the support of the stakeholders of the National Surface Transportation Safety Center for Excellence (NSTSCE) [Zac Doerzaph from the Virginia Tech Transportation Institute; John Capp from General Motors Corporation; Terri Hallquist from the Federal Motor Carrier Safety Administration; Mike Fontaine from the Virginia Department of Transportation and the Virginia Transportation Research Council; and Melissa Miles from State Farm Insurance] and the Division for Freight, Transit, and Heavy Vehicle Safety at the Virginia Tech Transportation Institute in funding this research. The authors would like to thank Dr. Richard J. Hanowski for contributing to this research study. The NSTSCE stakeholders have jointly funded this research for the purpose of developing and disseminating advanced transportation safety techniques and innovations.

Conclusions

The study identified an opportunity to limit costs and obtain full, rich drowsiness datasets using a targeted reduction approach, with cost reductions of up to half those of previous approaches. A targeted approach benefits from the strengths of multiple drowsiness measurement methods.

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