**Tenth International Conference on Managing Fatigue: Abstract for Review**

# Evaluation of an In-Vehicle Drowsiness Detection Device

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## Problem [100 words]

The ability of humans to perform in an operational setting is critically dependent on vigilant attention, which can be significantly impaired by fatigue. An important complement to a fatigue risk management system is the development of drowsiness detection technology that can be used in real-time to signal imminent performance failure. SIX Safety Systems has developed a drowsiness monitoring system, LUCI™. The system used infrared (IR) reflectance oculography to measure eye ratios and eyelid movements to predict drowsiness and impaired cognitive performance. A study was conducted to evaluate the validity of the drowsiness monitoring measures in a controlled laboratory setting.

## Method [250 words]

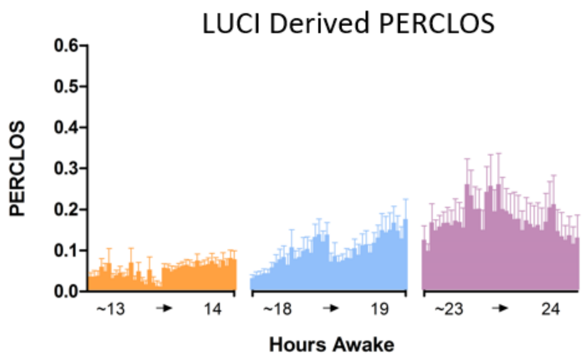
Thirteen young adults with drivers' licenses completed three 40-minute driving sessions in a dynamic, fixed-base driving simulator. The end of each session coincided with the 14th, 19th, and 24th hour of being awake. A five-minute Psychomotor Vigilance Task (PVT) was administered every hour, between 12 and 24 hours awake, to obtain scores on reaction time. Body temperature was measured orally every 30 minutes. Participants completed a subjective sleepiness rating (Karolinska Sleepiness Scale; KSS) before and after each driving session.

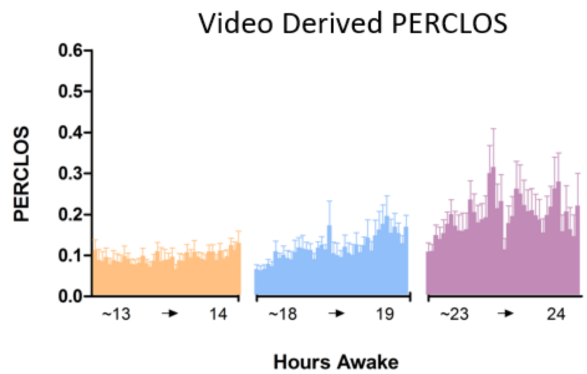
The driving simulator scenario was a monotonous two-lane rural highway. The route included several long straight sections, as well as curves, and side roads which merge onto the highway, all with varying traffic and posted direction and speed signs. Outcome measures included lane tracking (lateral position), tracking deviation (standard deviation of the lateral position), average speed, speed deviation, number of incidents, time to line crossing, mean steering wheel movements, standard deviation of steering wheel movements, headway (distance between the lead car and the participant's car), and time headway (distance to the lead car divided by speed of participant's car).

The LUCI system measured eye movements using sensors placed on the dashboard. The LUCI visual and auditory alerting stimuli were not delivered to participants. Video recordings of the eyes were also collected during the driving sessions with in-cab cameras.

## Results [250 words]

Eye ratios (height/width of visible eye) obtained from LUCI were processed to calculate PERCLOS. PERCLOS has been found to be a reliable and valid determination of a driver's alertness level[1]. PERCLOS is the percentage of eyelid closure over the pupil over time and reflects slow eyelid closures and slow blinking. Video data was manually processed to create a video-derived PERCLOS for comparison with the LUCI-derived PERCLOS. An ANCOVA used to compare the rate of change of PERCLOS from LUCI and the video analysis were not significantly different (F=1.4939, p>.05) indicating that PERCLOS by both measures increases at the same rate throughout the night. The calculations of LUCI-derived and video-derived PERCLOS are shown in the figure 3, measured in one-minute segments during the driving sessions.




To assess the LUCI-derived PERCLOS as a fatigue detection assay, the level of fatigue was compared between Drive Session 1 (13 – 14 hours awake) and Session 3 (23 - 24 hours awake) for several variables (table 1). Following sleep deprivation, drivers displayed a significantly higher proportion of eyelid closures, increased self-reported sleepiness, greater variation in lane position, more lane departures, and slower (longer) reaction times (vehicle braking and vigilance task). These results confirm that drowsiness increases between 13 to 24 hours awake and that PERCLOS changes in parallel with multiple validated fatigue measures.

**Table 1. T-Test Results for comparison of Fatigue Variables between Session 1 and 3.**

| | | Session 1 Mean | Session 3 Mean | Difference Score* | t value | df | p value |
|---|---|---|---|---|---|---|---|
| PERCLOS | Video PERCLOS | .096 | .199 | .103 | 3.33 | 9 | **.0044** |
| | LUCI™ PERCLOS | .057 | .177 | .120 | 3.27 | 11 | **.0037** |
| Subjective Sleepiness | KSS (1 - 9 Scale) | 4.231 | 8.541 | 4.31 | 6.48 | 11 | **<.0001** |
| Vigilance Task | PVT RT Z Score (ms) | -0.23 | 1.30 | 1.53 | 6.18 | 12 | **<.0001** |
| Driving Simulation Metrics | SD Lane Position (m) | 0.305 | 0.380 | .075 | 2.22 | 7 | **.0309** |
| | # of Lane Excursions | 73.09 | 786 | 712.91 | 1.93 | 10 | **.0410** |
| | Mean Vehicle Braking RT (s) | 1.37 | 2.19 | .82 | 1.96 | 10 | **.0391** |

* *Difference Scores were computed Session 3 – Session 1 with a positive number indicating an increase in drowsiness over time.*

LUCI-derived PERCLOS was associated with variability in vigilance performance (longer PVT reaction times [r=.99, p<.05]). LUCI-derived PERCLOS was also associated with variation in lane position, number of lane excursions, braking reaction time and subjective sleepiness ratings (table 2).

**Table 2: Correlations with video-derived PERCLOS, performance and subjective sleepiness**

| | Video PERCLOS | Driving Simulation Metrics | | | Subjective Sleepiness |
|---|---|---|---|---|---|
| | | SD Lane Position (m) | # of Lane Excursions | Mean Vehicle Braking RT (s) | KSS (1 – 9 Scale) |
| **LUCI™ PERCLOS** | r = .9633, **p = .0010** | r = .8144, **p = .0242** | r = .8823, **p = .0100** | r = .9456, **p = .0021** | r = .9750, **p = .0005** |

**Discussion [250 words]**

The results suggest that PERCLOS, as calculated by LUCI, shows a strong relationship with measures of drowsiness and the associated changes in physiology, cognition, subjective sleepiness and driving performance.

**Summary [150 words]**

Fatigue is a significant risk factor in work settings that involve operating moving vehicles during long duty hours or shift work rotations. A critical objective in fatigue management is to develop technology that monitors drowsiness and predicts performance failure. Research will continue with a larger pool of participants to further explore the validity and reliability of the drowsiness measures in the lab and in the operational field with industrial and commercial drivers. Results will assist in the identification of thresholds for determining fit for duty and for initiating visual/auditory feedback alerts to operators in advance of performance failure.

References:


1. Dinges DF, Mallis M, Maislin G, Powell JW. Evaluation of techniques for ocular measurements as an index of fatigue and the basis for alertness management. 1998 U.S. Department of Transportation, National Highway Traffic Safety Administration, Contract No. DTNH22-93-D-07007.