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# Advanced Countermeasures for Multiple Impairments

Drowsy driving is a significant contributor to death and injury crashes on our Nation's highways, accounting for more than 80,000 crashes and 850 fatalities per year. Prior research using data from the 100-car naturalistic study found that drowsy driving contributed to 22 percent to 24 percent of crashes and near-crashes observed. The rate of drowsy driving and the severity of the resultant crashes give clear cause for concern and research continues to be needed to help reduce the number of lives lost due to drowsy driving. Algorithms similar to those used to successfully detect alcohol impairment using lane position and steering could be implemented in vehicle-based safety systems to detect impairment from drowsiness.

## Data Collection in the NADS-1 Driving Simulator

Data was collected from volunteer drivers from three age groups (21 to 34, 38 to 51, and 55 to 68) driving through representative situations on three types of roadways (urban, freeway, and rural) at three times of day (9 a.m.–1 p.m., 10 p.m.–2 a.m., 2 a.m.–6 a.m.). The National Advanced Driving Simulator (NADS), shown in Figure 1, was used to collect representative driving behavior data from drowsy drivers in a safe and controlled manner. This is the highest fidelity simulator in the United States and allowed for precise characterization of driver response to realistic driving situations.

Drivers' control inputs, eye closure and direction of gaze, vehicle state, and driving context were captured in representative driving situations such as the urban environment shown in Figure 2. This data, individually and in combination, revealed that signatures of impairment from drowsiness, and algorithms built using these signatures successfully differentiated between drowsy and alert driving performance.

## Data Revealing the Effect of Drowsiness on Drivers

Analysis of common driving metrics demonstrates the sensitivity of the NADS-1 scenario to drowsiness. Driving data indicated that a complex relationship exists wherein driving performance improves with low levels of

Figure 1.
**The NADS-1 high-fidelity driving simulator**

Figure 2.
**An urban driving scene from the NADS-1 simulator**

***"Inexpensive vehicle-based sensors can be used to successfully detect driver impairment."***

Figure 3.
**Lane deviation scores by session**

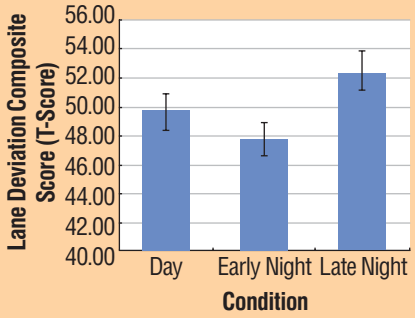



Figure 4.
**Receiver operator characteristic of steering**

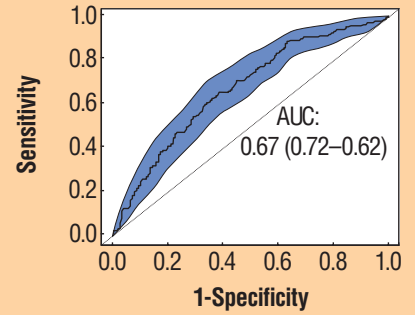
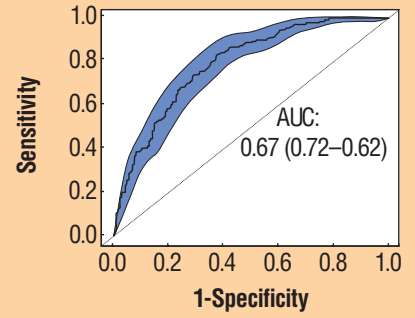



Figure 5.
**Receiver operator characteristic of TLC**




drowsiness in the early night session before degrading in the late night session (see Figure 3). Session time of day did not interact with age, gender, or roadway situation.

Machine learning algorithms (Bayesian networks and Random Forest), designed to detect and classify drowsiness in real time, successfully detected drowsiness 6 seconds before it resulted in a lane departure (Figures 4, 5). These algorithms were based on time-to-lane-crossing (TLC) and steering behavior using sensor data already available in cars. They performed better than percentage of closure (PERCLOS) of the eyelid, which uses eye-tracking cameras that are not currently in vehicles. We have demonstrated that inexpensive, vehicle-based sensors can be used to successfully detect driver impairment

It was found that such algorithms could be generalized to detect both alcohol impairment and drowsiness with additional training or by combining multiple algorithms. However, algorithms that were trained to detect alcohol impairment did not perform well when simply applied to drowsiness and vice versa.

Drowsiness has a strong transient component compared with alcohol intoxication that, judging by blood alcohol concentration, is longer-lasting. In fact a Bayes net algorithm was able to differentiate intoxication from the combination of intoxication and drowsiness, showing that the symptoms of intoxication do not necessarily mask those of drowsiness.

## Recommendations and Conclusions

This study demonstrates the feasibility of detecting drowsiness with vehicle-based sensors. Results show differences in alcohol and drowsiness impairment prevent a single algorithm from detecting both types of impairment; rather, a more complex approach is necessary where separate algorithms are used together. The results suggest promise in a vehicle-based approach to impairment detection. They suggest that further research is needed to better understand the underlying reasons for the effectiveness of the machine learning algorithms, and to evaluate their robustness with on-road sensor data.

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This Vehicle Safety Research Note is a summary of the technical research report: *Assessing the Feasibility of Vehicle-based Sensors to Detect Drowsy Driving* (DOT HS 811 886). This report can be downloaded free of cost on the Vehicle Safety Research section of NHTSA's Web site (www.nhtsa.gov).