Investigating the Impacts of Connected Vehicles on Driving Aggressiveness and Situational Awareness in Highway Crash Scenarios: A Driving Simulator Study

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Abstract

- Connected vehicles (CVs) can impact driving performance by altering drivers' aggressiveness and situational awareness.
- A driving simulator experiment was conducted to investigate the impacts of CVs in highway crash scenarios.
- Results showed that CV alerts significantly improved driving aggressiveness and situational awareness.
- The study provides insights for the development of driving assistance systems that consider psychological factors.

Objective

- The study investigates the impact of CV warning messages on psychological factors such as aggressiveness and awareness in highway crash scenarios.
- The study uses structural equation modeling (SEM) to understand the interrelationship between CV alerts, driving behavior, aggressiveness, situational awareness, and other factors.
- The study aims to obtain a robust understanding of the impact of CV alerts on psychological factors related to driving performance.

Methodology

a. Apparatus and participants

- A high-fidelity driving simulator (Realtime Technologies RDS - 1000) at Old Dominion University (**Fig. 1**)
- The experiment involved 26 participants.
- All participants had valid US driver's licenses and at least one year of driving experience.

b. Scenario Development

- The experiment used a virtual driving environment on a four-lane freeway with two crashes, one on a straight section and the other on a curve (**Fig. 2)**.
- Participants were tested in two scenarios: one with no warning and the other with two CV warnings before each crash **(Fig. 3)**.
- The warnings advised reducing speed limit by 10 miles, and were designed based on FHWA guidelines.
- Data were collected at 60 observations per second before and after each crash.

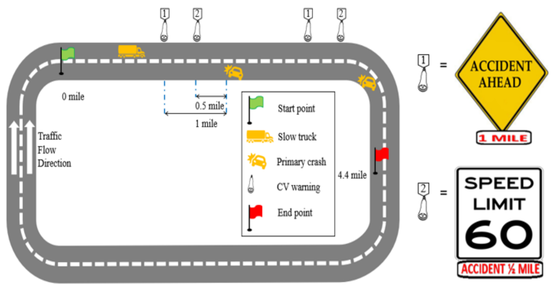
c. Mathematical Model

- The study uses structural equation modeling (SEM) to analyze how CV affects driving behavior by creating latent variables for aggressiveness and situation awareness.
- These variables are influenced by various factors, including CV technology, crash locations, and demographics **(Fig. 4)**

Results

- The proposed SEM shows satisfactory performance with a chi-square score of 39.938 and a p-value greater than 0.05, indicating acceptable goodness-of-fit **(Table1).**
- The RMSEA is 0.032, lower than the threshold of 0.05 **(Table1)**.
- The CFI and TLI are 0.988 and 0.982, respectively, both higher than the threshold of 0.95 **(Table1)**.
- The explanatory variables were found to be statistically significant with p-values less than 0.05. **(Table2)** and **(Fig.5)**.

Fig. 1. RDS-1000 driving simulator at ODU



Fig,2. Driving simulator experiment scenario

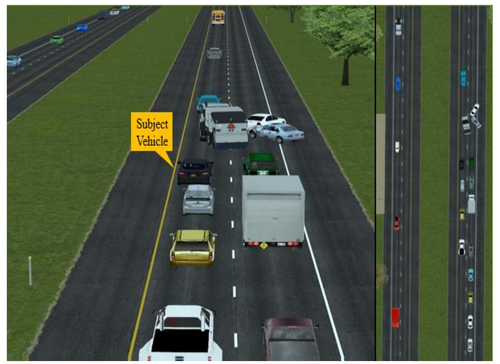


Fig.3. Traffic scenario (Crash 1)

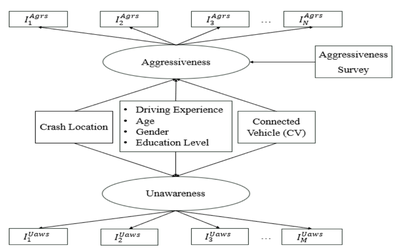


Fig.4. Conceptual path diagram of the SEM

Table 1. Performance metrics of the SEM

Performance Metric	Value
Chi-square statistics	
Chi-square	39.938
Degrees of freedom	28
P-value	0.320
RMSEA	0.032
CFI	0.988
TLI	0.982

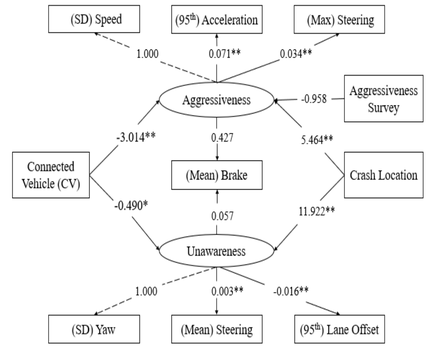


Fig.4. Path diagrams of the proposed SEM (Significance levels: * for 0.01 ≤ p-value < 0.05; ** for ≤ p-value < 0.01)

Table 2. Estimates of parameters in the SEM

Measurement Model	Estimate	Std. Err	P-value
Aggressiveness =~			
(SD) Speed	1.000		
(95th) Longitudinal Acceleration	0.071	0.007	0.000**
(Max) Steering	0.034	0.008	0.000**
(Mean) Brake	0.427	0.043	0.000**
Unawareness =~			
(SD) Yaw	1.000		
(Mean) Steering	0.003	0.001	0.004**
(95th) Lane Offset	-0.016	0.005	0.001**
(Mean) Brake	0.057	0.034	0.093
Structural Model			
Aggressiveness ~			
CV	-3.014	1.401	0.031**
Aggressiveness survey	-0.958	0.689	0.165
Crash location	5.464	1.428	0.000**
Unawareness ~			
CV	-0.490	0.205	0.017*
Crash location	11.922	0.253	0.000**

Discussion

The measurement model in Table 5 identifies various indicators that are positively associated with drivers' aggressiveness, such as the standard deviation of speed, the 95th percentile of longitudinal acceleration, the maximum steering angle, and the mean brake. Conversely, the standard deviation of yaw, the mean of steering, and the mean of brake have positive relationships with drivers' unawareness. The structural model further shows that the use of CV alerts can significantly reduce drivers' aggressiveness and increase their situational awareness, leading to a decrease in crash risk. Additionally, the location of the crash and self-reported aggressiveness were found to affect drivers' behavior during the experiment. These findings suggest that interventions aimed at reducing aggressiveness and increasing situational awareness, such as the deployment of CV alerts, can contribute to improving road safety.

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