How Effective are Connected Vehicle Safety Applications? Experimental Results Using the High-Fidelity LSU Driving Simulator

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OBU

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V2V

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I2I
Connected/Autonomous Vehicle SAFETY Applications

- Forward Collision Warning App
- Do Not Pass Warning App
- Merge Assist App
- Lane Keeping Assist App
- Blind Spot Warning App
- Intersection Assist App
- Crash Avoidance Systems
Research Questions

- How Effective are the safety applications?

- What factors affect their effectiveness?

- When do they become effective?
Connected/Autonomous Vehicle Applications

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LSU Driving Simulator
Forward Collision Warning (FCW): Impact of Driver Types
Design

TTC ≤ 3 seconds

TTC ≤ 1.5 seconds
Experiments

- 100% penetration rate assumed
- 30 participants
- Classified into aggressive and conservative based on Larson Driver’s Stress Profile questionnaire on Anger, Impatience, Competition, and Punishing Behaviors
- 20 conservative and 10 aggressive
- Drive the simulator with and without the alert message system
- Time-to-collision for each participant
Conservative Drivers’ Results

P-value = 0.7561
Aggressive Drivers’ Results

P-value = 0.0297
Blind Spot Warning (BSW): Impact of Market Penetration
Design

- Visual warning messages that appear to the simulator driver when a connected vehicle approaches or in the blind spot area
- Auditory warning messages when drivers attempt to perform lane changes while a vehicle is in the blind spot area
Experiments

• 80 participants

• Four different market penetration rates (zero, low 25%, medium 50%, high 75%)

• Practice drive + 15 min experiment

• Perform lane changes when they felt comfortable
BSW Results

- Actual Sample size used for analysis (1,216)

<table>
<thead>
<tr>
<th>Market Penetration</th>
<th>Total lane changes with veh. approaching (LC)</th>
<th>LC per driver</th>
<th>LC triggering visual warnings (VW)</th>
<th>LC triggering VW per driver</th>
<th>% LC to trigger VW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>279</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low</td>
<td>306</td>
<td>15</td>
<td>39</td>
<td>2</td>
<td>12.7</td>
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<tr>
<td>Medium</td>
<td>325</td>
<td>15</td>
<td>94</td>
<td>4.5</td>
<td>28.9</td>
</tr>
<tr>
<td>High</td>
<td>306</td>
<td>15</td>
<td>118</td>
<td>5.9</td>
<td>38.6</td>
</tr>
</tbody>
</table>

- Results show that medium MP rate (50%) is the minimum MP rate required to increase travel safety.

FIGURE 6 Kruskal-Wallis pairwise mean rank comparisons between MPs.
Do Not Pass Warning (DNPW) : Impact of Market Penetration
Design

• This application is designed in two-lane two way roadway environment.
• The simulator driver will receive a visual and auditory message “Do Not Pass” if he/she tries to pass a slow moving vehicle ahead when an opposing vehicle is coming.
Pilot Study

• Environment design
  – 2 lane 2 way rural roadway
  – Slow moving vehicles (35mph) in the Driver’s lane
  – Opposing vehicles travelling at 50mph
  – Drivers to receive only visual warnings

• Sample
  – MP of Zero, 25%, 50%, and 75%
  – 12 participants, each completed 2 experiments (24 total)
  – 5 overtaking maneuvers per experiment
  – Sample size of 30 overtaking maneuvers per MP

• Drivers asked to pass the slow moving vehicles whenever they felt comfortable doing so
Results

- Initial findings indicate no significant improvement in safety during overtaking maneuvers with CV DNPW (TTC)
- However, there are signs of potential safety improvement during the decision making process before the maneuver at medium and high MP
Research Findings
**Research Findings**

- **FCW**
  - Can be effective with aggressive drivers

- **BSW**
  - Requires a minimum level of MP of 50% to be effective
  - This is attributed to the increased situation awareness prior to executing a lane changing maneuver
  - Limitation: Virtual environment lacks 360 degree view which prevents the driver from looking over the shoulder to check blind spot before changing lanes

- **DNPW**
  - MP showed no significant difference in TTC at the beginning and end of maneuvers
  - A significant change in headway before maneuver (MP of 50% or more=larger headway)
  - Longer time in opposing lane with higher MP (increased passing distance)
  - Limitations:
    - Pilot study with limited number of participants and overtaking maneuvers
    - Warnings are limited to the 300m wireless communication range of CV

- **Simulators are an effective and safe substitute to physical testbeds for CV research**
Future Research
Future Research Plans

• Do Not Pass Warning
  • Larger sample
  • Indirect communication
  • Trucks ahead

• Vehicle Automation
  • Failed automation
  • Distracted driving
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