Risk Evaluation for In-vehicle Sign Information

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Project Background

- MnDOT conducted a demonstration project as part of the Connected Vehicles Program to:
  - Design, build, and test 3 new software applications to run on a commercially available personal navigation device (PND).
- The applications that run on the PND use GPS technology to:
  - Calculate and present **mileage based user fees** for the road on which a driver is traveling and an accumulated bill
  - Present **in-vehicle signing** (IVS) to drivers about specific zones they encounter (e.g., construction)
  - Present traveler information using **probe vehicle data** which will pass V2I information about **travel time**
Examining In-Vehicle Signing

• Study Goals
  – Examine the IVS function for 4 zones and determine the utility and potential distraction associated with the IVS information.
  – Determine the benefits or risks of eliminating external signs with IVS as a replacement

• The specific zones of interest
  – Speed zone changes, Notification of school zones, Notification of work zones, and Notification of curves

• Driving performance measures:
  – Distraction
  – Subjective usability
  – Workload

• Conduct a risk analysis to evaluate the safety associated with IVS technology, relative to status-quo safety levels.
Experimental Design

2 x 2 mixed-factorial design with IVS Status (On, Off) as a within-subjects measure and External Sign Status (Present, Absent) as a between-subjects measure.

<table>
<thead>
<tr>
<th></th>
<th>Baseline (IVS OFF)</th>
<th>Experimental Condition (IVS ON)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong></td>
<td>External Signs Only</td>
<td>In-Vehicle Signs <em>with</em> External Signs</td>
</tr>
<tr>
<td>(IVS +ES)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Group 2</strong></td>
<td>External Signs Only</td>
<td>In-Vehicle Signs <em>without</em> External Signs</td>
</tr>
<tr>
<td>(IVS -ES)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Participants

40 participants completed the study and all participants were used in the analyses.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Gender</th>
<th>Age Group</th>
<th>Mean Age (SD)</th>
<th>Mean Years Licensed (SD)</th>
<th>Mean Weekly Mileage (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVS +ES</td>
<td>12M, 9F</td>
<td>18-35: n = 7</td>
<td>45.05 (14.3)</td>
<td>27.71 (13.61)</td>
<td>150.95 (110.65)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36-54: n = 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>55+: n = 7</td>
<td></td>
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</tr>
<tr>
<td>IVS -ES</td>
<td>9M, 10F</td>
<td>18-35: n = 7</td>
<td>45.53 (17.19)</td>
<td>28.65 (17.03)</td>
<td>233.00 (235.94)</td>
</tr>
</tbody>
</table>
Simulated Route

• 24 Mile Route
IVS Information by Zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>IVS Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 0</td>
<td>Speed Reduction Warning – 55mph</td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>Speed Limit – 55mph</td>
<td></td>
</tr>
<tr>
<td>Zone 2</td>
<td>Curve – reverse turn left – 30 mph advisory speed</td>
<td></td>
</tr>
<tr>
<td>Zone 3</td>
<td>Curve – reverse turn right – 35 mph advisory speed</td>
<td></td>
</tr>
<tr>
<td>Zone 4</td>
<td>School zone speed reduction warning – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 5</td>
<td>School speed zone – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 6</td>
<td>Work zone speed reduction warning – 40 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 7</td>
<td>Work zone speed limit – 40 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 8</td>
<td>Speed warning zone – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 9</td>
<td>Speed zone – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 10</td>
<td>School warning zone – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 11</td>
<td>School zone – 35 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 12</td>
<td>Curve winding right – 40 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 13</td>
<td>Speed warning zone – 40 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 14</td>
<td>Speed zone – 40 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 15</td>
<td>Work zone speed reductions warning – 50 mph</td>
<td></td>
</tr>
<tr>
<td>Zone 16</td>
<td>Work zone speed limit – 50 mph</td>
<td></td>
</tr>
</tbody>
</table>
Results: Percent of Posted Speed

IVS *with* External Signs compared to baseline

IVS *without* External Signs compared to baseline

Percent Posted Speed Group Averages
IVS Risk Evaluation

Bayesian Network

Cross-validation predictive performance

IVS Model Predictions
Probability of Fatality by Crash Type

Sampling Distributions

Probability of Fatality

Expected Value Across Speed Zones

Average Expected Value

University of Minnesota
ROADWAY SAFETY INSTITUTE
Mental Workload

Impact of IVS on Subjective Mental Workload (NASA-RTLX)
Conclusions

- IVS system in the absence of external signs (IVS -ES) resulted in less compliance with the change in speed zones
  - The increased speed resulted in decreased levels of safety with various crash types.
  - Increased workload and decreased satisfaction associated with the IVS system in the absence of external signs.

- Using IVS information in the absence of external signs would presumably save money
  - It is NOT recommended that the current IVS system be utilized in the absence of external signs.

- Should further explore the potential of using IVS information in conjunction with external signs
  - This could involve additional simulation studies, in combination with higher-fidelity risk analysis, to ameliorate the limitations of the current effort
Limitations and Next Steps

• Drivers in the simulation were not penalized for driving above posted speeds.
• The IVS presented speed information through visual presentation only and did not include auditory redundancy.
• The work has potential to be expanded to examine
  – The role of compliance and distraction to emerging IVS systems, which may communicate connected vehicles (i.e., vehicle-to-vehicle) information to reduce vehicle speeds at points of conflicts (e.g., intersections, work zones).
  – Help understanding how drivers respond to dedicated IVS systems like those that could assist emergency vehicles in creating a cleared path or encouraging drivers to comply with “move over” laws would provide valuable insight into how such systems could enhance safety.
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