Examination of drivers’ cell phone use behavior at intersections by using naturalistic driving data

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Driving simulator studies of cell phone-related distraction

- Driving performance decreased and crash risk assumed to increase (Drews, et al., 2009; Liang & Lee, 2010)
- Decrements in lane-keeping, increases in speed variability (Crisler, et al., 2008)
- Increases in following distance variability (Hosking, et al., 2009; Owens, et al., 2011)

Survey study of cell phones and safety

- Cell phone use steadily increased while crash rates declined during the same time period (Insurance Institute for Highway Safety, 2010).
Research Question

- How driver behave when they use cellphone
  - Naturalistic driving environment
  - Specific scenario: go through signalized intersections
  - Driving performance: speed
  - Situational factors: lighting conditions, traffic conditions
Data Resources: IVBSS

- Naturalistic driving data from Integrated vehicle based safety system (IVBSS) program
  - 5-year long program
  - Integrated four types of warnings FCW, LDW, LCM, and CSW
  - 16 instrumented research vehicles (2006 Honda Accord)
  - 108 drivers (6 weeks of driving for each)
    - Younger drivers (M=25.2; SD=2.9)
    - Middle-aged drivers (M=46.0; SD=3.0)
    - Older drivers (M=64.6; SD=2.8)
IVBSS: Instrumented vehicles

Forward Crash Warning (FCW)

Lateral Drift Warning (LDW)

Lane-change/Merge (LCM)

Curve speed Warning (CSW)

GPS/Digital Map

Radar
Vision

16°
38°
IVBSS: Data Collection

- April 2009 to April 2010
- Data from 108 drivers
- Data Set
  - Over 213K miles
  - 23K trips
  - 6,200 hours
  - 600 data channels
  - 5 video channels

Percent of time in motion:
- ADAS map: 76.9%
- non ADAS map: 15.5%
- No map: 7.6%
Trained coders went through one week video data, 1381 conversations, 2149 Visual/Manual (VM) tasks
Method

- Case Control Study
  - Case: went through signalized intersections
  - Control: match on the same driver and intersection

- One way ANOVA
  - Test average, maximum and minimum driving speed between cell phone use and baseline (driving only)

- Mixed model
  - Dependent variable: average speed
  - Explanatory variables: traffic condition and lighting condition (situational factors), cellphone use condition
Signalized intersections were identified based on HPMS database.

Baselines were matched based on driver and intersection.

Min speed over 15 s (10s before the intersection + 5 s after) > 8.9 m/s = 20 mph.

Conversation (453), baseline (647)

VM (141), baseline (149)
Results: Conversation

- ANOVA for conversation and baseline
  - Significant differences on max and mean speed
  - No significant differences on minimum speed
  - The differences were small (but over 15 seconds of driving)

<table>
<thead>
<tr>
<th></th>
<th>Speed Difference m/s (mph)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>0.67 (1.50)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean</td>
<td>0.43 (0.96)</td>
<td>0.05</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.22 (0.49)</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Mixed model showed the consistent results

- Drove slower with conversation
- Lighting situation not significant
- Significant interaction between traffic and conversation

<table>
<thead>
<tr>
<th>Factors</th>
<th>Estimates</th>
<th>SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>18.33</td>
<td>0.38</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Conversation</td>
<td>-0.67</td>
<td>0.24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Moderate traffic</td>
<td>-0.74</td>
<td>0.24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Dense traffic</td>
<td>-0.53</td>
<td>0.33</td>
<td>n.s.</td>
</tr>
<tr>
<td>Conversation : Moderate traffic</td>
<td>0.11</td>
<td>0.31</td>
<td>n.s.</td>
</tr>
<tr>
<td>Conversation : Dense traffic</td>
<td>1.12</td>
<td>0.54</td>
<td>0.04</td>
</tr>
</tbody>
</table>
ANOVA for each traffic condition

Sparse and moderate had similar pattern, lower speed with conversation compared with baseline

- Relative balanced sample size
- Sparse: $\Delta_{B-C}=0.43 \text{ m/s, } p=0.02$
- Moderate: $\Delta_{B-C}=0.67 \text{ m/s, } p=0.005$

Dense had opposite pattern, higher speed with conversation

- $\Delta_{B-C}=-0.75 \text{ m/s, } p=0.43$
- 47 conversation (10%), 107 baseline
Results: VM Tasks

- ANOVA for VM tasks and baseline
  - Significant differences on max and mean speed
  - No significant differences on minimum speed
  - The differences were greater

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<tr>
<td>Maximum</td>
<td>1.36 (3.04)</td>
<td>0.005</td>
</tr>
<tr>
<td>Mean</td>
<td>1.24 (2.77)</td>
<td>0.004</td>
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<tr>
<td>Minimum</td>
<td>0.84 (1.88)</td>
<td>0.9</td>
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</table>
**Results: VM Tasks (Cont.)**

- Mixed model showed the consistent results
  - Drove slower with VM tasks
  - Lighting situation not significant
  - Significant interaction between traffic and VM tasks

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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>18.97</td>
<td>0.58</td>
<td>&lt;0.01</td>
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<tr>
<td>VM tasks</td>
<td>-1.76</td>
<td>0.49</td>
<td>&lt;0.01</td>
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<tr>
<td>Moderate traffic</td>
<td>0.27</td>
<td>0.57</td>
<td>n.s.</td>
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<tr>
<td>Dense traffic</td>
<td>-0.72</td>
<td>0.80</td>
<td>n.s.</td>
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<tr>
<td>VM : Moderate traffic</td>
<td>0.79</td>
<td>0.79</td>
<td>n.s.</td>
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<tr>
<td>VM : Dense traffic</td>
<td>2.54</td>
<td>1.08</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Mixed model showed the consistent results:

- Drove slower with VM tasks
- Lighting situation not significant
- Significant interaction between traffic and VM tasks.
Results: VM Tasks (Cont.)

- Sparse and moderate: lower speed with VM tasks
  - Sparse: $\Delta_{B-T}=2.15 \text{ m/s}, p<0.01$
  - Moderate: $\Delta_{B-T}=0.53 \text{ m/s}, p=0.1$
- Dense: higher mean speed with VM tasks, $\Delta_{B-T}=-0.74 \text{ m/s}, p=0.46$, 18 VM
Discussion

- Adaptive behavior
  - Reduced speed more with VM vs Conversations
    - Adapt their behaviors to compensate for higher driving demand
  - Significantly much lower speed with VM tasks under sparse traffic
    - Drivers engage in VM tasks in low demand situations (sparse traffic)
    - Reduced speed as well to compensate for the increased demand from secondary tasks
Discussion

- Adaptive behavior
  - Speed increase but not significant with cellphone use under dense traffic
    - Few cellphone use events under dense traffic, drivers might avoid to use cellphone under high driving demand situations
    - Two participants contributed most of cellphone use events, might be risker drivers
    - Maintain traffic flow which might cause increased driving demand
    - Further examinations are needed with larger sample size
Future Work

- No critical situations occurred in this one week driving duration
- Future analysis could focus on safety critical events, such as crash or near crash events
Questions?

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