Mitigating Risk in Work Zones: Informing Drivers Using In-Vehicle Technology

Jake Achtemeier
HumanFIRST Laboratory
University of Minnesota
In-Vehicle Technology?

- Industry continues toward implementing native infotainment systems
- Average passenger vehicle age: 12 years (USDOT, 2016 data)
- **Smartphones as the *bridging* technology**
  - Increasingly ubiquitous, financially obtainable
  - More equitable across socio-economic continuum
Can smartphones convey work zone information as well as or better than conventional signage?
Literature Review

• Environmental Risks in Work Zone crashes
  – 78% of MN WZ crashes occur during day & clear conditions
  – Rural and local roads with a high speed limit
  – Perceived safety elicits riskier driving
  – Static signs are often ignored (especially low speed limits)
  – 40-57% of crashes occur in activity areas, rear-end and side-swipe crashes in advance and transition areas

• Driver Behavior in Work Zone crashes
  – Varies by work zone type
  – Teens and older drivers pose the most risk as a group
  – Men riskier than women overall
  – Older vehicles and trucks
  – Alcohol and impairment, inattention, speeding
Safety Culture Survey

• Goals
  – Identify driver use, outlook on driving with phones
  – Examine driving safety culture within Minnesota

• Procedure and Method
  – 46 questions on safety culture and technology use
  – Eligible participants (97 drivers)
    • 18 years of age or older
    • Lived in Minnesota
    • Held a valid driver’s license
Safety Culture Survey

• Summary of Results
  • Drivers open to a work zone smartphone app
    • 20% had no reservations
    • 42% open but wanted issues with distraction ironed out
  + Drivers with less patience with work zones
    • Distrust road signs and rely on other drivers for cues
    • More open to a smartphone app
  – Drivers more concerned about work zone safety
    • Attend to sign information and less on other drivers
  + Drivers more anxious or uncomfortable in work zones
    • Less confident in signage, but more open to smartphone app
Drivers’ Phone Placement Location

- Console: 20
- Cup Holder: 16
- Dash: 15
- Pass. Seat: 14
- Purse/Bag: 14
- Lap: 15
- Pocket: 15
- Mount: 5
- Hand: 3

N = 97
In-Vehicle Message Design

• Auditory Guidelines
  – Minimize annoyance
  – Choose appropriate timing and word choice
  – Urgency (e.g., female voices)

• Visual Guidelines
  – Redundant color coding
  – Limit distractions
Design and Method

• Work Zone Messaging
  – Roadside: Portable Changeable Message Signs (PCMS)
  – 2 In-vehicle messages
    • Audio-Visual & Audio-Only conditions
  – Message Placement
    • Dash & Passenger Seat

• Driving simulation with 2 work zone types
  – Lane Closure & Shoulder Work

• Metrics
  – Driving performance, eye-tracking, mental workload
  – Usability, user friendliness, driver preference
## Work Zone Messaging Example

<table>
<thead>
<tr>
<th>Message Placement</th>
<th>Audio-Only Message</th>
<th>Audio-Visual Message (Icon displayed)</th>
<th>Portable Changeable Message Sign (PCMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mile Marker 1.25</td>
<td>“Work Zone Ahead”</td>
<td><img src="image1.png" alt="icon" /> <strong>WORK ZONE AHEAD</strong></td>
<td><img src="image2.png" alt="image2.png" /> <strong>WORK ZONE AHEAD</strong></td>
</tr>
<tr>
<td>Introductory Drive (Before Transition Zone)</td>
<td>“Half Mile”</td>
<td><img src="image3.png" alt="icon" /> <strong>REDUCE SPEED</strong></td>
<td><img src="image4.png" alt="image4.png" /> <strong>REDUCE SPEED</strong></td>
</tr>
<tr>
<td></td>
<td>“Reduce Speed”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Exposure time consistent for PCMS, in-vehicle messages*
Design and Method

• Simulated work zone routes
  – 9.2 miles based off of segment of MN US Hwy 169
  – 2 drive layouts
    • Shoulder work, Lane closure
Design and Method

• Participants
  – 48 drivers, 25 men, 23 women, average age 25.3
  – 2 groups, dashboard or passenger seat placement
    • Dashboard per best practices, passenger seat to reflect drivers’ phone placement locations

• Method
  – Participants drove the 2 routes, 6 times
    • Shoulder work & Lane closure
  – Each drive they would experience one of the three work zone event message conditions
    • PCMS, Audio-Visual, Audio-Only
Work Zone Events

• Shoulder Work
  – Slow Traffic Ahead
  – Debris in Lane
  – Trucks Entering Roadway
  – Heavy Machinery Ahead
  – Crash Ahead

• Lane Closure
  – Work Zone Ahead
  – Lane Closure
  – Active Work Zone Ahead
  – Workers Ahead
  – Stopped Traffic Ahead
Measurements

• Driving Performance
  – Average speed, speed deviation, lane deviation

• Subjective Measures
  – Situational Awareness Inventory
  – Rating Scale Mental Effort
  – System Usability Scale

• Visual Attention
  – Four camera eye tracking system (Smart Eye AB)
    • Glances, or fixations, to road events and message source
Driving Performance Results

• Average Speed
  – Lane closure slower than shoulder work
    • Overall
    • During work zone event messages
  – Lane closure route may be more challenging for participants
Driving Performance

• Speed Deviation
  – Lane closure route had greater speed deviation than shoulder work overall, but less speed deviation during event messages
    • Suggests higher mental workload for lane closure route
  – During event messages, PCMS had less speed deviation than the Audio-Visual and Audio-Only
    • Suggests less likely to change speed during PCMS
Lane Deviation During Messages

Shoulder work | Lane closure

PCMS | Audio-Only | Audio-Visual
Rating Scale Mental Effort

PCMS | Audio-Only | Audio-Visual
---|---|---
50 | 45 | 40
System Usability Scale

<table>
<thead>
<tr>
<th></th>
<th>PCMS</th>
<th>Audio-Only</th>
<th>Audio-Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Participants who Preferred System</td>
<td>2</td>
<td>38</td>
<td>8</td>
</tr>
</tbody>
</table>
Situational Awareness Inventory

• Recall scores
  – Overall
    • PCMS (.407) < Audio-Only (.509)
      – Higher recall in Audio-Only
    – For passenger seat placement of in-vehicle interface, on the lane closure route
      • PCMS (.348) < Audio-Only (.530) & Audio-Visual (.522)
      • Task demand and placement as possible explanation
Overall Average Fixations on Interface

PCMS: 60
Audio-Only: 2
Audio-Visual: 8
Interface Fixation (Route / Modality)

Shoulder work | Lane closure

- Northbound
- Southbound

PCMS

Audio-Only

Audio-Visual
Driving Simulation Summary

• Driving Performance
  – Better driving performance for in-vehicle messages, worse for PCMS and lane closure route

• Subjective Measures
  – Prefer in-vehicle messages (esp. Audio-Only)
  – Less mental workload, better usability and situation awareness for in-vehicle conditions relative to PCMS

• Visual Attention
  – Drivers with PCMS fixate more on signs and take gaze off of road
Take-Away Message

• Safety survey indicates that drivers
  – Are open to in-vehicle messages, especially if distrustful or uncomfortable around work zones

• Simulation results suggest in-vehicle message systems may be useful for work zone safety
  – Not found to be distracting if in-vehicle messages are related to driving task
  – Placement does not appear to matter much
    • Non-dashboard placement could even be beneficial
  – The more difficult driving scenario, the more effective the in-vehicle messages