Rural Intersection Collision Warning System (RICWS) Evaluation and Design Investigation

NCITE/ITS Joint Meeting

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Outline

• Background
• Rural Intersection Collision Warning System (RICWS)
• Primary Human Factors Concerns
• Project Goals
• Usability Test Results
• Driving Simulator Study
• Preliminary Findings
Background

- 55% of rural thru-STOP intersections in Minnesota has had at least one crash (Preston & Storm, 2003).
- Drivers’ failure to select sufficient gaps has been identified to be a major contributing factor for crashes at thru-STOP intersections.
- More than 50 RICWS signs have been deployed across the state of Minnesota to aid motorists to safely cross these intersections.
RICWS System

Minor Road Warning System

Major Road Warning System

RICWS System Layout

Primary Concerns

• **Primary concerns:**
  – Complaints reported from local road users
  – Potential road user confusion about signs
    • Ordering of message components
    • Saliency of “Traffic Approaching” component
    • Sign status
  – Overreliance on the sign
    • Behavioral Adaptation to Sign
Project Goals

• Use iterative design modifications and usability tests to:
  – Identify critical human factors issues associated with the original RICWS sign and develop alternative design options
  – Evaluate the effectiveness of each sign’s ability to convey information for traffic approaching, sign-on, and sign-off states
  – Understand driver’s cognitive processes and decision making regarding each sign
  – Evaluate the clarity and appropriateness of terminology and other design elements

• Determine the most appropriate design that:
  – Best captures driver’s visual attention
  – Promotes sign acceptance
  – Promotes safe gap acceptance at rural thru-STOP intersections
Usability Testing

• 3 rounds of usability tests
  – Total N=30
  – Mean age=43.3, SD=16.5

Intersection layout provided to participants

<table>
<thead>
<tr>
<th>Sign States</th>
<th>Traffic is too close to safely cross</th>
<th>Sign is on/operating</th>
<th>Sign is non-operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Examples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Message Conveyed</td>
<td>There is not enough time to cross.</td>
<td>There is enough time to cross.</td>
<td>This officer is not operational, like signs can sometimes be.</td>
</tr>
</tbody>
</table>
Usability Test

• Sign comprehension
• Decision making
• Overall design preferences
• Terminology preferences
  – Not safe to cross
  – Sign is on/operating
• Likes/Dislikes
<table>
<thead>
<tr>
<th>Names of Design Options</th>
<th>SIGN IS ON</th>
<th>DO NOT CROSS/TURN</th>
<th>SIGN IS OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SIGN A: “GOING ROGUE”</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>SIGN B: “BE THERE OR BE SQUARE”</strong></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>SIGN C: “THE FIRST BORN”</strong></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>SIGN F: “TWO-FACED”</strong></td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Alternative Sign Options

*NOTE: SIGN OPTION HAS NOT BEEN TESTED WITH DRIVERS
OUR ASSESSMENT IS THAT THIS SIGN IS TOO CLUTTERED AND MAY NOT SOLVE DRIVER CONFUSION ABOUT WHAT WILL BE FLASHING
FHWA (2016) STUDY FOUND MOST DRIVERS REPORTED THIS TO BE TOO WORDY
**Alternative Sign Options**

*NOTE: SIGN OPTION HAS NOT BEEN TESTED WITH DRIVERS*

FHWA (2016) study found that drivers reported that the sign had the same meaning without the placard; however, we feel the experimental design was flawed and the conclusions are biased.
Sign A

Red Frame Flashing
Alternative Sign Options

*NOTE: SIGN OPTION HAS NOT BEEN TESTED WITH DRIVERS*
Sign Set A: Retest

Red Frame Flashing

LED SIGN

LED SIGN

Preference Count:
1st: 21
2nd: 13
3rd: 7

Preference Count:
1st: 12
2nd: 19
3rd: 10

Preference Count:
1st: 8
2nd: 9
3rd: 24
Sign Set B: Retest

Version 1:
- Cross Traffic Too Close
- Beacons Alternate Flashing

Preference Count: 33

Version 2:
- Cross Traffic Too Close
- Beacons Alternate Flashing

Preference Count: 7
Final Usability Test Results

Sign B
- CROSS TRAFFIC TOO CLOSE
- CROSS TRAFFIC DOES NOT STOP

Sign C
- TRAFFIC APPROACHING WHEN FLASHING
- TRAFFIC APPROACHING

Sign F
- TRAFFIC APPROACHING
- WATCH FOR TRAFFIC WHEN FLASHING

Sign G
- WAIT CROSS TRAFFIC APPROACHING
- CROSS TRAFFIC DOES NOT STOP
Driving Simulator Study

• Recruitment goals (N=80)
  – 2 age groups (40 per group)
    • Older drivers (65-77)
    • Novice teenage drivers (<18)

• Experimental design
  – Randomly assigned to one sign option
  – ABAB design (reversal design)
  – 2 levels of visibility
  – 2 levels of traffic volume condition
  – Sign-off state
Driving Simulator Study

• Experimental design

Drive 1 & 3: Baseline

Drive 2 & 4*: Treatment

Low | Moderate | Low | Moderate
Unobstructed | Obstructed

Low | Moderate | Low | Moderate | Sign-Off*
Unobstructed | Obstructed

Unobstructed View

Obstructed View
Driving Simulator Study

• Materials and Apparatus

HumanFIRST partial motion-based driving simulator set up

Smart-Eye Pro Eye Tracking Camera
Data Collection

• On approaching the intersection:
  – Speed
  – Braking
  – Wait time
  – Stop sign violations

• When crossing the intersection:
  – Gap acceptance
  – Acceleration
  – Crossing behavior
  – Sign compliance
  – Collision rate
Data Collection

• Visual Attention
  – Percent of eyes-on and -off road
  – Frequency and duration of fixations on signs
  – Visual search patterns

• Subjective Measurements
  – Sensation Seeking
  – Driving History
  – Mental Workload
  – System Trust
  – Usability Test
General Research Questions

• Which sign design most clearly conveys the information being presented to road users?
• Which sign design best captures drivers’ attention and requires less visual workload?
• Under which environmental (visibility and traffic volume) condition does the warning sign best aid road users to safely cross the intersection?
• To which extent do road users rely on the signs at these intersections?
• Do road users continue to adhere to stop signs once they become familiar with the signs’ operations?
Research Hypothesis

• Gap Acceptance Hypothesis
  – Older drivers are expected to be more likely to:
    • Misjudge the size of gap
    • More frequently reject a gap
    • Longer total wait time at intersections

• Visual Attention Hypothesis
  – Older drivers are expected to be more likely to:
    • Take longer time to process
    • Use more fixations
    • Higher visual workload
    • Less eye-off-road behavior
Preliminary Findings

• Sign Comprehension
  – Misinterpretations of sign states

• Sign Acceptance
  – Teenage Drivers
    • Overconfidence on signs
    • Less reliance on signs

• Sign Acquisition
Preliminary Findings

• An Example:
  – Eye Tracking on Sign C (Original RICWS)
Next Steps

• Complete data analysis of teen and older driver participants

• Pursue a “middle-aged” adult population
  – 30-45
  – Determine how high-risk groups’ behavior compared to middle-adult drivers
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