On-Road Evaluation of Connected Motorcycle Crash Warning Interface

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Background
How Connected Vehicle Systems Can Increase Motorcycle Safety?

Bi-Directional Wireless Communications between Vehicles and Infrastructure
• Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I)
• Dedicated Short Range Communications (DSRC)
  • Transmit Vehicle Kinematic, Position Information, etc.
  • Omni-Directional Range: ~300m
  • Transmission Rate: 10Hz

Raises awareness of motorcycles in the roadway
• Provides warnings to riders/drivers when a potential crash is predicted
  • Can help address the common “looked but did not see” crash type
• Example Applications
  • Forward Collision Warnings
  • Blind Spot Warnings
  • Intersection/Gap Warnings
  • Back-Up Cross Traffic Warnings
Why On-Road Evaluation?

• Nature of CWS studies
  • Should aim to put participants in crash or near-crash situations

• Simulation
  • Widely adopted in motorcycle CWS studies
  • Pro – Well controlled risk
  • Con – Exposed and dynamic environment
    • Motorcycle noise
    • Wind impacts
    • Vibration

Background

Key Factors of Interests

• Motorcycle Crash Types
  • Right-of-way (ROW) violation crashes at intersections
  • Rear-end crashes
  • Side-side crashes related to overtaking behaviors

• Motorcycle Types
  • Cruiser, Sport, and Touring
  • It is believed that rider demographics, preferences, riding position, etc. will vary by motorcycle type, potentially affecting preference and acceptance of a CWI.
Objectives

• Refine the base connected motorcycle system to include warning capabilities
• Design and develop the warning interface for riders
• Evaluate prototype interfaces
• Report observations and provide recommendations on appropriate crash warning interfaces for motorcycles in a connected vehicle environment
Methodology
Prototype Interface

- **Visual**
  - Mirror LED strips/Visor LED strips

- **Alert**
  - Flashing red LEDs
    - Caution Alert – 2 Hz
    - Warning Alert – 4 Hz

Pilot test -

- The majority experienced difficulties detecting mirror LED strips
  - Mirror LED strips are outside of rider’s central visual field
  - Visual cues could be easily overwhelmed by background noise

- Mirror LED strips vs. visor LED strips
  - LED strips located on visor were preferred in terms of rapid attention direction.
Prototype Interface

• Auditory
  • In-helmet headset
  • Alert
    • Caution Alert
      Pulse rate - 1.5 Hz
    • Warning Alert
      Pulse rate - 6 Hz

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Prototype Interface

• Haptic
  • Wristbands
  • Alert
    • Caution Alert
      Pulse Rate – 1 Hz
    • Warning Alert
      Pulse Rate – 10 Hz
Setup
Test Bed and Scenarios

- Smart Road, Blacksburg, VA
  - Controlled access
- Test Scenarios
  - Intersection Movement Assist
  - Lane Change/Blind Spot Warning
  - Forward Collision Warning
Safety Application

• Intersection Movement Assist (IMA)
  • Speed
    • Motorcycle – 25 mph
    • Car – 5 mph
  • Alert
    • Caution alert – when < 3 sec TTC
    • Warning alert – when < 2 sec TTC
Safety Application

• Lane Change/Blind Spot Warning (LCW)
  • Speed
    • Motorcycle – 25 mph
    • Car – 30 mph
  • Alert (left turn signal is turned on)
    • Caution alert when < 2 sec headway
    • Warning alert when motorcycle is being overtaken
Safety Application

- Forward Collision Warning (FCW)
  - Speed
    - Motorcycle – 25 mph
    - Car – 25 mph
  - Initial headway – 3 sec
  - Alert
    - Caution alert – when car is braking
    - Warning alert – when < 2 sec headway
Test Fleet
Procedure

• A Mixed-Factorial Design
  • Within-subject factor
    • Crash warning interface, scenario, time (pre-ride, post-ride)
    • Crash warning interface
      • Visor LED strips / In-helmet headset / Haptic wristbands / Combo of all plus mirror LED strips
  • Between-subject factor: motorcycle type

• Assessment
  • Subjective – Questionnaires to assess user acceptance and feedback
    • Pre-Ride / Post-Scenario / Post-Trial / Post-Ride
  • Objective – To assess user performance and reaction
    • Video data by two motion cameras
      • Front view and face view
Results
Results

39 riders completed the study
- Fell evenly into three motorcycle types
- 29 males, 10 females
- Age ranging from 18 to 69

After the experience, participants’ benefit ratings of CWS and applications are significantly higher
- No significant difference in motorcycle type, but cruiser and touring riders gave higher benefit ratings
Results

Visor-mounted LED light strips

• Like
  • “location in field of vision”; “get user's attention fast”; and “bidirectionality that is easy to interpret”.

• Dislike
  • “obtrusive and distracting being in field of vision”; “not working in direct sunlight”; and confusion with other red light sources such as taillights or stoplights.

• Change
  • “relocate and make them less obtrusive” and "change color"

In-helmet headset

• Like
  • "not interfering with vision"; "cannot miss no matter where user looks"; "get attention fast"; and "alert levels conveyed urgency well"

• Dislike
  • “affected by environment noise” and “alerts (direction) are confusing”

• Change
  • “use speech/unique tone” and “automatically adjust volume"
Results

Haptic wristband

• Like
  • "Using new sensation and location"; physical stimuli "gets riders’ attention fast"; "cannot be missed no matter where they look"; and "good at presenting direction information".

• Dislike
  • “bulky and interfering design”; “maybe hard to distinguish from environment”

• Change
  • "integration into bike, jacket or gloves" or "making them slimmer"

Combination

• Like
  • "impossible to miss or ignore" and "get user’s attention fast"

• Dislike
  • "too much and distracting" for the same reason. It might not be appropriate for low urgency situations.

• Change
  • "reduce the number of displays" to a balanced level or, making it “a dynamic combo" based on urgency level
Results

Customized Combination

- The majority have in-helmet headset in their ideal interface (74.4%)
- Haptic warning interface was well accepted (56.4%)
- Double-interface was the most popular combo size (56.4%)
- By motorcycle type
  - Double combos were preferred by cruiser riders and sport riders while touring riders tended to have fewer
  - Cruiser and touring riders preferred in-helmet headset over others while sport riders showed no preference
Lessons Learned

- Combined auditory and haptic displays show considerable promise for implementation.
  - Auditory - the adoption rate of in-helmet auditory systems.
  - Auditory display’s weakness of presenting directional information
    - Use simple speech/Assist of haptic design
  - A somewhat bulky working prototype of haptic display was also found to be attractive to riders.
    - Better integration (gloves or a jacket) would keep warning benefits and also encourage the use of riding gear.
- Both opportunities and challenges of visual displays in general were revealed for motorcycle CWSs
  - Further testing is needed - elicit desired responses without being distracting
    - Location; color
- Combination – be dynamic (number of warning modalities and warning intensity)
- Overall System
  - Smarter CWI – Environmental feedback
  - Style and Integration
  - The effect of motorcycle type on riders' acceptance of a CWI
- The findings would benefit both CVT based motorcycle CWS design and traditional CWS design for motorcycles
For More Details...

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