On-Road Evaluation of Connected Motorcycle Crash Warning Interface

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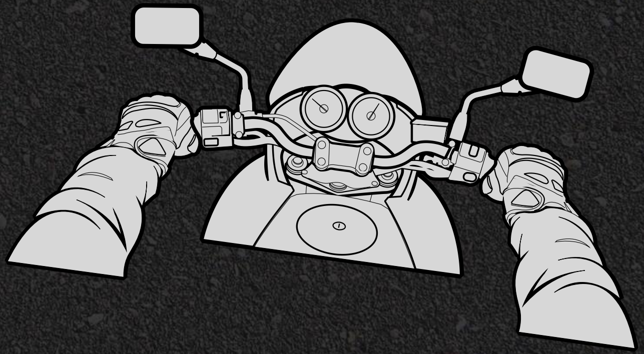
Background



How Connected Vehicle Systems Can Increase Motorcycle Safety?

Bi-Directional Wireless Communications between Vehicles and Infrastructure

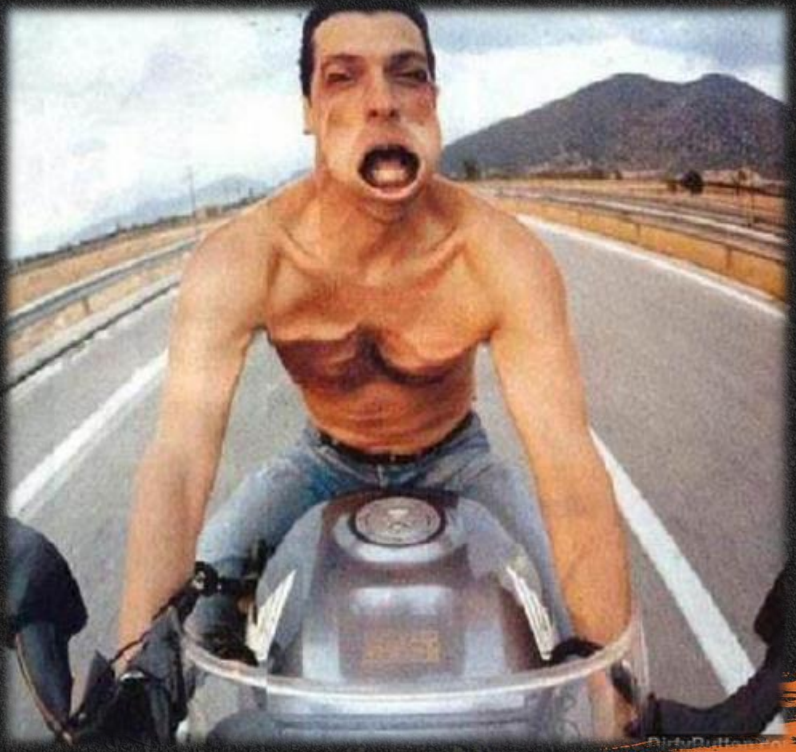
- Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I)
- Dedicated Short Range Communications (DSRC)
  - Transmit Vehicle Kinematic, Position Information, etc.
  - Omni-Directional Range: ~300m
  - Transmission Rate: 10Hz

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



Motorcycle Wind [digital image].Retrieved from http://www.dirtybutton.com/media/db2612-motorcycle-wind.jpg

Background

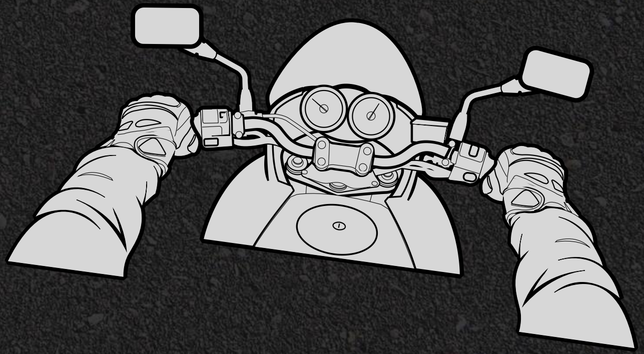
Key Factors of Interests

- 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

Prototype Interface

- Haptic
  - Wristbands
  - Alert
    - Caution Alert
      Pulse Rate – 1 Hz
    - Warning Alert
      Pulse Rate – 10 Hz

Setup

Test Bed and Scenarios

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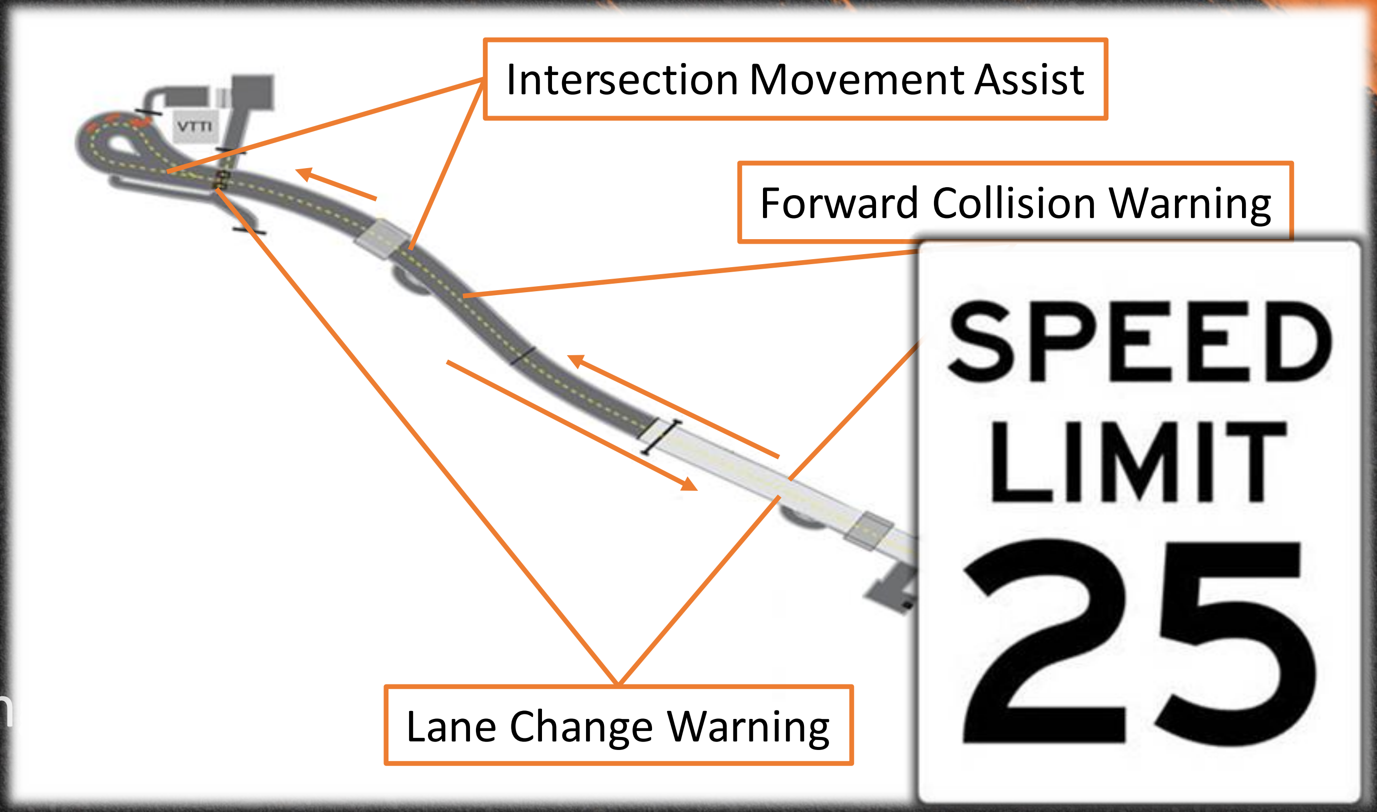
- Smart Road, Blacksburg, VA
  - Controlled access
- Test Scenarios
  - Intersection Movement Assist
  - Lane Change/Blind Spot Warnin
  - Forward Collision Warning



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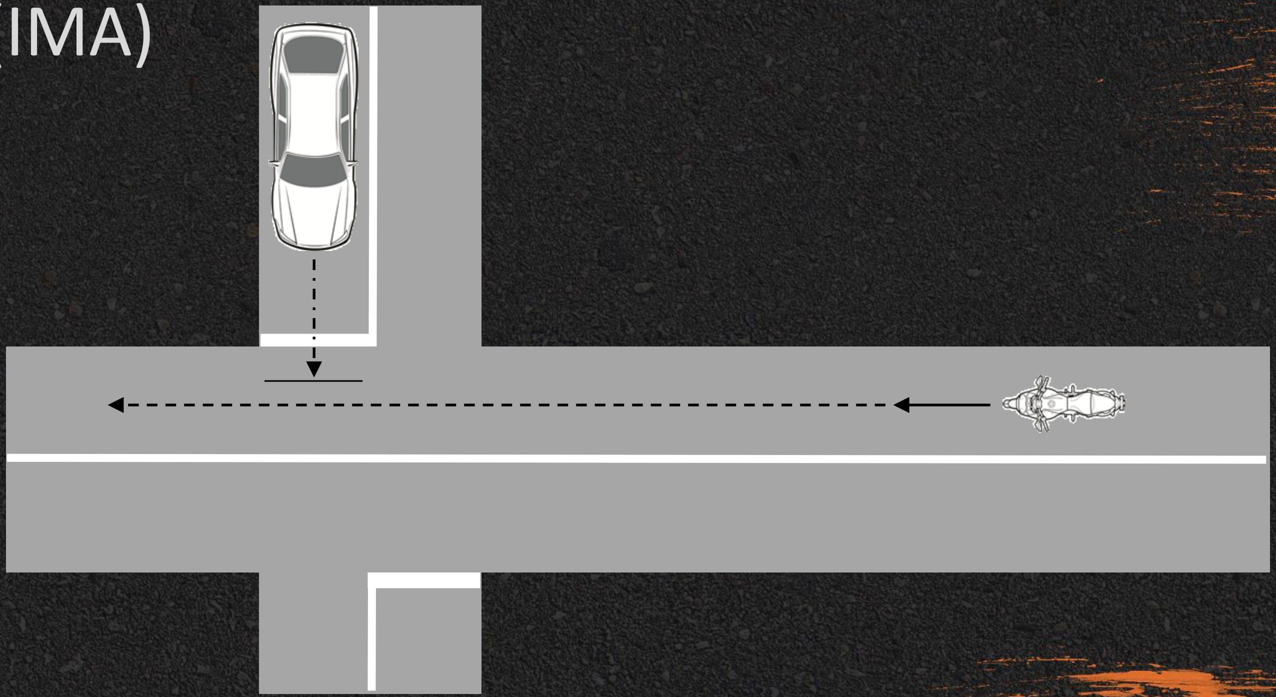
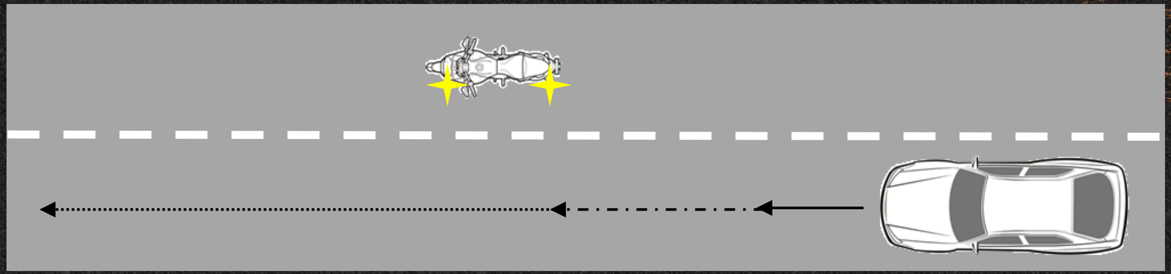
Safety Application

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



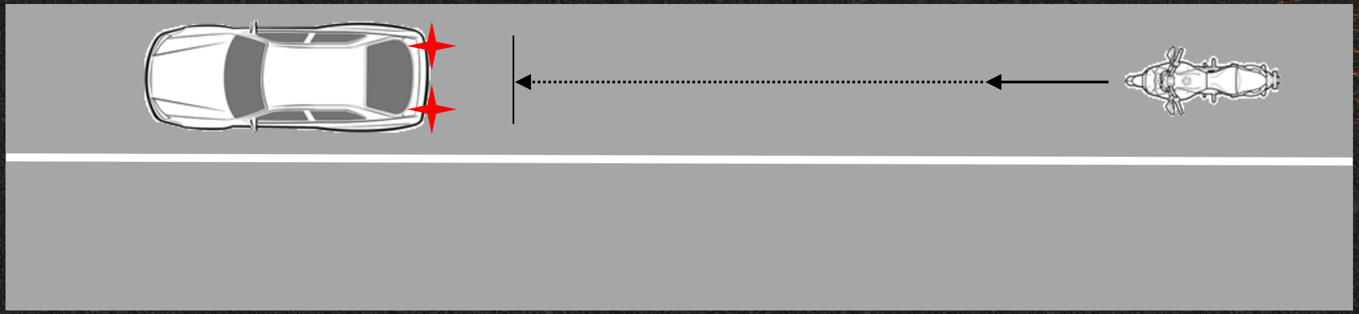
Safety Application

- 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

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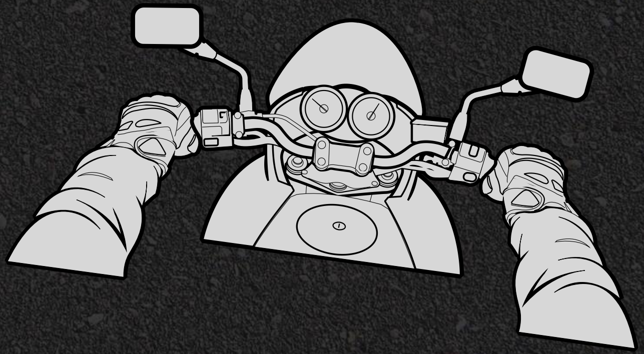
Results



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

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

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"

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…

Song, M., McLaughlin, S., and Doerzaph, Z. An On-Road Evaluation of Connected Motorcycle Crash Warning Interface with Different Motorcycle Types. (Accepted) *Transportation Research Part C: Emerging Technologies.*

Song, M., McLaughlin, S., and Doerzaph, Z. *An On-Road Evaluation of Connected Motorcycle Crash Warning Interface.* Paper presented at the Transportation Research Board 95th Annual Meeting, January 11-15, 2016, Washington, D.C.

Thank You

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Thanks to the CVI UTC and the USDOT for funding this research

Thanks to the Motorcycle Safety Foundation for providing Motorcycles and guidance in the conduct of this research