U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA
www.nhtsa.gov

TRAFFIC SAFETY FACTS
Vehicle Safety Research Notes

DOT HS 811 471 July 2011

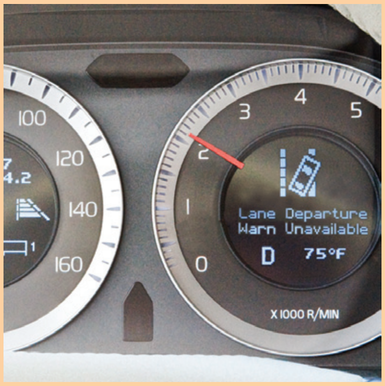
Crash Warning Interface Metrics, Phase 2

Advanced crash warning systems (ACWS) assess emerging hazard situations and provide crash warning information to the driver. In some cases the system may also initiate some vehicle control action. Examples of ACWS include forward collision warning (FCW) and lane departure warning (LDW). ACWS have the potential to improve driver performance and reduce the frequency and severity of common crash situations, but the success of any ACWS will depend in part on the quality of the driver-vehicle interface (DVI). The DVI refers to the displays and controls through which the driver and the vehicle interact. Figure 1 shows an example display.

"…The success of any ACWS will depend in part on the quality of the driver-vehicle interface."

ACWS are increasingly common in passenger vehicles and the characteristics of these systems vary considerably among vehicle manufacturers. The objectives of the crash warning interface metrics (CWIM) project were to identify the effects of certain warning system features (e.g., warning modality) on driver behavior and comprehension, consider methods that may be applied for DVI evaluation in different vehicles, and identify areas in which there may be concerns related to DVI variation among vehicles. The CWIM effort included five experiments that are described below. Two of these studies were performed under separate contracts at the University of Iowa (the FCW driving simulator study) and NHTSA's Vehicle Research and Test Center (the FCW test track experiment).

Figure 1. Detail from status display experiment photo



Three Studies of Warning Modes for ACWS Driver-Vehicle Interfaces

In the LDW driving simulator experiment, participants drove on a simulated two-lane rural highway. At three points during the drive, while participants were visually engaged in a distraction task, the simulator induced a lane shift without motion cues that caused the vehicle to begin to drift out of its lane. Four warning modes were evaluated through comparison to a no-warning condition: acoustic alert, tactile (steering wheel vibration) alert, weak active countersteer torque, and stronger active countersteer torque.

The FCW driving simulator experiment had a similar procedure. The experiment included two FCW events: lead vehicle slowing and lead vehicle stopped. The DVIs tested included an auditory/head-up display (HUD) and a brake pulse, compared to no warning (control).

The FCW test track experiment involved a car-following procedure. The FCW event occurred when the vehicle that the participant was following suddenly moved out of its lane to reveal a stopped "vehicle" ahead

Figure 2. Area of lane exceedance as a function of LDW warning condition

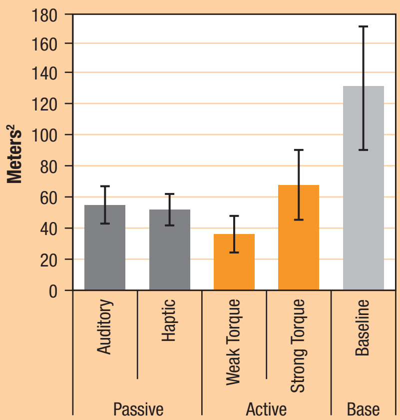


Figure 3. Elapsed time between initiation of FCW alert and brake pedal pressed

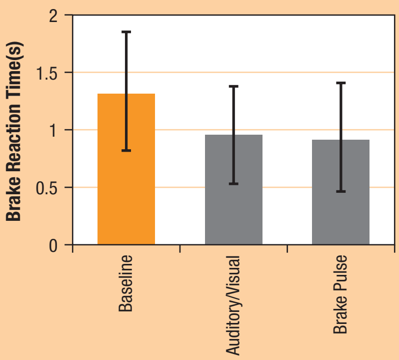


Table 1. Test track collision results by FCW alert condition

FCW Alert Condition	Number of Participants	
	Collided	Avoided
No alert	8	0
HUD alone	8	0
Beep alone	7	1
Belt alone	5	3
Beep+HUD	7	1
Belt+HUD	3	5
Belt+Beep	5	3
Belt+Beep+HUD	4	4

(actually an inflatable "balloon" vehicle). The warning modes tested included auditory; an HUD; a seat belt pre-tensioner; an auditory and HUD combination; a seat belt pre-tensioner and auditory combination; a seat belt pre-tensioner and HUD combination; and a combination of aseat belt pre-tensioner, anauditory warning, and an HUD, all of the above compared to a no-warning control.

Two Studies of DVI Variability

The FCW negative transfer study was a driving simulator experiment that examined what happens when drivers familiar with one auditory FCW warning encounter a different FCW auditory warning in an unfamiliar vehicle.

The ACWS status display experiment presented participants with detailed images of vehicle interiors as seen by the driver under various system status conditions. At issue was how well people understood what ACWS were present in the vehicle and their functional status. The experiment also considered the effects of familiarity with owner's manuals.

Key Findings

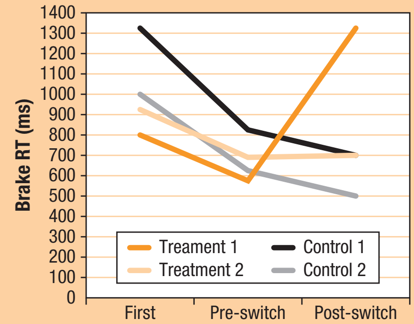
- The LDW modality simulator study found that all tested modes were better than no warning, and the weak steering torque was generally the best performing (see Figure 2).
- The FCW modality simulator study found that both FCW alerts produced a faster response than the no-warning condition (see Figure 3), and the brake pulse produced a lower peak deceleration that may indicate smoother braking than the auditory/visual alert with equivalent crash avoidance outcomes.
- The FCW modality test track study found that across all warning modes the addition of a seat belt pre-tensioner was effective at directing distracted drivers' eyes back to the forward roadway and led to faster throttle release, brake application, and avoidance steering, as well as fewer collisions (see Table 1).
- The FCW negative transfer study found that drivers respond more slowly to an FCW event when they experience a new, unfamiliar auditory FCW alert after previously becoming familiar with a different alert (treatment conditions), particularly for one of the two directions of shift, relative to participants who repeatedly experienced the same, familiar FCW alert (control conditions) (see Figure 4).
- The laboratory study of ACWS status display comprehension found that naïve participants had difficulties comprehending information about ACWS presence and current status, and that having prior exposure to the vehicle's owner's manual helped, but only to a limited extent.

Considerations for DVI Evaluation Methods

The CWIM study highlighted 10 specific factors that must be defined and controlled in order to specify a common general method that will achieve reproducible results for ACWS driver-vehicle interface evaluation. These are:

- **Driving scenario:** Characteristics of the driving situation and details of the potential collision event scenarios;
- **Participants:** Test driver population characteristics;
- **Distracting the driver:** Need for distraction and criteria for the distraction task;
- **Warning system context:** Evaluation of individual warning functions that are designed as a part of an ACWS;
- **Familiarity with the technology:** Control of the level of familiarization that research participants have with the general technology and specific product;
- **Participant expectancy:** Factors influencing what participants expect from the situation and understand their task to be, such as the presumed purpose of the study, exposure to multiple near-crash events, incentive structures;
- **Accommodating user settings and options:** How to test products that allow the user to modify performance features;
- **Comparison conditions/benchmarks:** Comparison groups or performance levels/standards against which the DVI is measured;
- **Treatment of data:** Data quality and analysis, definition, and treatment of bad trials;
- **General test method:** Simulator and test track methods.

Figure 4. Brake reaction time to FCW auditory alerts



U.S. Department of Transportation
National Highway Traffic Safety Administration

This Vehicle Safety Research Note is a summary of the technical research report: *Crash Warning Interface Metrics Final Report* (DOT HS 811 470). This report can be downloaded free in the Vehicle Safety Research section of NHTSA's Web site (www.nhtsa.gov).