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SURFACE VEHICLE INFORMATION REPORT

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Road/Lane Departure Warning Systems: Information for the Human Interface

RATIONALE

Detailed human interface recommendations do not currently exist for road or lane departure warning systems. Knowledge of driver behavior regarding in-vehicle warning systems has not yet been compiled into a document specifically for road or lane departure warnings. The information given in this report will assist designers in the creation of the human interface for road/lane departure warning systems.

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1. SCOPE

The Road/Lane Departure Warning System is a crash-avoidance technology which warns drivers if they are drifting (or have drifted) out of their lane or from the road. This warning system is designed to help prevent the possibility of a run-off-road crash. This system will not take control of the vehicle; it will only let the driver know that he/she needs to steer back into the lane. This warning system is not designed as a lane-change monitor, which addresses intentional lane changes, or a merging system which warns of other vehicles.

This informational report applies to OEM and after-market Road/Lane Departure warning systems for light-duty vehicles on relatively straight roads with a radius of curvature of 500 m or more, and under good weather conditions. Future revisions should consider the implications of newer variations on the user experience.

1.1 Purpose

J2808 was created with the purpose of coordinating with ISO in establishing standards for the operating characteristics and/or user interface of road/lane departure warning systems.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 Normative References

Draft international standard for lane departure warning systems—Performance requirements and test procedures; Working Document Number: N123.35 (May 2004) Committee ID: ISO/TC204/WG14

Draft international standard for graphic symbols for use on equipment—Index and synopsis; ISO Working Document Number 7000 (2006) Committee ID: ISO/TC145

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Pomerleau, D., Jochem, T., Thorpe, C., Batavia, P., Pape, D., Hadden, J., McMillan, N., Brown, N., and Everson, J. (1999). *Run-Off-Road Collision Avoidance Using IVHS Countermeasures: Final Report.* Report No. DOT-HS-809-170, EDL No. 13342, Prepared by Carnegie Mellon University for the NHTSA and USDOT. Washington, DC: December 1999.

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3. DEFINITIONS

3.1 Road

The surface that a vehicle would be expected to travel along in the absence of any obstruction.

3.2 Road Boundary

The borderline of the road that is determined by incidental visible road features or other means such as GPS.

3.3 Lane

“The area of roadway that a vehicle would be expected to travel along in the absence of any obstruction without the driver’s desire to change the path of travel.” From ISO draft standard N123.35.

3.4 Lane Boundary

The borderline of the lane that is determined by a visible lane marking and in the absence of a visible lane marking by incidental visible road features or other means such as GPS, electromagnetic nails, etc. In the case of a visible lane marking, the boundary shall be at the centre thereof.” From ISO draft standard N123.35.

3.5 Departure

From ISO draft standard N123.35: “The situation in which the outside of one of the front wheels of a vehicle or of the leading part of an articulated vehicle is crossing a specified line. In the case of a 3-wheel vehicle, it is the same except that the wheel is one of the wheels on the axle with the widest track.”

3.6 Road Departure

The point of departure across the road boundary.

3.7 Lane Departure

“The point of departure across the lane boundary.” From ISO draft standard N123.35.

3.8 Rate of Departure (V)

“The subject vehicle’s approach velocity at a right angle to the lane boundary at the warning issue point.” From ISO draft standard N123.35.

3.9 Straight Road

Road with a radius of curvature of 500 m or more.

3.10 Warning Condition

“A condition in which departure across the warning threshold occurs.” From ISO draft standard N123.35.

3.11 Earliest Warning Line

“The innermost limit of the warning threshold.” From ISO draft standard N123.35.

3.12 Latest Warning Line

“The outermost limit of the warning threshold.” From ISO draft standard N123.35.

3.13 Lane Departure Warning

“A warning given to the driver in accordance with the lane departure warning condition in the absence of suppression requests.” From ISO draft standard N123.35.

3.14 Road Departure Warning

A warning given to the driver in accordance with the road departure warning condition in the absence of suppression requests.

3.15 System Incapable

“A state of the system in which it is unable to warn the driver of a lane departure due to temporary conditions.” From ISO draft standard N123.35.

3.16 Status/Function Indication

An indication that reflects a system may not (or is less likely to) deliver a road/lane departure warning.

3.17 Haptic Warning

“A warning that stimulates the driver’s sense of touch, vibration, force and motion (e.g., steering wheel motion, steering wheel vibration, seat and pedal vibrations, etc.).” From ISO draft standard N123.35.

3.18 Time Critical Warning

Warning that changes as the warning condition becomes closer in time.

3.19 Road/Lane Departure Warning System

A system which provides road departure warnings or lane departure warnings.

4. HUMAN INTERFACE

4.1 Warning Levels

Time-critical warning levels are not realistic for road/lane departure warning systems, since "…the time course of lane departure events will typically not allow for a graded series of warnings – several warnings of increasing urgency." (Pomerleau et al., 1999)

Systems with imminent versus cautionary warning levels are intended to convey the likelihood of a crash caused from a road or lane departure. Lane departures with a high likelihood of a crash (imminent) might be presented differently than departures with a low likelihood of a crash (cautionary). Systems that determine these levels usually have additional information about the driving environment; such as the identification of dashed versus dotted lane markings, blind-spot monitoring, or side-collision warning systems.

For systems with any type of warning levels, care should be taken to determine whether the drivers find the levels intuitive or confusing.

4.2 Warning Presentation Modality

The draft international standard for Lane Departure Warning Systems (LDWS) requires that LDWS present haptic and/or auditory warnings. A review of the current warning modality research with regards to lane departure systems is consistent with this requirement. Much of the research currently published related to warnings for LDWS is about warnings for Side Collision Avoidance Systems (SCAS). SCAS are systems that detect objects located to the sides of the vehicle, in order to assist the driver in avoiding a side collision when making a lane change. Although these two systems are not interchangeable, they do suggest similar driver responses with the steering wheel.

4.2.1 Visual

Effectiveness:

- Visual warnings can be useful as status indications (Olsen, 2004), and to help drivers understand the meaning of lane departure warnings (LeBlanc et al., 2006). For lane departure warnings, the visual modality should be used as a secondary modality only. This is consistent with the draft international standard for Lane Departure Warning Systems.

Type:

- The draft ISO 7000 document includes a standard visual icon for road/lane departure warnings. The icon below is ISO 7000-2682:

FIGURE 1 - ROAD/LANE DEPARTURE WARNING ICON FROM ISO 7000-2682

Location:

- LeBlanc et al. (2006) displayed a visual alert on the left side of the instrument panel, seen through the steering wheel. Four out of 25 focus-group participants questioned after field testing with this visual alert suggested that the display be moved toward the center of the dashboard or in a head-up display.

4.2.2 Haptic

Effectiveness:

- Haptic warnings have been found to be effective in alerting drivers quickly (Ho, Spence, and Tan, 2005; Zador, Krawchuck, and Voas, 2000). Evidence suggests that drivers can respond faster to haptic (vibrotactile) warnings than visual or auditory warning signals. (Ho, Spence, and Tan, 2005; Stanley, 2006). Haptic warnings are more easily detected than visual warnings, assuming that the body is in contact with the tactile feedback. Haptic warnings can be created so they do not disturb the passenger(s) (Ho, Spence, and Tan, 2005; Sayer, Sayer, and Devonshire, 2005). Drivers have reported warnings in the haptic modality were less annoying compared to auditory (Stanley, 2006; LeBlanc et al., 2006) or the auditory-haptic combination (Stanley, 2006). Drivers from Stanley (2006) ultimately preferred the auditory-haptic combination, however, as most preferred to have with roadway departure systems.

Type:

- The most common types of haptic warnings for SCAS , which is similar in driver reaction to RLDWS, are vibration (usually to the seat back, seat pan, or steering wheel) or constant torque (to the steering wheel).
- Drowsy drivers in Kozak, et al. (2006) only recognized steering wheel torque warnings 32% of the time.
- Often, haptic warnings for road departure mimic the sensation of rumble strips. A rumble strip is grooved pavement on a road shoulder or beside a road which, when driven over, causes a strong vibration and noise inside the vehicle. In Kochhar and Tijerina (2006), approximately 55% of participants (n=54) identified a 'rumble strip' vibration in the seat pan as a lane departure warning.

Location:

- The most common locations for haptic warnings for SCAS are located on the steering wheel (as vibration or torque), or seat pan or seat back (as vibration).
- Kochhar and Tijerina (2006) suggest to put the haptic warning in the driver's seat pan to be spatially compatible with the lane departure warnings.
- Kozak, et al. (2006) found steering wheel vibration was an effective lane departure warning for drowsy drivers.
- Haptic warnings, especially when presented through a vehicle control (like the steering wheel), can be interpreted as indicating problems with the vehicle. Shutko (2001) found commercial motor vehicle drivers misinterpreted brake-pulse warnings for a vehicle problem. This can cause the driver confusion and even incorrect responses to haptic warnings. In Suzuki and Jansson (2003), 50% of participants had inappropriate (opposite) reactions to lane departure warnings presented as steering wheel torque.
- Although driving performance with a combined haptic and auditory warning showed promise, Tijerina et al. (1995) concluded that participants might have felt overloaded by the combination of steering wheel vibration (.5 sec, square wave, 10 Hz, 1.5 Nm) or torque (1 sec, triangle wave, 2 Nm) and a complex tone (.5 sec, 2000 Hz) for lateral warnings.
- Some evidence has shown the combination of haptic and auditory warnings is effective for brake responses (Brown, 2005).
- Directional haptic warnings, which distinguish the source of the warning between right and left, were found to be slightly preferred over non-directional haptic warnings in Pomerleau et al. (1999).

4.2.3 Auditory

Effectiveness:

- Auditory warnings (tone and voice) provide faster response times (Delphi-Delco Electronic Systems, 2000) and are superior at attracting attention (Campbell et al., 1996) when compared to visual warnings for SCAS.
- Auditory warnings are perceived to be more annoying compared to visual and haptic warnings. (Delphi-Delco Electronic Systems, 2000)

- Drivers from LeBlanc et al. (2006) felt earcon auditory warnings for lane departure systems to be more distracting than visual or haptic warnings.
- As stated previously, Tijerina et al. (1995) concluded that participants might have felt overloaded by the combination of a complex tone (.5 sec, 2000 Hz) and either a steering wheel vibration (.5 sec, square wave, 10 Hz, 1.5 Nm) or torque (1 sec, triangle wave, 2 Nm) for lateral warnings.
- Auditory warnings combined with visual warnings enhance performance and reduce time to respond to information (Selcon, Taylor, and Shadrake, 1992).

Type:

- Types of auditory warnings for SCAS include tonal, voice/speech, and earcons (sometimes called auditory icon).
- Auditory icons (earcons) have been found to be more effective than tone (Belz et al., 1999) or speech (Graham 1999). Graham (1999), however, found auditory icons of a car horn and of skidding tires more likely to be misinterpreted for brake responses. Harder et al. (2003) recommend a double-beep auditory icon for side-collision warnings, because participants felt the double-beep was more urgent than a single-beep earcon.

Location

- Auditory warnings should be directional to indicate whether the lane deviation is on the left or right, to improve driver response time (Suetomi and Niibe, 2002). Directional auditory warnings were also found to be slightly preferred over non-directional warnings by drivers (Pomerleau et al., 1999).

4.2.4 Auditory + Haptic

Effectiveness:

- Stanley (2006) found that participants reacted slower to the combination of auditory + haptic (rumble strip sound + seat vibration) compared to haptic alone, although they ultimately preferred the combination of auditory + haptic over separate modalities for roadway departure warning systems.
- As stated previously, Tijerina et al. (1995) concluded that participants might have felt overloaded by the combination of steering wheel vibration (.5 sec, square wave, 10 Hz, 1.5 Nm) or torque (1 sec, triangle wave, 2 Nm) and a complex tone (.5 sec, 2000 Hz) for lateral warnings.

4.2.5 Auditory + Visual

Effectiveness:

- As stated previously, the draft international standard for Lane Departure Warning Systems (LDWS) requires that LDWS present haptic and/or auditory warnings, and that visual warnings are secondary sources of information only.
- Auditory warnings combined with visual warnings enhance performance and reduce time to respond to information (Selcon, Taylor, and Shadrake, 1992; Belz et al., 1999).
- Participants in LeBlanc et al. (2006) found they tended to rely on auditory and haptic cues to interpret warnings, and used the visual display as a confirmation only.

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Effectiveness:

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