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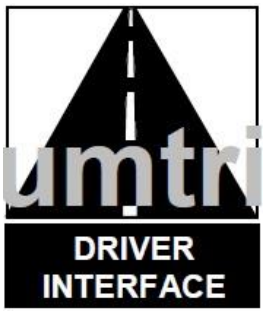
SAE and ISO Standards for Warnings and Other Driver Interface Elements: A Summary

Heejin Jeong and Paul Green



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16. Abstract

This document summarizes 8 SAE documents (4 information reports, 3 recommended practices, and 1 standard), 8 ISO documents (5 standards, 2 technical specifications, and 1 technical report), and 3 NCAP documents. Standards and Recommended Practices describe what must ("shall") and should be. Information Reports generally provide useful information and guidance without requirements or recommendations.

The SAE documents include J2395 (message priority), J2396 (definitions and measures for visual behavior), J2399 (ACC characteristics and user interface), J2400 (FCW operating characteristics and user interface), J2802 (blind spot system operating characteristics and user interface), J2808 (Road/LDW system user interface), J2830 (icon comprehension test), J2831 (recommendations for alphanumeric text messages).

The ISO documents include PDTR 12204 (integration of safety warning signals to avoid conflicts), 15005 (dialog management principles and compliance procedures), CD 15006 (specification for auditory information), 15008 (specification and tests for visual information), 16951 (procedure to determine message priority), 17287 (procedure to assess suitability for use while driving), DTS 15007 (measurement of driver visual behavior).

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SAE and ISO Standards for Warnings and Other Driver Interface Elements: A Summary

UMTRI Technical Report 2013-16, February 2013

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1 Questions

1. What are the SAE and ISO design standards relevant to the design of in-vehicle warnings?
2. What are their requirements?

2 Methods

Search: the web site of the SAE Safety and Human Factors Steering Committee and ISO TC 22/SC 13/WG 8 (Road Vehicle Ergonomics: Transport Information and Control Systems)

Summarize: maintaining the numbering of the original document to aid in retrieving information and speed of the production of the report

1. scope- keeping quoted passages under 50 words to avoid copyright infringement
2. definitions- not repeating, but all terms defined in the original documents are listed
3. requirements/recommendations- attempting to distinguish between ‘shall’ and ‘should’

3 Results

1. What are the SAE and ISO design standards relevant to the design of in-vehicle warnings?

16 documents reviewed (8 SAE and 8 ISO documents)

	Document #	Partial Title
SAE document	Recommended Practice J2395	ITS In-Vehicle Message Priority
	Recommended Practice J2396	Definitions & Measures for Visual Behavior
	Standard J2399	ACC Characteristics & User Interface

	Information Report J2400	FCW Human Factors: Operating Characteristics & User Interface Requirements
	Recommended Practice J2802	Blind Spot Monitoring System: Operating Characteristics & User Interface
	Information Report J2808	Road/LDW Systems: Human Interface
	Information Report J2830	Process for Testing Icon Comprehension
	Information Report J2831	Recommendations for In-Vehicle Alphanumeric Text Messages
ISO Document	PD Technical Report 12204	Integration of safety critical warning signals to avoid conflicts
	Standard 15005	Dialogue management principles & compliance procedures
	CD Standard 15006	Specifications for in-vehicle auditory information
	CD Standard 15007-1	Measurement of driver visual behavior - Part 1: Definitions and parameters
	DTS (Draft Technical Specification) 15007-2	Measurement of driver visual behavior - Part 2: Equipment & procedure
	Standard 15008	Specifications & tests for in-vehicle visual information
	Technical Specification 16951	Procedure: determine message priority
	Standard 17287	Procedure: assess suitability for use while driving

2. What are their requirements?

Most of documents provide requirements and recommendations clearly, but several documents involve only the descriptions, not requirements/ recommendations.

	Document #	**Contents and Key Requirements/ Recommendations**
SAE document	Recommended Practice J2395 (Message Priority)	- shall consist of at least 3 people from a range of disciplines and stakeholder communities - shall determine safety relevance (direct, indirect/somewhat, not relevant), operational relevance (high, moderate, little or none), and time frame levels (emergency, immediate, near term, preparatory, discretionary)
	Recommended Practice J2396 (Visual Measures)	(1) terms such as fixation, glance, saccade (2) independent variables - target factors: shall have separation angle of ≥ 20 degrees - driver factors: shall be characterized (e.g. age, gender, license, visual acuity) - experimental conditions : shall specify road (e.g. type of highway, # and width of lanes) : shall specify vehicle (e.g. size, type of transmission)
	Standard J2399	- should set minimum speed 25 mph

	(ACC)	- shall be minimum steady-state following time gap ≥ 1.0 s - shall be time gap ≥ 1.5 s - should illuminate stop lamps for a ≥ 0.5 s - should be min. available time gap ≥ 1.0 s - should be max. available time gap test ≥ 1.5 s - shall activate auditory, visual, and/or haptic alert whenever transition from ACC engaged to manual control
	Information Report J2400 (FCW)	- should be default warning intensity 75 dBA - shall locate visual display within a 10-degree cone of the driver's line of sight - should be min. zone width of the vehicle, max. zone 3.6 meters for alert zone - must satisfy ≥ 5 of 7 trials for passing the entire test protocol
	Recommended Practice J2802 (Blind Spot)	- should be in a forward gear at a min. speed of 37.3 mph - should be capable of achieving at least 6,000 cd/m^2 (luminance) - should be min. subtended visual angle: for the symbol is 24 arcmins, for a point source (e.g. LED) is 13 arcmins - should illuminate the ISO symbol or point source in amber not red
	Information Report J2808 (LDW)	- should use ISO symbol for visual modality - should be different failure modes/malfunctions than the indication for no road/lane boundaries tracked - shall be speed threshold ≥ 44.74 mph - operating in reverse is not required
	Information Report J2830 (Icon Test)	(1) candidate icons shall be - pre-testable, having a message and general function, context descriptions given to subjects during testing, 10 - 20 icons should be included (2) test subjects should be - total # 30 - 40, having license, approximately equal mix (age, gender) (3) analyze the data for subject response to the icons with 1-9 scales
	Information Report J2831 (Text Format)	- should limit navigation instruction to 3 - 4 information units - should abbreviate words of 5 - 8 letters, using the key consonant and ≥ 8 letters, using first syllable strategy - should span a min. visual angle of 0.5 degrees for title and other key elements in a message - should be all lines and gaps between lines ≥ 0.05 degrees wide - should limit the # of state change alerts to 3 - 4
ISO Document	PD Technical Report 12204 (Warning Integration)	*Note: for information only* (1) classification of warning signals - 3 levels of criticality (injury and damage, damage, non-safety) - 3 time frames for urgency (immediately, within a few seconds, preparation) - 2 durations of signal (continuous, discrete)

		- 3 directions of hazard (front, side, rear of vehicle) (2) warning signals - share the same sensory - are in close spatial proximity - have the same signal characteristics - occur simultaneously or in close temporal proximity
	Standard 15005 (Dialog Management)	- shall not require removal of both hands from the steering wheel while driving - shall not require the continuous visual attention of the driver providing it with input - shall be consistent with mode, location, orientation and dialog management - shall be able to control the flow of information displayed by TICS
	CD Standard 15006 (Auditory Information)	- should be frequency range of spectrum 200 - 8,000 Hz - should be non-speech coding have 2 functions, attracting attention and providing information - temporal classification: short (0 - 10 s), medium (10 - 20 s), long (> 20s)
	CD Standard 15007-1 (Visual Definitions)	(1) terms such as fixation, glance, saccade (2) should report following parameters and measurements for consistent recording of comparable data - parameters (total glance time, mean glance duration, max. glance duration) - measurements (range, 10^{th}, 85^{th} and 90^{th} percentiles)
	DTS (Draft Technical Specification) 15007-2 (Visual Measurement)	*Note: for information only* (1) subject parameter (age, sex, distance, years of driving, visual legal compliance, visual ability) (2) interpretation of glance metrics (# of glances, total glance time, glance rate, percentage of transition times)
	Standard 15008 (Visual Information)	- shall illumination range ≤ 10 lx (night), = 250 lx (twilight), = 5 klx (day with diffuse ambient light), = 45 klx (direct sunlight) - shall be min. contrast ratio 5:1 (night), 3:1 (twilight, day), 2:1 (direct sunlight) - shall continue at least 4 s for observation of image instability - for alphanumerical character : should ≥ 20 arc minutes for height : should be 0.6 - 0.8 for width by height ratio : shall be 0.08 - 0.2 for stroke width by height ratio
	Technical Specification 16951 (Message Priority)	*Note: for information only* procedure to determine priority index 1: select examiner 2: identify and assemble messages 3: define driving context and situation 4: select the evaluators (at least 5 per a examiner) 5: evaluate criticality (4 levels) and urgency (3 levels) of a message

		6: develop instructions for the examiner 7: utilize alternative method for determining message priority
	Standard 17287 (Suitability)	*Note: such as a high-level of ISO 9000 process* - procedure for assessment 1: define of assessment plan 2: select TICS representation 3: define assessment context 4: definite assessment criteria 5: select assessment method 6: perform assessment and analyze data 7: interpret results - shall define intended use of TICS and the context of use - should include following for TICS identification: product name and version, build status, documentations - shall describe steps taken to prevent reasonably foreseeable misuse for improper use and misuse - should identify TICS failures

TABLE OF CONTENTS

INTRODUCTION

Designing motor vehicles that are safe and easy to use is important. To do that, designers and engineers need information that serves as the basis for design. That information is available in a variety of forms—books, journal articles, proceedings papers, technical reports, and most importantly design guidelines and standards. (See Green, 2001a,b; Green, 2002; Green, 2008a,b. Green, 2011; Green, 2012 for previous summaries.)

Standards concerning interface design fall into several categories. The first are the "big 10," the 10 generic human factors/ergonomic standards that have broad applicability. The include Mil Standard 1472 (U.S. Department of Defense, 2012), AAMI HE 75 (American Association of Medical Instrumentation, 2009), ANSI/AAMI/IEC 62366 (American Association of Medical Instrumentation, 2001), NUREG 0700 (United States Nuclear Regulatory Commission, 2002), ANSI/HFES 100 (American National Standard Institute/Human Factors and Ergonomics Society, 2007) and 200 (American National Standard Institute/Human Factors and Ergonomics Society, 2002), NASA Standard 3001 National Aeronautics and Space Administration, 2009) and NASA SP-2010-3047 (National Aeronautics and Space Administration, 2010), FAA HF-STD -001 (Federal Aviation Administration, 2007). Because of their broad applicability, these standards and guidelines are likely to be cited in product liability actions. For example, because of it is viewed as the human factors bible, Mil Standard 1472 may be cited as relevant, even if the product is for civilian and not military use.

The second category is Society of Automotive Engineers (SAE) Standards. Although SAE is technically a global organization, many of its design requirements are U.S.-centric. SAE documents, all referred to as standards, are of 3 types, (1) standards, (2) recommended practices, and (3) information reports. Admittedly, referring to all SAE documents as standards and having standards as a category within standards is confusing. Standards, as a specific document, contain information describing what must be done, generally indicated by the use of the word shall. Recommended Practices describe what it is recommended to do, with should be the appropriate verb. Information reports are collections of information generally without recommendations. What makes interpreting these documents confusing is any one of these types of documents—standard, recommended practice, or an information report--may use the terms shall and should. Particularly confusing is when the terms should and shall appear in information reports. Further complicating matters is that SAE has no enforcement powers for its documents. However, in a product liability action not complying with recognizing industry standards is very problematic, and not complying with a recommended practice is also problematic, but not as much.

Table 1 lists SAE Standards relevant to warnings.

Table 1. SAE Standards Related to Warnings

SAE Document	Partial Title	Year	# Pages
Recommended Practice J2395	ITS In-Vehicle Message Priority	2002	7
Recommended Practice J2396	Definitions & Measures for Visual Behavior	2000	13
Standard J2399	ACC Characteristics & User Interface	2003	11
Information Report J2400	FCW Human Factors: Operating Characteristics & User Interface Requirements	2003	23
Recommended Practice J2802	Blind Spot Monitoring System: Operating Characteristics & User Interface	2010	10
Information Report J2808	Road/LDW Systems: Human Interface	2007	10
Information Report J2830	Process for Testing Icon Comprehension	2008	14
Information Report J2831	Recommendations for In-Vehicle Alphanumeric Text Messages	2012	41

The International Standards Organization (ISO) produces information reports (which convey information) and standards, which are requirements. However, just as with SAE, ISO has no direct enforcement powers. However, in some countries, to produce or import a vehicle, type compliance is required, which means that a product must comply with are recognized standards, such as those of ISO or it cannot be sold or imported.

Relevant ISO documents are listed in Table 2.

Table 2. ISO Documents Related to Warnings

ISO Document	Partial Title	Year	# Pages
PDTR (Technical Report) 12204	Integration of safety critical warning signals to avoid conflicts	2011	59
Standard 15005	Dialogue management principles & compliance procedures	2002	22
CD (Standard) 15006	Specifications for in-vehicle auditory info	2009	20
CD (Standard) 15007-1	Measurement of driver visual behavior - Part 1: Definitions and parameters	2011	18
DTS (Draft Technical Specification) 15007-2	Measurement of driver visual behavior - Part 2: Equipment & procedure	2011	18

Standard 15008	Specifications & tests for in-vehicle visual info	2009	26
TS (Technical Specification) 16951	Procedure: determine message priority	2004	36
Standard 17287	Procedure: assess suitability for use while driving	2003	36

The U.S. government also produces a variety of regulations and guidance documents, the most notable of which are the Federal Motor Vehicle Safety Standards, with which compliance is required for vehicles sold in the U.S. The only safety standard of relevance to this report is the 101 standard, which primarily deals with basic controls and displays, not the warning systems that are the focus of this report. In addition, the U.S. Department of Transportation has written 3 guidelines for the New Car Assessment Program (NCAP) relating to warning systems for lane departure warning, forward collision warning, and electronic stability control. Europe has a similar program. Instead of requiring compliance, the NCAP program provides incentives for manufacturers to provide safety systems by identifying test procedures for those systems, which if passed, allow manufacturers to identify a safety system on a vehicle window sticker. The NCAP procedures are primary engineering test to verify under what conditions the warnings trigger, not human factors documents that specify the modality or format of warnings.

The NHTSA Visual-Manual guidelines for driver interfaces (U.S. Department of Transportation, 2012) are an important and related set of guidelines. These draft guidelines should be updated soon.

Finally, readers should be aware of a variety of research-based guidelines that recommend how driver interfaces should be designed including the University of Michigan Transportation Research Institute (UMTRI) guidelines (Green, Levison, Paelke, and Serafin, 1993), the HARDIE guidelines (Ross, Midtland, Fuchs, Pauzie, Engert, Duncan, Vaughan, Vernet, Peters, Burnett, and May, 1996), Battelle guidelines (Campbell, Carney, and Kantowitz, 1997), the (Transport Research Laboratory) TRL guidelines (Stevens, Quimby, Board, Kersloot and Burns, 2004), Japan Automobile Manufacturers Association (JAMA) guidelines (2004), and the Alliance of Automobile Manufacturers (AAM) guidelines (Alliance of Automobile Manufacturers, 2006), and the EU Statement of Principles (Commission of the European Communities, 2007).

Finally, in addition to these documents, there a number of standards and guidelines under development related to warnings and driver interfaces. They are shown in Table 3. Of them, SAE J2944 is likely to have surprisingly far reaching effects because compliance with it may be required for submission of papers to conferences and journals. That Recommended Practice defines terms such as gap, headway, lane departure, roadway departure, and other terms that have broad use.

Table 3. Related Standards and Guidelines Under Development

Document	Title
SAE J2889	Vehicle Sound Measurement at Low Speeds
SAE J229/1	Measurement of Minimum Noise Emitted by Road Vehicles
SAE Recommended Practice J2944	Definitions of Driving Performance Measures and Statistics
SAE J2972	Definition of Automotive Hands-Free Operation of a Person-to-Person Voice and/or Data Wireless
SAE J2988	Principles and Guidelines for Voice User Interfaces as a Driver Vehicle Interface
ISO/NP 17488	Road vehicles – Transport information and control systems – Detection-Response Task (DRT) for assessing selective attention in driving

In addition to these standards, ISO 2575, Symbols, is worth noting as it is revised almost every year to include new symbols.

For additional information on automotive standards, see Green chapter in the Driver Distraction book (Young, Lee, and Regan, 2008) and Karwowski (2005) review of standards for Human Factors. Also useful is the 2012 Green webinar on human factors/ergonomics standard on the Human Factors and Ergonomics Society web site (HFES.org). Finally, particular valuable are the ISO TC 22/SC 13/WG 8 web site (http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=46880) and the SAE Safety and Human Factors Committee web site (http://www.sae.org/servlets/works/committeeHome.do?comtID=TEITSSHF).

METHODS

To identify standard relevant to warnings, the web site of the SAE Safety and Human Factors Steering Committee, and ISO Technical Committee 22, Subcommittee 13, Working Group 8 (ISO TC 22/SC 13/WG 8-Road Vehicle Ergonomics: Transport Information and Control Systems) were examined. Table 1 lists the documents on the SAE site and Table 2 lists those relevant to Working Group 8. In addition, selected documents from ISO TC 204 (Intelligent Transport System), in particular, WG 14 (Vehicle/Roadway Warning and Control Systems) was examined as well.

Each document was read and a structured tabular summary was developed for each one, attempting to maintain the numbering of the original document to aid in retrieving information and speed the production of this report. In creating that format, the challenge was to provide enough information so the content of each document was apparent without violating copyrights but keeping quoted passages under 50 words, a rule of thumb that is sometimes used. Thus, the information presented here is intended as a guide to relevant standards and guidelines, not a substitute for having them or reading them.

Typically standards and guidelines include a scope statement, a definitions section, subsequent sections of content, and either near the beginning or at the end, a few references. Because of the need to summarize documents and avoid copyright infringements, many of the nuances and wording of the original documents were not preserved. Definitions were not repeated, but all terms defined in the original documents are listed. To verify requirements and obtain precise definitions, readers are therefore encouraged to retrieve the original documents and read them.

PRIMARY DOCUMENTS OF INTEREST

This section lists the SAE, ISO, US DOT (NCAP) document of interest in that order.

SAE Documents

SAE Recommended Practice J2395: ITS In-Vehicle Message Priority (7 pages)

Note: This document specifies how to compute message priority, information that is needed when multiple warnings are triggered at the same time.

1. Scope

for "… OEM and aftermarket ITS … systems for passenger vehicles and heavy trucks." … describes "the method for prioritizing ITS in-vehicle messages and/or displayed information based on a defined set of criteria. Each criterion has a fixed number of levels that are used to rate/rank a given message or information item to determine its" priority. The priority is used to determine the order in which messages are presented to drivers.

2. Definitions

message priority	information item filter
information item	prioritization criteria
chunk or unit	priority order index (POI)

3. How to determine ITS message priority

Procedure	**Requirements** *(shall)*
select prioritization evaluators	- at least 3 people from a range of disciplines and stakeholder communities - have good understanding of functions and are objective
delineate information items	(e.g., "turn right onto Poplar in 0.1 mile," "toll cost is $1.25")
categorize each information item	(1) requested by driver, (2) continuous visual information always required by driver, (3) presented due to external events
determine the priority order index	1) determine safety relevance (direct, indirect/somewhat, not relevant), operational relevance (high, moderate, little or none), and time frame levels (emergency: 0-3 s, immediate: 3-10 s, near term: 10-20 s, preparatory: 20-120 s, discretionary > 120 s) 2) determine the priority index rank using the

	table provided in the practice (see the practice for details) 3) have evaluators discuss their rankings, 4) compute mean ranks 5) resolve ties 6) add in new information items into an existing rank structure

SAE Recommended Practice J2396: Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques (13 pages)

Note: This is not a warning standard per se, but describes the terms pertaining to eye fixations, which may be collected to assess visual warnings.

1. Scope

"defines key terms" for "analysis of video based driver eye glance behavior." for "real world trials to … simulator studies evaluating TICS." … also for other "assessments of driver visual behavior in the absence of TICS or … systems associated with … (ITS)." … to create "common source of reference for driver visual behavior data."

2. References

3. Definitions

direction of gaze	sample interval (period)
dwell time	separation angle (in-vehicle devices)
fixation	target (target location)
frame	time off road scene
glance duration	transition
glance frequency	transition time
glance location probability	visual display (TICS or ITS device)
link value probability	visual angle
saccade	

4. Measure and analyze eye glance behavior in driving

Key Concepts	**Recommendations** *(should)*
avoid confusing terms used.	need to distinguish between fixations and glances, which can be a series of glances. Fixations are separated by saccades. (see the practice for details.)
group fixations into glances.	- ignore transition times - assign transition times forward to the next target location - assign transition times back to the previous target location - add both transitions to and from a target to that target

5. Develop a glance allocation measure database

Categories	**Requirements** *(shall)*
required measures and statistics	- measure specifications (e.g., number of observations, mean, variance, frequency distribution of the data) - target (e.g., road scene ahead, side mirror, side window, in-vehicle device, instrument panel)
optional statistics	e.g., medians, cumulative distributions
conditions	baseline and test

6. Specification of independent variables

Independent Variables	**Specification** *(uncertain if should or shall)* To avoid problems, only a sample of the specifications are given.
target factors	- target: generally includes road scene, mirrors, in-vehicle displays, controls - TICS or Information display (overall size, character size, color, and contrast) - target calibration exercises
driver factors	- subject characteristics (e.g. driver age, gender, licenses, visual acuity, driving experience) - subject instructions - subject debriefing
experimental conditions	- road (e.g., type of highway, number and width of lanes, speed limits) - traffic (e.g. mean speed and gap) - lighting (e.g., ambient light level, headlight beam pattern at night) - delineation (e.g., lane markings) - vehicle (e.g., size of vehicle, type of transmission, eye distance to the screen)

SAE Standard J2399: Adaptive Cruise Control (ACC) Operating Characteristics and User Interface (11 pages)

Note: ACC is not a warning system per se, but SAE J2399 includes requirement for warnings.

1. Scope

contains … “minimum requirements for ACC system operating characteristics and elements of the user interface.” for “original equipment and aftermarket ACC systems for passenger vehicles (including motorcycles)”, but not “commercial vehicles.” Future revisions … should consider “enhanced versions of ACC and “integration of ACC with Forward Collision Warning (FCW).”

2. References

3. Definitions

adaptive cruise control (ACC)	minimum set speed: v (set_min)
brake	minimum steady-state following time gap: τ (min)
clearance (c)	maximum sensor range: d (max)
conventional cruise control (CCC)	set speed
forward Vehicle	steady state
free-flowing Traffic	subject vehicle
maximum selectable time gap: τ (max)	system state
maximum set and operating speed: v (max)	time gap: (τ)
minimum operating speed for automatic positive acceleration: v (low)	

4. Requirements

4.1 Sensor Capability

Categories	**Requirement** *(shall)*
vehicle types	- all motorized road vehicles including motorcycles
stationary vehicle exemption	- be informed if they are not detectable

4.2 Operational Characteristics

Categories	**Requirement**
minimum set speed	should be 25 mph, ±10%
minimum operating speed for automatic positive acceleration	shall be 20 mph, ±10%
maximum set and operating speeds	should be maximum sensor range divided by current time gap. see ISO 15622 for compliance procedure.
minimum steady-state following	shall be ≥ 1.0 s

time gap	
time gap	shall be ≥ 1.5 s
stop lamps	should illuminate for a minimum 0.5 s

4.3 Operating State Transitions

Categories	**Requirement** *(shall)*
ACC System States	ACC Off, ACC Stand-By, ACC Engaged
ACC disengagement	via service brake, accelerator, clutch

4.4 Displays

Categories	**Requirement/Recommendations**
time gap selection indicator	shall be displayed when ACC system is first activated and when a time gap is changed
set speed indicator	shall be displayed when driver activates the ACC system or selects a new set speed (> 5 mph than current speed)
vehicle detected signal	should be provided when ACC system is in engaged state
system malfunction signal / warning	- should remain until ACC system is switched OFF - for using symbols, refer to ISO 2575
CCC and ACC indicators	- for using symbols, refer to ISO 2575
manual control alert	- auditory, visual, and/or haptic alert shall occur whenever transition from ACC engaged to manual control - be replaced by a FCW alert (refer to J2400)

4.5 Performance Evaluation Test Methods

Categories	**Recommendations** *(should)*
minimum available time gap test	minimum steady-state time gap ≥ 1.0 s
maximum available time gap test	functional time gap ≥ 1.5 s

SAE Information Report J2400: Human Factors in Forward Collision Warning Systems: Operating Characteristics and User Interface Requirements (23 pages)

Note: This specifies how and when FCWs are presented.

1. Scope

"describes elements for a FCW operator interface, as well as requirements and test methods for systems capable of warning drivers of rear-end collisions." …for "original equipment and aftermarket FCW systems for passenger vehicles," but not "heavy trucks". … "could be inappropriate for an ACC system integrated with a FCW system."

2. References

3. Definitions

forward collision warning (FCW) systems	kinematic situation
active mode	lead vehicle (LV)
actual deceleration parameter (ADP)	non-functioning
alert zone	required deceleration parameter (RDP)
actual acceleration of the LV	standby mode
actual acceleration of the SV	subject vehicle (SV)
brake system lag	telltale visual display
time gap	total delay time (DT)
host vehicle	actual speed of the SV: V (SV)
imminent collision warning	actual speed of the LV: V (LV)

4. Operating Characteristics

4.1 Systems and Information Display Characteristics

Categories	Requirements/Recommendations
application of power	shall be applied to FCW system at engine start-up
activation for use	should be automatically shifted from standby mode to the active mode for hazard detection
minimum operating speed	should be no greater than 40 kph
maximum operating speed	should be no upper speed limit
non-functioning or system limitation indication	brief tone should accompany the onset of the failure or system limitation
built-in diagnostic testing	shall be performed automatically each time the ignition switch is turned on
automatic termination of warnings	should terminate the warning automatically if the problem no longer exists or driver responds
auditory displays	shall be distinctive, non-speech acoustic

	warning
default warning intensity	should initially be 75 dBA
onset and offset rates	should be greater than 1 dB/msec but less than 10 dB/msec
warning duration	should terminate the warning automatically when the triggering condition no longer exists
interruption of other auditory displays	should automatically interrupt or decrease the volume of other inputs
visual, auditory, and haptic warnings	shall not be used for stand-alone imminent collision warnings
visual display	shall be located within a 10-degree cone of the drive's line of sight
manual adjustment of visual display intensity	- should not be adjust if display is a telltale - should be restricted if not a telltale
characteristics of the visual crash icon	- should be red for collision warning - should be ISO symbol or alternative given in document - should be black on red

4.2 Requirements for the Occurrence of Crash Alerts

Categories	**Requirement/ Recommendations**
geometric characteristics of the alert zone	minimum width shall be width of the vehicle (see the document for additional details.)
longitudinal conditions for alerts	- only final stage of multiple-stage alert or single-stage (imminent) warning considered - a crash alert timing for too early, recommended and too late are given (see document for details)
computing alert timing requirements (6 steps)	1: consider the kinematic conditions which helps these steps are applicable 2: project the vehicle speeds from current values to the end of a delay time 3: evaluate the driver acceleration response (that is assumed to occur after the delay time) 4: compute the minimum range at which an alert would be needed 5: determine the maximum range at which an alert is required (e.g. 70 meters for a stopped target vehicle, 90 meters for a moving target vehicle) 6: if the distance to the lead vehicle is < 5 meters, driver alert is not required
environment around the alert zone	- shall function in all weather conditions or warn the driver if its operation is limited - shall operate during day, night, sunrise, sunset conditions or warn the driver if its operation is reduced - shall generate alerts when the SV is in danger of imminent

	collision with the rear-end of a licensable motor vehicle

5. Performance Evaluation Test Methods

5.1 Testing Criteria and Assumptions

Categories	Requirements/ Recommendations
pass/fail criteria	1) timeliness of crash alerts, 2) acceptable frequency of in-path nuisance alerts, 3) acceptable frequency of out-of-path nuisance alerts
crash alert timeliness	- should not occur later than described by the crash alert timing recommendation of 3.2 - shall pass 5 of 7 test trials for each crash alert test
in-path nuisance alerts	- shall meet the criteria for at least 5 of 7 crash alert tests for each crash alert test
out-of path nuisance alerts	- triggered by objects or vehicles outside the alert zone - should not exceed a threshold

5.2 Test Procedure Descriptions

#	Condition	Parameters
1	SV at 100 kph approaches stopped vehicle	- range at alert onset for nominal conditions : too early-144 m (472 ft), recommended-135 m (442 ft), too late- 69 m (229 ft) - alert window duration: 2.7 s
2	SV 70 kph behind a 70 kph principal other LV that changes lanes to reveal a stopped vehicle	- range at alert onset for nominal conditions : too early- 91 m (298 ft), recommended- 84 m (276 ft), too late- 69 m (229 ft) - alert window duration: 1.07 s
3	SV (nominally at 60 kph) approaches 10 kph vehicle in a curve	5 levels for following parameters - radius of existing curve - required SV speed - range at alert onset for nominal conditions (too early, recommended, too late) - alert window duration
4	SV at 100 kph approaches a motorcycle that is following a truck at 35 kph	- range at alert onset for nominal conditions : too early- 99 m (326 ft), recommended- 93 m (305 ft), too late- 60 m (199 ft) - alert window duration: 2.13 s
5	SV at 50 kph approaches a 30 kph principal other LV	- range at alert onset for nominal conditions : too early- 21 m (70 ft), recommended- 19 m (64 ft), too late- 12 m (38 ft) - alert window duration: 1.67 s
6	SV tailgating a principal other LV at 100 kph	- range at alert onset for nominal conditions : too early- 16 m (52 ft), recommended- 15 m (50 ft), too late- 12 m (39 ft) - alert window duration: 1.52 s
7	SV at 100 kph principal other	- range at alert onset for nominal conditions

	LV braking moderately hard from same initial speed	: too early- 66 m (216 ft), recommended- 64 m (209 ft), too late- 62 m (203 ft) - alert window duration: 0.63 s
8	SV (nominally at 100 kph) passes principal other LV traveling at 40 kph in adjacent lane in curve	3 levels for following parameters - radius of curve - required SV speed
9	SV at 100 kph passes between trucks travelling at 35 kph in adjacent lanes	- each lane: 3.5 – 3.8 m - 2 trucks travel in the outer lanes at 35 kph
10	SV passes roadside signs along straightaways and curves	3 levels for following parameters - radius of curve - required SV speed
11	SV at 100 kph approaches overpass	- clearance under the reflector: 4.22 m (13 ft) - optical retroreflector o simulate a sign indicating clearance : 0.32 m tall and 0.70 m wide

5.3 Evaluating Test Results

Test	**Requirements to Pass the Entire Test Protocol**
for tests 1-7 FCW system	- shall pass the crash - must satisfy the in-path nuisance alert timing criteria in 5 or more of 7 trials
for tests 8-11	% of exposures to the nuisance is multiplied by a weight - test weight: 0.54 (for test 8), 0.27 (for test 9), 1.00 (for test 10), 0.63 (for test 11)

SAE Recommended Practice J2802: Blind Spot Monitoring System (BSMS): Operating Characteristics and User Interface (10 pages)

Note: This document specifies how and when blind spot warnings are presented/

1. Scope

specifies “minimum recommendations for BSMS operational characteristics and elements of the user interface.” A visual BSMS indicator” is recommended.” … “not intended to replace … interior and exterior rear-view mirrors … applies to “original equipment and aftermarket BSMS systems for passenger vehicles.” only... does not address “Lane Change Warning systems” … (see ISO FDIS 17387).

2. References

3. Definitions

blind spot monitoring system (BSMS)	operational zone
lane change warning system	adjacent blind spot zone (ABSZ)
subject vehicle	visual indicator
symbol	FMVSS 111 viewing triangle
BSMS targets (mandatory, optional, non-target)	

4. Requirements

4.1 Operational characteristics

Categories	Requirements/ Recommendations
operational speed	- shall be in a forward gear at a minimum speed of 60 kph (37.3 mph) - may be operational at lower forward speed
criteria for eliciting a visual indicator	- shall be zone on left/right side (see the figure the original document) - shall give a visual indicator for mandatory targets and may give a visual indicator for optional targets. BSMS should not give visual indicator to non-targets.
deactivation	- shall inform the user of the activation state at start-up, or whenever the state changes - may provide a method to allow permanent deactivation
fault indication	shall notify the driver at the time of fault and at all subsequent vehicle ignition cycles

4.2 Displays

Categories	Requirements/ Recommendations
location	- shall have indicators for the left and right zones - shall be located on or near side view mirror
use of ISO symbols	- should be used as either the visual indicator or as the

	identifier the visual indicator (see ISO/IEC 7000-2796) - should display the symbol on the passenger's side as a reverse image of the driver's side symbol
color	- should illuminate the ISO symbol or point source in amber - shall not be red
luminance	- should provide at least 6,000 cd/m^2 (daytime) - should be dimmable at night to mitigate the potential glare
symbol height (H)	- should be minimum subtended visual angle (VA) : for the symbol is 24 arcmins : for a point source (e.g. LED) is 13 arcmins

SAE Information Report J2808: Road/Lane Departure Warning Systems: Information for the Human Interface (10 pages)

Note: This document specifies how and when road and lane departure warnings are presented.

1. Scope

This report describes the design of an interface for a system that "warns drivers if they are drifting (or have drifted) out of their lane or from the road." …for "OEM and aftermarket R/LDW systems for light-duty vehicles on relatively straight roads with a radius of curvature of 500 m or more..in.. good weather..." … "not designed as a lane-change monitor"

2. References

3. Definitions

road	earliest warning line
road boundary	latest warning line
lane	lane departure warning
lane boundary	road departure warning
departure	system incapable
road departure	status/function indication
lane departure	haptic warning
rate of departure (V)	time critical warning
straight road	road/lane departure warning system
warning condition	

4. Human interface

4.1 Warning levels
- only time for 1 level of warning
- but if cautionary and imminent warning are provided, they might be presented differently

4.2 Warning presentation modality (ISO requires haptic and/or auditory)

Categories	Effectiveness
visual	- can be useful as status indications - for LDW, should be used as a secondary modality only - use ISO symbol
haptic	- effective in alerting derivers quickly - more easily detected than visual warnings.
auditory	- provides faster response time than visual - perceived as more annoying than visual and haptic warnings
auditory + haptic	even though preferred, reaction was slower than haptic alone

auditory + haptic	enhance performance and reduce time to response

4.3 System Status Indication

Categories	Requirements/ Recommendations
enabled vs. disabled status	ISO states it should be indicated to the driver
system incapable - failure modes/malfunctions	should be different than the indication for no road/lane boundaries tracked
- below speed threshold	- indication must be available at all times that the system is deactivated - 'below speed threshold' status should be notified to the driver
- no road/lane boundaries tracked	current LDWS will only track 60-90% of road/lane boundaries when the systems are enabled

4.4 System Behavior

Categories	Requirements
speed threshold	shall be equal to 44.74 mph and faster
reverse speeds	not required to operate in reverse

4.5 System Control Interface
- System deactivation
- Sensitivity adjustment (Time-to-Line- Crossing)
  ISO varies earliest warning line location with rate of departure.

SAE Information Report J2830: Process for Comprehension Testing of In-Vehicle Icons (14 pages)

Note: This document specifies how to test icons (symbols) some of which will be for warnings.

1. Scope

"describes a process" (which is paper and pencil but could be electronic) "for testing the comprehension of" … "ITS active safety symbols or icons (e.g., collision avoidance), or other" ITS functions … "criteria are used to identify … which … perceived meaning matches the intended meaning for a … sample of drivers." …

2. References

3. Process steps

4.1 Step1: Review candidate icons for comprehension testing

Procedure	Description
candidate icons for testing	- recommended that all icons undergo some pre-testing - have well defined message for each icon
notes	- should include 10-20 candidate icons in each comprehension test - will likely reflect many distinct messages

4.2 Step 2: Prepare for comprehension testing

Procedure	Description
prepare test materials	- prepare icons be similar in size, color, resolution to production - place candidate icons on separate sheets of paper, slides, or computer screens - should test some standard icons for comparison - randomize order across subject - separate different candidates for the same message - provide examples to subjects - develop context statements
control for learning effects	counterbalancing order to minimize
schedule subjects	- should be 30-40 total - should be licensed drivers - goal is approximately equal mix of age, gender - should be representative as possible of the larger driving population - typically test in groups of 10-20

4.3 Step 3: Conduct comprehension test

Procedure	Description
provide subjects with instructions and examples	- indicate context of icon use - explain test task
test candidate symbols with a representative group of subjects	subjects write down the action, condition etc., icon represents
conduct appropriateness ranking test (if not done prior to the comprehension test)	subjects rank order the candidate symbols

4.4 Step 4: Analyze comprehension data and summarize results

Procedure	Description
analyze data	have 2 people score responses for each icon and reach consensus
if appropriateness ranking data were collected, analyze these data	calculate mean rankings for each symbol (1-9 scale, see document)
interpret and summarize results	see document for details.

SAE Information Report J2831: Development of design & engineering standards for in-vehicle text messages (41 pages)

Note: This documents describes the format for text messages, some of which will be for warnings.

1. Scope

This … provides recommendations for “alphanumeric messages that are supplied to the vehicle by external (e.g., RDS, satellite radio) or internal (e.g., infotainment system) sources”. … “contained in this report apply to OEM and aftermarket systems.”

2. References

3. In-vehicle information system (IVIS) information sources

Categories	Description
IVIS information sources	- navigation - motorist services (e.g. delivery related information) - augmented signage - safety/warning (e.g. immediate hazard warning, road condition information) - collision avoidance and vehicle control (e.g. forward collision avoidance, backing aid) - comfort, communication , and convenience (e.g. entertainment, communications)
basic driver performance limits	- driver maintains vehicle control with periodic views of the road - when the uncertainty exceeds a threshold, the driver looks at the road
life of a message	nominal state-> state change-> initiate message entry-> read message-> initiate message scroll-> message end (see the figure description on the original document)

4. Design recommendations format

Categories	Description
display-relevant message content	- time urgency: 0-3 s (emergency), 3-10 s (immediate), 10-20 s (near term), 20-120 s (preparatory), >120 s (discretionary) - criticality: low or high - driving context dependency: related or unrelated - message length: ≤ 3 information units (short), 4-6 (medium), ≥ 7 (long) - message structure: structured or unstructured
message format characteristics	- words vs. abbreviations - font - color - message length (usually number of lines)

flow parameters	how it enters the display and subsequently information is presented and/or accessed

5. Recommendations for display-relevant message content

Characteristic	Description	Recommendations
message priority, urgency, and criticality	- time urgency (emergency, immediate, near term, preparatory, discretionary) - criticality (highly, moderately, little or no relevant)	- should precede high-priority information with an alerting tone - need highly time urgency messages to be salient and compelling to attract the driver's attention - need highly critical messages to convey priority and relative importance
message length	- 2 units (e.g. crash ahead) - 4 units (e.g. road construction on interstate 5) - 6 units (e.g. interstate 380 closed for construction between Iowa City and Cedar Rapids) - 8 units (e.g. Road construction next 5 miles. Take highway 6 to Lone Tree, turn left on highway 214)	- minimize what the driver needs to read - should limit navigation instructions to 3 or 4 information units - limit messages presented while the vehicle is moving to 4 units of information
message style	- staccato: message in brief, incomplete sentences - short form: message as short or partial sentences - conversational: message in full sentences, all descriptors and connecting words	- use short form or staccato when retention is important - use signal word at the beginning of the message to help convey message purpose
driving context dependency	- related: linked to driver control - unrelated: no relation to driving context	- use caution in augmenting an auditory display with a redundant visual head-down text display - focus on enhancing driver's understanding and response time - impose standard rules for abbreviating words - generally, words of 5 to 8 letters should be abbreviated using the key consonant strategy and word 9 letters or more should be abbreviated using first syllable

		strategy - street names should not be abbreviated
font	design goal for symbol font is to avoid extensive flourishes and embellishments of the symbols	- character dimensions should comply with ISO 15008 - titles and other key elements in a message should span a minimum visual angle of 0.5 degrees - all lines and gaps between lines should be at least 0.05 degrees wide
color and accentuation	the color combination used to present messages and the methods used to draw the driver's attention to particular content within a message	- use light characters on a dark background - use ISO 15008 color specifications - double-stroke characters can be used to accentuate text
display length	the amount of information presented on the display during a single scrolling	- for short messages, displaying one line of text is proper for reading and comprehension

5. Recommendations for message presentation and flow parameters

Categories	**Description**	**Recommendations**
state change indication and message initiation	- intra-message state change - to alert derivers that additional information is available within a message - inter-message state change - to alert drivers that new information is available	- should use a different method for inter-message state changes than intra-message state changes - use auditory alert when a previously static visual display changes - limit the number of state change alerts to 3 or 4
message entry	how information is introduced on the display	- prefer static display for longer messages - leading messages require a smooth continuous horizontal motion across the screen and if jumped use 5 characters
scrolling strategy	how much information is advanced upon each activation of scrolling	- when a single line of information is presented, the line-by-line and page-by-page scrolling strategies are equivalent

scroll control	how control of scrolling of information is allocated	- keep the user in control, the system should serve the driver, not the other way around - should give user control of message initiation so vehicle stable prior to beginning a message

ISO Documents

ISO/PD Technical Report 12204: Road Vehicles - Ergonomics aspects of transport information and control system - Integration of safety critical and time critical warning signals: Information of avoiding conflicts (59 pages)

Note: This report provides information on designing an interface to deal with multiple warnings being triggered at the same time.

1. Scope

… "integration of … warning signals into existing in-vehicle messages presented to a driver." … 1) … approaches for determining if … vehicle system may "degrade the driver's comprehension of, or response to, safety-critical warning signals from another system(s)", … 2) … methods for "assessing and addressing potential integration conflicts." … not provide "prescriptive guidance in how to design an integrated warning HMI."

2. Definitions

abstract visual signal	safety-critical signal
active safety warning system	scenario
auditory icon	signal
ambient noise	symbol
comprehensibility	telematics
criticality level	time-critical signal
distinguishability	tone
event	urgency level
human machine interface	voice message
priority	warning event
response time	warning signal

3. Symbols and abbreviated terms

ACC (Adaptive cruise control systems)	HMI (Human machine interface)
BSM (Blind spot monitoring)	HUD (Head up display)
CSW (Curve speed warning System)	LCDAS (Lane change decision aid systems)
ERBA (Extended-range backing aid systems)	LCM (Lane change/merging warning systems)
ESC (Electronic stability control)	LDWS (Lane departure warning systems)
FCW (Forward Collision Warning)	LKAS (Lane keeping assistance systems)
FVCWS (Forward vehicle collision warning systems)	MALSO (Maneuvering aids for low speed operation)

4. Warning signals and situations

4.1 Classification of warning signals (4 characteristics)

Characteristics	Description
criticality (3 levels)	- “injury and damage” level to avoid possible severe or fatal injury - “damage” level to avoid a low-speed collision causing vehicle and possibly risk the safety of occupants and pedestrians - non-safety-related signal (e.g. traffic congestion and weather information)
urgency (3 time frames)	- respond immediately (0 - 3 s) - respond within a few seconds (3 -10 s) - response preparation (10 - 120 s) - information only (no direct driver action or decision required)
duration of signal (2)	- continuous (until end of the event) - discrete (independent of the duration of the event itself)
direction of hazard (3)	- front of vehicle - side of vehicle - rear of vehicle

4.2 Hazard perception by drivers (3 levels)

Categories	Description
visible and detected by the driver	situations the driver is easily able to see (e.g. lead vehicle braking)
visible but not detected by the driver	- driver failed to look (e.g. vehicle in adjacent lane) - driver looked but did not see because of cognitive distraction
not readily perceptible to the driver	e.g. losing traction due to hydroplaning or ice, a stopped car on a blind curve

4.3 Vehicle system that signal the driver (4 types)

Systems requiring	Description
both time- and safety-critical response	- active safety vehicle dynamic system (e.g. electronic stability control system) - driver assistance system with warning signal - driver assistance system with warning signal and intervention
time-critical, but not safety-critical response	- vehicle condition information system - navigation system
safety-critical, but not time-critical response	e.g. low tire pressure signal
neither safety-critical, nor time-critical response	e.g. entertainment, communication and other telematics systems

4.4 Possible driver responses (2 types)

Categories	Description
preparation	after directing one’s attention to a certain object/event, drivers prepare

	to respond behaviorally by deciding on an action
responses	- hard braking or acceleration to avoid crash - emergency steering maneuver to avoid crash - terminate of initiated or intended action to avoid crash - retake control (from an autonomous control system)

5. Discussion of integration vs. prioritization

Categories	Description
prioritization	"relative importance of ≥ 2 messages, which determines their ranking in a time sequence or emphasis of presentation" (ISO/TS 16951)
integration	organization of signals into a unified and coherent HMI

6. Distinguishability and Comprehensiblity

Categories	Description
distingushability	≥ 2 warning signals that indicate different events and expect different response should be capable of being separately perceived
comprehensiblity	safety criticality, urgency, driving situation, and hazard direction

7. Warning integration is needed where

Warning signals	Description
share the same sensory mode	- possibility for the driver to become overloaded - the primary task is largely a visual task
are in close spatial proximity	difficult to distinguish which warning signals is indicated
have the same signal characteristics	a difficulty distinguishing between multiple warning signals which indicate hazards (e.g. spoken warnings from FVCWS and BSM)
expectations about frequent vs. infrequent may misled the driver	driver may assume frequently-issued signal is indicated
occur simultaneously or in close temporal proximity	- driver may be confused, startled, or distracted - difficulty making a decision

8. Methods for integrating warning signals

Methods	Description
adjust thresholds	for when a warning signal is issued or discontinued
select modes	compatible with mode's urgency and criticality
enhance distinguishability	- spatial - temporal
modify salience	from other warning signals

ISO Standard 15005: Road vehicles- Ergonomic aspects of transport information and control systems - Dialogue management principles and compliance procedures (22 pages)

Note: These principles and assessment procedures apply to warnings when there is some significant interaction involved, a dialog.

1. Scope

…"presents ergonomic principles for the design of the dialogues that take place between the driver of a road vehicle and the vehicle's transport information and control systems (TICS) while the vehicle is in motion. It also specifies compliance verification conditions. It is not applicable to … TICS failures or malfunctions."

2. References

3. Definitions

primary control	manufacturer
secondary control	primary driving task
control action	prompt
data entry	sensory mode
dialogue	status
dialogue effectiveness	system acknowledgement
dialogue efficiency	system initiated information
dialogue management	system mode
display	task
distraction	transport information and control system (TICS)
driver	timing
dwell time	traffic situation relevant information
function	vehicle in motion
H-point	vehicle not in motion
interface	

4. Application

5. Dialog principles

5.1 & 5.2 Appropriate for use while driving

Principles	Requirements/ Recommendations
compatible with driving	- whenever TICS provides driving control, response to driver operation of these controls shall not be adversely affected - shall not require removal of both hands from the steering wheel while driving - displays and controls shall be designed and positioned such that both the driving task and the TICS function can be accomplished in an unhindered manner

	- functions not intended to be used by the driver while driving shall be inaccessible for, or inoperable by, the driver, or both, when the vehicle is in motion
simple	- should be designed to maximize understanding and facilitate operation - should optimize physical and mental driver effort and minimize distraction
timing fitting its priority	- shall regulate the flow of information into sufficiently short and concise groups that can be easily perceived - shall not require the continuous visual attention of the driver providing it with input - shall respond to or acknowledge driver input in 250 ms - shall be designed to guide the driver in giving a priority to the information displayed - should not limit the amount of time within which the driver has to respond when providing inputs - should maintain visually displayed information for as long as needed

3.2 Appropriate for the TICS task

Principles	**Requirements/ Recommendations**
consistency	- shall be consistent with mode, location, orientation and dialogue management - state changes shall be displayed without driver action, and information about current TICS states shall be displayed either continuously or on request - should be appropriate and consistent with the content and characteristics of the information
controllability	- driver able to terminate a dialogue at any step - able to resume the dialogue at the point of interruption or at the last completed control action - shall be able to control the flow of information displayed by the TICS, except several case - should be designed and positioned to avoid their inadvertent operation - should be able to select the TICS information to be displayed from that available within the TICS

3.3 Appropriate for the driver

Principles	Recommendations
self-descriptiveness	- particular input should be made obvious to the driver - only symbols, signals, tell-tales, graphical elements and terms
conformity with driver expectations	- content and style for inducing the understanding of the driver - consistent, simple vocabulary and syntax
error tolerance	- when incorrect input, should request driver confirmation when there is an apparent deviation - when incorrect inputs, should support drivers in achieving their intended goals - no driver input should cause undefined TICS states or failures

ISO/CD Standard 15006: Road vehicles- Ergonomic aspects of transport information and control systems - Specifications for in-vehicle auditory presentation (20 pages)

Note: These specifications for auditory characteristics apply to warnings.

1. Scope

…"establishes ergonomic specifications for the presentation of auditory information related to transport information and control systems (TICS) through speech or sounds. It applies … when the vehicle is in motion… set of requirements and recommendations for … for maximizing auditory signal intelligibility and utility while helping prevent … overload.

2. References

3. Definitions

ambient auditory noise	safety warning
audibility	signal-to-noise ratio (SNR)
auditory signal	sone
comprehensibility	sound pressure level
distinguishability	specific loudness spectrum
loudness	time-critical signal
main audible component	tonal signal
narrowband spectrum	unit of information
safety criticality	

4. Signal specifications

Categories	Requirements/ Recommendations
spectrum	- recommended frequency range is 200 - 8,000 Hz - tones: the main audible component should be 400 - 2,000 Hz, should avoid pure tones
signal levels	- maximum audibility is main criterion for selecting a sound level - in-vehicle audibility should be as high as possible. 5 - 250 sones to prevent hearing damage, signal-to-noise ratio > 1.3 - appropriate for the warning - time from onset to full loudness: < 30 ms

5. Coding of information

Categories	Description/ Recommendations
temporal classification of auditory signals	short-/medium-/longer- term respond to auditory signals (0 - 10 s/10 - 20 s/> 20s),
non-speech coding (tonal signals)	- should have 2 functions: attracting attention and providing information - number of tonal signals should be limited for comprehensibility and distinguishability - both visual and tonal information should be presented at the same time
speech coding	- should have simple, consistent vocabulary - signal: maximum number of information units should be < 6 and provide key words - should provide redundant visual displays and key words

ISO/CD Standard 15007-1: Road vehicles- Measurement of driver visual behavior with respect to transport information and control system - Part 1: Definitions and parameters (17 pages)

Note: If eye fixation data is used to assess warnings, this standard specifies the measures and statistics to collect and report.

1. Scope

"defines key terms and parameters applied in the analysis of driver visual behaviour focused on glance and glance related measurements." …for.. "real-world trials to laboratory-based driving simulator studies." … "could also apply to more general assessments of driver visual behavior" ... serve as "a common source of reference for driver visual behavior data."

2. References

3. Terms and Definitions

accommodation	fly through (artefactual fixation)
adaptation	sample interval
direction of gaze	area of interest (AOI)
fixation	transition
glance	visual angle
saccade	visual demand
smooth pursuit movement	visual display
"normal" blink	minimum glance duration
"long" blink	

4. Definition of metrics

4.1 Basic measures

duration of diversion	transition time
dwell time	scan duration
glance duration	

4.2 Glance metrics

number of glances	glance location probability
total glance time	percentage of non-driving relevant glances durations
mean glance duration	link value probability
glance rate	time off road-scene-ahead (TORSA)
area of interest attention ratio	percentage of time off road-scene-ahead (PTORSA)
maximum glance duration	percentage of transition times

5. Data collection and analysis sources

Guidance	Source
guidance on the collection and analysis of driver visual behavior data	ISO 15007-2
guidance of how to treat missing data	Annex A of ISO 15007-2
guidance on the categorization and interpretation of experimental data	Annex A of ISO 15007-1
statistical interpretation of data	ISO 2854, ISO 13245

6. Data presentation should include

To enable consistent recording of comparable data, following parameters and measurements should be reported.

Categories	Description
parameters	- condition/task/subtask/sub-subtask duration - total glance time - mean glance duration - maximum glance duration - area of interest attention ratio - glance rate - measurement type
measurements	- range - 10^{th}, 85^{th} and 90^{th} percentiles - percentage of extended duration glances

ISO Draft Technical Specification 15007-2: Road vehicles- Measurement of driver visual behavior with respect to transport information and control system - Part 2: Equipment and procedure (18 pages)

Note: This document, a companion to part 1, describes in a very general manner how to collect eye fixation data, which could be collected for warnings.

1. Scope

provides … "guidelines on equipment and procedures for analyzing driver visual behavior, … to enable assessors of transport information and control systems (TICS)" to "plan evaluation trials, specify (and install) data capture equipment, and validate, analyze, interpret and report visual-behavior metrics … "applicable to both road trials and simulated driving" but not "head-up displays."

2. References

3. Definitions

Given in ISO 15007-1

4. Evaluation and trial planning

Categories	Description
subject selection	- representative sample from the target population for the specific TICS - categorized by age, sex, visual ability, and driving experience
trial procedures	- roadway/traffic specification: - vehicle specification - TICS specification - subject training - data exclusion - experimental conditions, tasks, subtasks, sub-subtasks, and relationship

5. Recording equipment

Categories	Description
eye-tracking equipment	2 different methods - head-mounted eye-tracking systems - remote eye-tracking systems (both are including scene camera, eye camera, infrared LED, CPU, Eye-tracking software)
additional recording equipment	- cameras, video monitors - microphones - event markers - head tracker
installation	generally, the systems and procedures should not obscure the

	driver's view of the roadway and not cause the driver any unnecessary distraction

6. Data reduction

Categories	Description
sample interval	2 regimes - reduction of the entire experimental session - reduction of the forward view and other region-of-interest pairs
summary data	- subject parameter (age, sex, distance, years of driving, visual legal compliance, visual ability, exclusion criterion) - experimental design parameter (experimental conditions, factors, duration of condition, independent/dependent variables, type of road, traffic density) - TICS and control condition parameter (system, tasks, subtasks per task, task and subtask pacing) - visual data classification parameter (number of regions, start/stop of experimental conditions)

7. Data analysis and presentation

Categories	Description
interpretation of glance metrics	- number of glances - total glance time - mean glance duration - glance rate - maximum glance duration - glance location probability - percentage of non-driving relevant glances durations - link value probability - time off road-scene-ahead, percentage of time off road-scene-ahead - percentage of transition times
interpretation of multiple glance metrics	necessary when drawing conclusions about visual behavior and driver workload

ISO Standard 15008: Road vehicles- Ergonomic aspects of transport information and control systems - Specifications and test procedures for in-vehicle visual presentation (26 pages)

Note: These image quality and legibility specifications apply to warnings.

1. Scope

“specifies minimum requirements for the image quality and legibility of displays containing dynamic (changeable) visual information” … while the vehicle is in motion. This … is applicable to mainly “perceptual, and some basic cognitive, components of the visual information, including character legibility and color recognition.” This document does not consider coding, dialog characteristics, HUDS, camera images, or maps.

2. References

3. Definitions

adaptation	flicker
blink	disability glare
brightness	discomfort glare
critical specular line (CSL)	jitter
chromatic	legibility
contrast	map
contrast ratio	night condition
cyclopean eyellipse	pixel
day condition	quasi static information
direct sunlight condition	redundantly presented information
dynamic information	segment
eyellipse	twilight condition

4. Requirements and measurement methods

Generally for test, temperature (18 - 28 °C) and illumination (stable state). Refer to SAE J 1757/1: 2007 for details.

4.1 Design viewing position and illumination range

Categories	Requirements
design viewing position	- contrast shall only be fulfilled in the direction of the critical specular line for direct sunlight conditions - standard default for angles
illumination range	- night: shall not exceed 10 lx (± 5%) - twilight: shall be 250 lx (± 5%) - day with diffuse ambient light: shall be 5 klx (± 5%) - direct sunlight: shall be 45 klx (± 5%)

4.2 Display illumination, minimum contrast, luminance and polarity

Categories	Requirements/ Recommendations
display illumination	should have a brightness control which allows adjustment over a suitable range
minimum contrast ratio	shall be 5:1 (night), 3:1 (twilight, day), 2:1 (direct sunlight)
display mode	- negative display mode (light symbols on a dark background) should be used under the light condition - for non-sheltered displays, positive display mode (dark symbols on a light background) should be used for reducing the visibility of reflections

4.3 Color combinations

Only certain symbol/background color combinations are acceptable. (refer to the table on the original document)

4.4 Alphanumerical character dimensions

Categories	Requirements/ Recommendations
height	Recommended ≥ 20 arc minutes (5.815 radians)
width by height ratio	- should be between 0.6 and 0.8 - wider range of 0.5 -1 may be used when particular factors are important (e.g. line length, proportional spacing)
stroke width by height ratio	shall be between 0.08 and 0.2
spacing	depends on if there exists adjacent parallel lines to the characters

3.5 Pixel matrix character format

Categories	Requirements/ Recommendations
upper and lower case of alphanumeric characters	shall be at least 5 x 7 pixel for alphanumeric characters, 4 x 5 pixel for subscripts and superscripts etc.
automotive symbols	should be minimum 32 x 32 pixel matrix (see ISO 2575)
Chinese and Japanese characters	shall be minimum 16 x 16 pixel matrix

3.6 Reflections and glare – should minimize effect on drivers

3.7 Characteristics of presentation

Categories	Requirements/ Recommendations
image instability	- image should be free from temporal and spatial instability - observation shall continue at least for 4 s
image blinking	- should be used only when attracting attention and informing about critical conditions - should be single frequency of 1 Hz to 5 Hz with a duty cycle of 50%

ISO Technical Specification 16951: Road vehicles- Ergonomic aspects of transport information and control systems - Procedure for determining priority of on-board messages presented to drivers (36 pages)

Note: This report provides information on compute the priority of warnings so that if multiple warnings occur at the same time, they can be presented in priority order.

1. Scope

"provides … two… methods … for determining the priority of on-board messages presented to drivers of road vehicles by TICS and other systems. … applicable to ... navigation, … traffic advisories, … warnings, systems status, … as well as to messages from non-TICS sources such as telephone, warnings and telltales.

2. Definitions

contents of message	message management system
criticality	priority
display	priority index
driving	scenario
evaluator	system-initiated message
examiner	transport information and control system (TICS)
*K*c (weighing of criticality)	urgency
*K*u (weighing of urgency)	

3. Procedure to determine priority index

Procedure	Description
1. select examiner	shall be familiar with the prioritization process, knowledgeable on message management, automotive experience to coordinate the data preparation, analysis, and reporting
2. identify and assemble messages	shall 1) collect the messages which generally represent the aggregate output by the TICS and non-TICS and 2) prepare them for presentation to the evaluators
3. define driving context and situation	- consider the sensing capability of the vehicle - consider in developing the driving scenarios (e.g. trip context, road environment, traffic situation, vehicle condition) - document the driving context and situation
4. select the evaluators	- select a minimum of 5 evaluators per a examiner - experienced human factors and road safety practitioners
5. evaluate criticality and urgency of a message	- shall ensure that evaluators understand the concept of criticality and urgency - 4 criticality rating scales (no injury including no vehicle damage, no injury including vehicle damaged, injury or possible injury, severe or fatal injury) - 3 urgency rating scales (information only, response preparation, respond within a few seconds, respond

	immediately)
6. develop instructions for the examiner	record information about each evaluator, create the questionnaire, explain the evaluation items and contents of the message in the questionnaire etc
7. utilize alternative method for determining message priority	*priority matrix method* which determines priority subjectively by having subject matter experts make pair-wise comparisons of all messages (see Annex A on the original document)

4. Compute the priority index (weighted mean value of criticality and urgency ratings) See the original document for details.

5. Application of results

Categories	**Description**
prioritization of priority ranking	- designers should use the priority rankings, particularly for auditory messages, to avoid the simultaneous messages. - if the standard deviation of one message is extremely larger than other messages, take steps to avoid overlap.
how to deal with additional messages	replacement evaluators should be selected from a similar discipline as previous evaluators
documentation	- evaluators' profiles - list of messages with driving situations and consequences if a message is ignored - priority index of each message

ISO Standard 17287: Road vehicles- Ergonomic aspects of transport information and control systems - Procedure for assessing suitability for use while driving (36 pages)

Note: In many ways one could think of this document as a high-level ISO 9000-like process to develop a usable and easy to use driver interface. It is unknown how many manufacturers and suppliers actually follow this process.

1. Scope

… "specifies … procedure for assessing whether specific TICS (transport information and control systems), or a combination of TICS with other in-vehicle systems are suitable for use by drivers while driving" (including improper use and foreseeable misuse). "It addresses … context of use, task description and analysis, the assessment process, and documentation."… but does not recommend specific assessment variables or acceptance criteria.

2. References

3. Definitions

suitability	intended use
interference	manufacturer
controllability	method
efficiency	misuse
learning	mode
assessment	performance
behavioral adaptation	primary driving task
context of use	satisfaction
criterion	task analysis
workload	technique
environment	transport information and control systems (TICS)
failure	tool
failure modes and effects analysis	usability
HMI component	variable
improper use	

4. Requirements and recommendations

4.1 User-oriented TICS description and context of use

Categories	Requirements/ Recommendations
introduction	shall define intended use of the TICS and the context of use
general description	should include following elements: - market (for which product is intended) - general function performed by the system - technical context (including comparisons with existing systems) - benefits (3 levels of driving task- navigating, maneuvering, and handling)
TICS Identification	should include following elements: - product name and version (a one line description) - manufacturer (name, address, contact points) - subsystems (including HMI components) - build status (the state of development) - documentation (including the suitability assessment)
context and restrictions for intended TICS use	should consider following elements: - vehicle, driver, road, traffic - other environment and infrastructure
improper use and misuse	shall describe steps taken to prevent reasonably foreseeable *misuse* (e.g. using an ACC system as a collision warning system, using a large-scale map as a driving aid in fog)
failures	- should be identification of TICS failures - the way in which the failure will be apparent to the driver shall be described - the consequences of failure on TICS operation should be considered

4.2 Task description and analysis

Task	Description
first level tasks	significant system task (e.g. route guidance destination entry)
second level tasks	- individual sub-tasks for completing the first level task - decomposition to further levels can be undertaken as required for the assessment
typical task frequency	frequency with which the sub-task is carried out (e.g. once per journey or every maneuver)
task priority (and time pacing)	- qualitative description of the importance of the second level task for safety - time interval should be estimated
exceptional environments or scenarios	space for comments (e.g. where 2 maneuvers are required in close succession)

4.3 TICS Assessment

Categories	Description
when to assess	at various stages of the product design life-cycle (specification, development, prototype, manufacture, deployment)
aspects to be assessed	interference with the driving task, controllability, efficiency, and ease of use while learning (e.g. driver's workload, driver's performance of driving task)
assessment process	1: define of assessment plan 2: select TICS representation 3: define assessment context 4: definite assessment criteria 5: select assessment method 6: perform assessment and analyze data 7: interpret results

US DOT (NCAP) Documents

For additional information, see the U.S. NCAP site, http://www.globalncap.org/NCAPProgrammes/Pages/USNCAP.aspx. Most recent versions of the NCAP test procedures can be obtained from regulation.gov by entering the docket number (2006-26555) and filtering the search for "rule only."

NHTSA-2006-26555-0133: Laboratory Test Procedure for the New Car Assessment Program Electronic Stability Control System Testing and FMVSS No. 126, Electronic Stability Control Systems Indicative Test for Compliance (80 pages)

Note: The primary human interface requirements for ESC is that malfunction and off telltales be provided.

1.0 Purpose and Application and General NCAP and FMVSS No. 126 Requirements

"This document … is applicable to passenger cars, multipurpose passenger vehicles, trucks and buses with a gross vehicle weight rating of 4,536 kilograms or less…. Vehicles to which this standard applies must be equipped with an ESC system that is capable of applying brake torques individually to all four wheels …, is operational during all phases of …, except when the driver has disabled ESC, the vehicle speed is below 20 km/h (12.4 mph), the vehicle is being driven in reverse or during system initialization, ..." The document also provides requirements for maximum acceptable yaw rate.

13.2 ESC MALFUNCTION AND "ESC OFF" TELLTALES --- LOCATION, LABELING AND BULB CHECK (Data Sheet 3)

"verify that it" (the ESC tell tale) "is mounted inside the occupant compartment in front of and in clear view of the driver. …."

And "the malfunction telltale symbol or abbreviation is as specified in FMVSS No. 101." …verify that it "(ESC OFF") "is mounted inside the occupant compartment in front of and in clear view of the driver." and "the ESC Off telltale symbol or abbreviation is as specified in FMVSS No. 101 and that they work properly.

13.8 Slowly Increasing Steer (SIS) Maneuve13.8 SLOWLY INCREASING STEER (SIS) MANEUVER (Data Sheet 7)

> "The SIS maneuver is used to characterize the lateral dynamics of each vehicle. The maneuver is used to provide the data necessary for determining the steering wheel angle capable of producing a lateral acceleration of 0.3 g. This steering wheel angle is then used to determine the magnitude of steering required during the sine with dwell maneuver executed in section 13.9."
>
> Steer left "and measure the lateral acceleration at the 30 degree steering wheel angle." Drive "in a straight line at 80 + 2 km/h (50 + 1 mph)" and … "activate the

steering controller. …"The 30 degree steering wheel angle must be held constant for two seconds "…. The steering wheel is then returned to zero degrees". …"Measure the lateral acceleration at the 30 degree steering wheel angle."

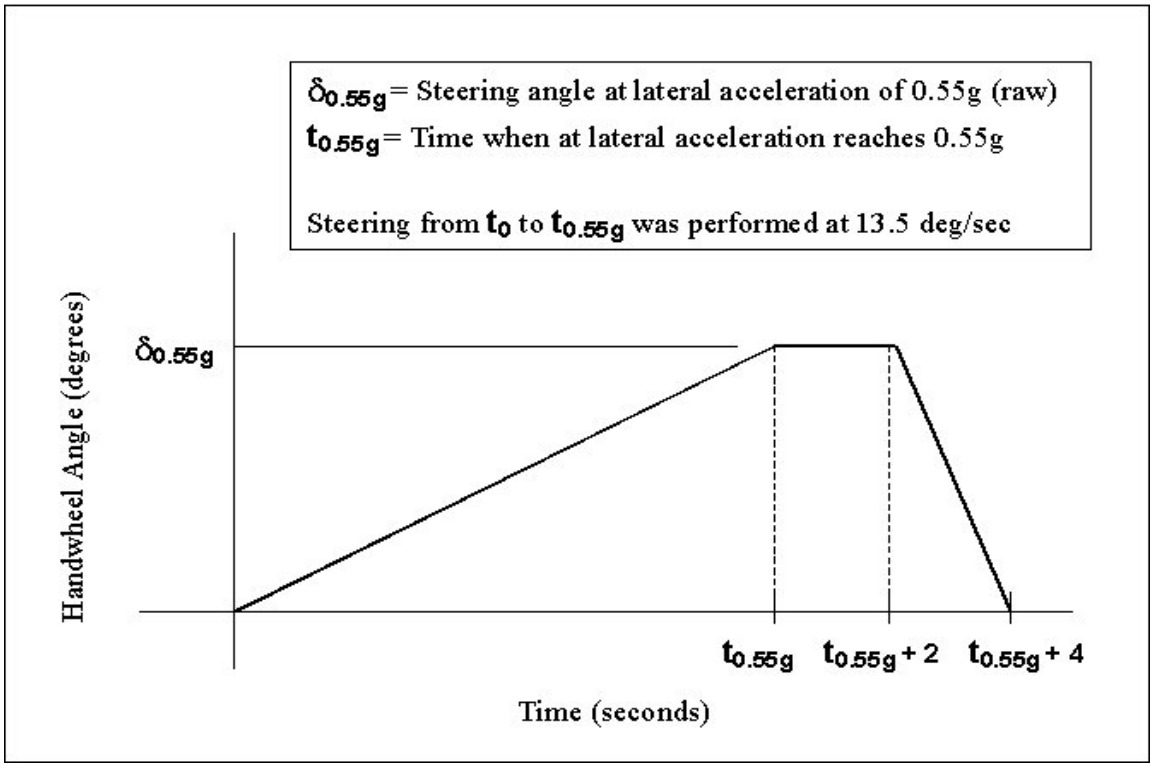
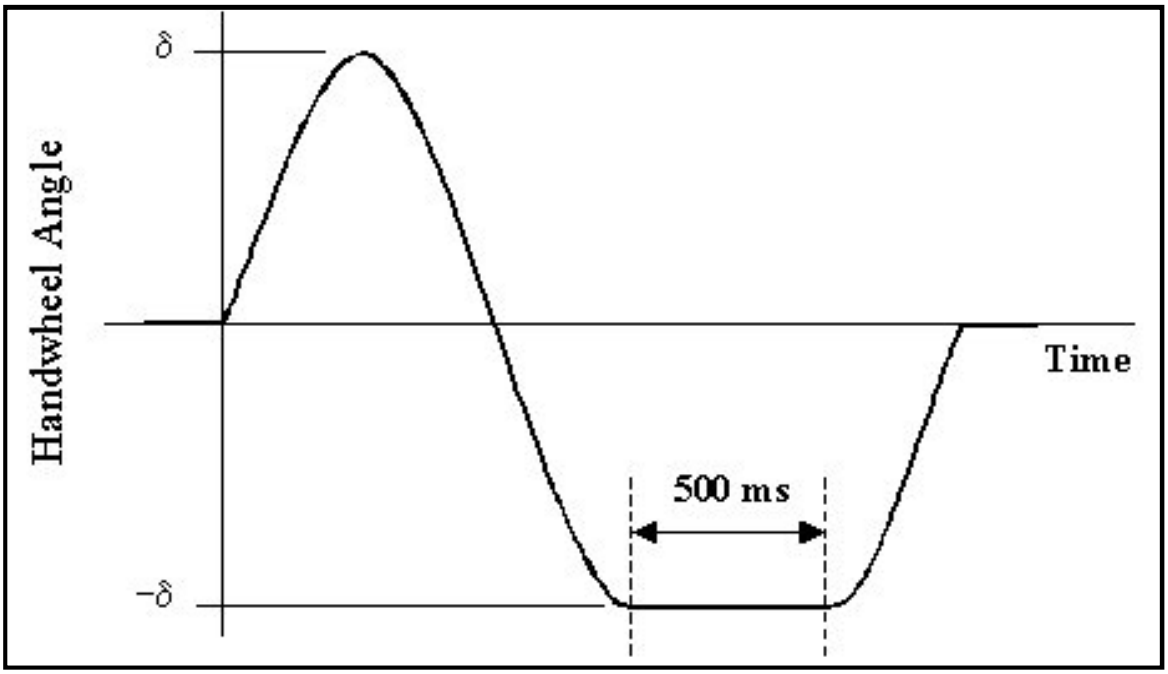


Figure 1. Slowly Increasing Steer steering profile.

13.9 VEHICLE LATERAL STABILITY AND RESPONSIVENESS (SINE WITH DWELL MANEUVER)



“The vehicle is subjected to two series of test runs using a steering pattern of a sine wave at 0.7 Hz frequency with a 500ms delay beginning at the second peak amplitude as shown in Figure 3 (the sine with dwell test). During the test runs, one series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle. …”

NHTSA-2006-26555-0134: Forward Collision Warning System Confirmation Test
(40 pages)

Note: This document describes a process for assuring the proper functioning of an FCW system. Basically, the human interface requirement is that a warning of some type be provided, when the TTC is 2.0 to 2.4 s depending on the condition.

1 & 2 Purpose and General Requirements

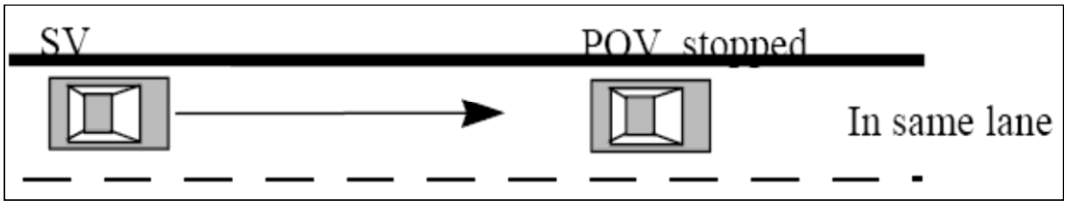
"This laboratory test procedure provides specifications for conducting tests to confirm the existence of a Forward Collision Warning (FCW) system on a passenger vehicle with a gross vehicle weighting rating (GVWR) of under 10,000 pounds … This test evaluations the ability of a forward collision warning system to detect and alert drivers of potential hazards in the path of the vehicle. Three driving scenarios are utilized to assess this technology. In the first test, a subject vehicle (SV) approaches a stopped principle other vehicle (POV) in the same lane of travel. A second test begins with the SV initially following the POV at the same constant speed. After a short while, the POV stops suddenly. The third test consists of the SV traveling at a constant speed, approaching a slower moving POV, which is also being driven at a constant speed."

10 Definitions

FCW systems provide an audible, visual, or haptic warning, or any combination thereof, to alert the driver of an FCW-equipped vehicle of a potential collision with another vehicle or vehicles in the anticipated forward pathway of the vehicle. FCW may be provided in combination with adaptive cruise control (ACC); however use of any form of ACC automatic vehicle control is not permitted during the following tests. Non-adaptive cruise control shall not be permitted during the following tests. The driver shall modulate the throttle.

12.0 Test Execution and Test Requirements

Test 1 – Subject Vehicle Encounters Stopped Principal Other Vehicle on a Straight Road



12. Test Execution and Test Requirements

12.2.1 Test 1 Alert Criteria

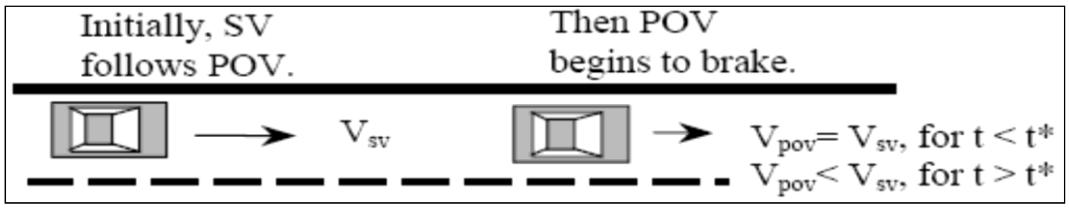
The FCW alert shall be issued when the time-to-collision (TTC) is at least 2.1 seconds.

The TTC for this test shall be calculated by considering the speeds of the SV and the lead vehicle (POV) at the time of the FCW alert (i.e., when the SV and POV speeds are nominally equal to 45 mph and 0.0 mph) (72 and 0 km/h), respectively).

12.2.2 Test 1 Procedures – see the document

12.3 Test 2 – Subject Vehicle Encounters Decelerating Principal Other Vehicle

The SV in this test initially follows the POV at a constant time gap, and then the POV suddenly decelerates. The test evaluates the ability of the FCW to recognize a decelerating lead vehicle and to issue an alert to SV driver in a timely manner.



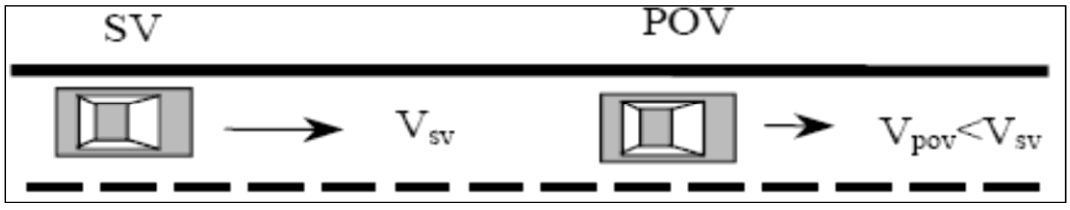
12.3.1 Test 2 Alert Criteria

The FCW alert shall be issued when the time-to-collision (TTC) is at least 2.4 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, shall be calculated by considering several factors at the time of the FCW alert: (1) the speed of the SV, (2) the speed of the POV, (3) the deceleration of the POV1, and (4) the relative position between the SV and POV.

12.3.2 Test 2 Procedures – see the document

12.4 Test 3 – Subject Vehicle (SV) Encounters Slower Principal Other Vehicle (POV)

This test examines the ability of the FCW system to recognize a slower lead vehicle being driven with a constant speed and issue a timely alert. The scenario should be conducted with a closing speed equal to 25 mph (40 km/h).



12.4.1 Test 3 Alert Criteria

The FCW alert shall be issued when the time-to-collision (TTC) is at least 2.0 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, shall be calculated by considering the speeds of the SV and POV at the time of

the FCW alert.

12.4.2 Test 3 Procedures – see the document

NHTSA-2006-26555-0135: Lane Departure Warning System Confirmation Test and Lane Keeping Support Performance Documentation (39 pages)

Note: This document describes a process for assuring the proper functioning of an LDW system. Basically, the human interface requirement is that a warning of some type be provided. The document also provides for collecting data on LKS (lane keeping support) systems.

1.0 and 2.0 Purpose and Application and General Requirements

"This laboratory test procedure provides the specifications for confirming the existence of Lane Departure Warning (LDW) hardware on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000. … In addition to being equipped with LDW systems to passively alert the driver of impeding lane departures, some vehicles are equipped with technology designed to actively mitigate lane departures. In this document, these systems are referred to as Lane Keeping Support (LKS) systems.

LDW performance is evaluated by considering the proximity of the vehicle with respect to the edge of a lane line at the time of the LDW alert."

"This document also includes language specifying how LKS tests may be performed to supplement the LDW performance evaluations. These supplemental tests are performed for informative purposes only, intended to expand NHTSA's knowledge of how such systems operate."

11.6.2.6 LDW Activation Data Flag

"The LDW system shall provide a warning to the driver by presenting an auditory alert, a visual alert, haptic vibration, haptic vehicle cue (for example, braking vibration, steering vibration, or seat vibration), or any combination thereof. (Steering torque or brake torque from a Lane Keeping Support system should not by itself be deemed a haptic signal, if a more definitive signal exists.)"

12.0 TEST EXECUTION AND TEST REQUIREMENTS

"If the Lane Departure Warning system provides a warning-time adjustment for the driver, at least one setting must meet the criterion of the test procedure."

12.2 Test Maneuver Overview

"To begin a test trial, the vehicle shall be driven in a straight line on a white-line- marked test track at a constant speed of 45 mph (72 km/h) for up to 200 feet if possible. … "

12.2.1 Lane Departure Warning (LDW) Test Maneuver

"… the driver shall manually input sufficient steering to achieve a lane departure with a target lateral velocity of 1.6 ft/s (0.5 m/s) with respect to the lane line. Throughout the maneuver the driver (or cruise control) shall modulate the throttle such that vehicle

speed remains constant. The test shall be considered complete when the vehicle has crossed at least 1.7 ft (0.5 m) over the lane edge boundary."

"The test shall consist of two departure directions (left and right) and use three styles of roadway markings (continuous white lines, discontinuous yellow lines, and discontinuous Botts dot raised pavement markers). Each test condition shall be repeated five (5) times. …"

12.2.2 Lane Keeping Support (LKS) Test Maneuver (supplemental – Information collection only)

12.2.2.2 Threshold Determination Tests

"The second series of LKS tests are intended to quantify the systems' ability to prevent lane departures. With one exception, the input conditions of these tests are identical to those used in S12.1.1, differing only in the magnitude of the lateral velocities used during the series. Using a series of ten (10) tests per direction of steer, the lateral velocities used during this test series are iteratively increased by 1.6 - 2.0 ft/s (0.5 - 0.6 m/s) to a magnitude where the LKS can no longer prevent a lane departure from occurring. … "

12.3 Straight Lane Departure Test Course

"The straight lane departure test course shall be set up at a location that allows the test vehicle to easily reach the 45 mph (72 km/h) target speed, provides approximately 300 m (1000 ft) of area after the test starting point, and provides > 15 ft (5 m) of lateral runoff to ensure the vehicle may safely depart the lane. The test course shall have a start line constructed from retro-reflective tape, 15 in (38 cm) deep, and wide enough so that the vehicle will pass over it when the center of the vehicle is near the center of the lane. …"

12.4.2.2.2 LKS Threshold Determination Evaluation

"The lateral velocities used … nominally range from 2.0 ft/s (0.6 m/s) to a magnitude where the LKS can no longer prevent a lane departure from occurring.

12.5 LDW Pass or Fail Criteria

"… a lane departure is said to occur when any part of the two-dimensional polygon used to represent the test vehicle breaches the inboard lane line edge. In the case of tests performed in this procedure, the outside front corner of the polygon will cross the line edge first. In other words, if the vehicle departs its lane to the left, the left front corner of the polygon would first breach the lane line edge."

"For an individual trial to successfully pass the test, …

The lateral velocity of the vehicle at the time of the LDW alert must be between 0.3 to 2.0 ft/s(0.1 to 0.6 m/s).

The LDW alert must not occur when the lateral position of the vehicle is greater than +2.5 ft (+0.75 m) from the lane line edge. Vehicles in-lane are given positive values.

The LDW alert must occur before the lane departure exceeds – 1.0 ft (- 0.3 m).

…To be awarded an overall passing grade, the LDW system must satisfy the pass criteria for 3 of 5 individual trials for each combination of departure direction and lane line type (60 percent), and pass 20 of the 30 trials overall (66 percent). If more than 5 trials are deemed valid, the Pass/Fail criteria must be met for 3 of the first 5 valid trials."

CONCLUSIONS

1. What are the SAE and ISO design standards relevant to the design of in-vehicle warnings?

As shown Table 4, there were 16 documents (8 SAE and 8 ISO) relevant to the design of in-vehicle warnings. The SAE documents consist of 4 information reports, 3 recommended practices, and 1 standard. The ISO documents consist of 5 standards, 2 technical specifications, and 1 technical report.

Table 4. SAE and ISO documents relevant to warnings

	Document #	Partial Title
SAE document	Recommended Practice J2395	ITS In-Vehicle Message Priority
	Recommended Practice J2396	Definitions & Measures for Visual Behavior
	Standard J2399	ACC Characteristics & User Interface
	Information Report J2400	FCW Human Factors: Operating Characteristics & User Interface Requirements
	Recommended Practice J2802	Blind Spot Monitoring System: Operating Characteristics & User Interface
	Information Report J2808	Road/LDW Systems: Human Interface
	Information Report J2830	Process for Testing Icon Comprehension
	Information Report J2831	Recommendations for In-Vehicle Alphanumeric Text Messages
ISO Document	PD Technical Report 12204	Integration of safety critical warning signals to avoid conflicts
	Standard 15005	Dialogue management principles & compliance procedures
	CD Standard 15006	Specifications for in-vehicle auditory info
	CD Standard 15007-1	Measurement of driver visual behavior - Part 1: Definitions and parameters
	DTS (Draft Technical Specification) 15007-2	Measurement of driver visual behavior - Part 2: Equipment & procedure
	Standard 15008	Specifications & tests for in-vehicle visual info
	Technical Specification 16951	Procedure: determine message priority
	Standard 17287	Procedure: assess suitability for use while driving

2. What are their requirements?

Tables 5 and 6 list contents and key requirements/recommendations distributed among 16 in-vehicle warnings-related documents. In terms of documents that mention the requirements unclearly, ‘UNK (unknown or unclear)’ is marked. These are the keys, thus please refer to the original documents to see the details.

Table 5. Contents and key requirements/recommendations for SAE documents (warning-related)

SAE Document	Partial Title	Contents	Key Requirements/ Recommendations
Recommended Practice J2395 (Message Priority)	ITS In-Vehicle Message Priority	procedure to determine ITS message priority 1: select prioritization evaluations 2: delineate information items 3: categorize each information item 4: determine the priority order index	- shall consist of at least 3 people from a range of disciplines and stakeholder communities - shall determine safety relevance (direct, indirect/somewhat, not relevant), operational relevance (high, moderate, little or none), and time frame levels (emergency, immediate, near term, preparatory, discretionary)
Recommended Practice J2396 (Visual Measures)	Definitions & Measures for Visual Behavior	(1) measuring eye glance behavior in driving - concepts for the measurement - 4 strategies possible for defining a glance (2) developing a glance allocation measure database - required measures and statistics - experimental evaluation of TICS against comparison conditions	independent variables (1) target factors - shall have separation angle of ≥ 20 degrees (2) driver factors - shall be characterized (e.g. age, gender, license, visual acuity) (3) experimental conditions - shall specify road (e.g. type of highway, # and width of lanes) - shall specify vehicle (e.g. size, type of transmission)
Standard J2399 (ACC)	ACC Characteristics & User Interface	requirements of following categories: - sensor capability - operational characteristics - operating state transitions - displays - performance evaluation test methods	- should set minimum speed 25 mph - shall be minimum steady-state following time gap ≥ 1.0 s - shall be time gap ≥ 1.5 s - should illuminate stop lamps for a ≥ 0.5 s - should be min. available time gap ≥ 1.0 s - should be max. available time gap test ≥ 1.5 s

			- shall activate auditory, visual, and/or haptic alert whenever transition from ACC engaged to manual control
Information Report J2400 (FCW)	FCW Human Factors: Operating Characteristics & User Interface Requirements	(1) operating characteristics - systems and information display - occurrence of crash alerts (2) performance evaluation assumptions - testing criteria and assumptions - test procedure descriptions - evaluating test results	- should be default warning intensity 75 dBA - shall locate visual display within a 10-degree cone of the drive's line of sight - should be min. zone width of the vehicle, max. zone 3.6 meters for alert zone - must satisfy ≥ 5 of 7 trials for passing the entire test protocol
Recommended Practice J2802 (Blind Spot)	Blind Spot Monitoring System: Operating Characteristics & User Interface	requirements and recommendation of following categories: (1) operational characteristics - speed, deactivation, fault indication (2) display - location, use of ISO symbols, color, luminance, symbol height	- should be in a forward gear at a min. speed of 37.3 mph - should be capable of achieving at least 6,000 cd/m^2 (luminance) - should be min. subtended visual angle: for the symbol is 24 arcmins, for a point source (e.g. LED) is 13 arcmins - should illuminate the ISO symbol or point source in amber not red
Information Report J2808 (LDW)	Road/LDW Systems: Human Interface	(1) effectiveness of warning presentation modality (2) system status indication - enabled vs. disabled - system incapable- (3) system behavior - speed threshold - reverse speeds	- should be indicated to the driver - should be different failure modes/malfunctions than the indication for no road/lane boundaries tracked - shall be speed threshold ≥ 44.74 mph - operating in reverse is not required
Information Report J2830 (Icon Test)	Process for Testing Icon Comprehension	process steps 1: review candidate icons for comprehension testing	(1) candidate icons shall be - pre-testable, having a message and general function, context descriptions given

		2: prepare for comprehension testing 3: conduct comprehension testing 4: analyze comprehension data and summarize results	to subjects during testing, 10 - 20 icons should be included (2) test subjects should be - total # 30 - 40, having license, approximately equal mix (age, gender) (3) analyze the data for subject response to the icons with 1-9 scales
Information Report J2831 (Text Format)	Recommendations for In-Vehicle Alphanumeric Text Messages	recommendations for (1) display-relevant message contents - message priority, urgency, criticality - message length and style - font, color, accentuation (2) message presentation and flow parameters - state change indication and message initiation - message entry, scroll control	- should limit navigation instruction to 3 - 4 information units - should abbreviate words of 5 - 8 letters, using the key consonant and ≥ 8 letters, using first syllable strategy - should span a min. visual angle of 0.5 degrees for title and other key elements in a message - should be all lines and gaps between lines ≥ 0.05 degrees wide - should limit the # of state change alerts to 3 - 4

Table 6. Contents and key requirements/recommendations for ISO documents (warning-related)

ISO Document	Partial Title	Contents	Key Requirements/ Recommendations
PD Technical Report 12204 (Warning Integration)	Integration of safety critical warning signals to avoid conflicts	(1) classification of warning signals - 3 levels of criticality (injury and damage, damage, non-safety) - 3 time frames for urgency (immediately, within a few seconds, preparation) - 2 durations of signal (continuous, discrete) - 3 directions of hazard (front, side, rear of vehicle) (2) warning signals - share the same sensory - are in close spatial proximity - have the same signal characteristics - occur simultaneously or in close temporal proximity	UNK
Standard 15005 (Dialog Management)	Dialogue management principles & compliance procedures	(1) Appropriate for use while driving - compatible with driving, simple, timing fitting its priority (2) Appropriate for the TICS task - consistency and controllability (3) Appropriate for the driver - self-descriptiveness, conformity with driver expectations, and error tolerance	- shall not require removal of both hands from the steering wheel while driving - shall not require the continuous visual attention of the driver providing it with input - shall be consistent with mode, location, orientation and dialogue management - shall be able to control the flow of information displayed by TICS
CD Standard 15006 (Auditory Information)	Specifications for in-vehicle auditory info	(1) signal specification - spectrum and signal levels (2) coding of information - temporal classification of auditory	- should be frequency range of spectrum 200 - 8,000 Hz - should be non-speech coding have 2 functions, attracting attention and providing

		signals - non-speech coding (tonal signals)	information - temporal classification: short (0 - 10 s), medium (10 - 20 s), long (> 20s)
CD Standard 15007-1 (Visual Definitions)	Measurement of driver visual behavior - Part 1: Definitions and parameters	(1) definition of metrics - basic measures (e.g. dwell time, glance duration, transition time) - glance metrics (e.g. # of glances, glance rate, % of transition times) (2) sources for data collection - guidance for driver visual behavior data - guidance of how to treat missing data	should report following parameters and measurements for consistent recording of comparable data - parameters (total glance time, mean glance duration, max. glance duration) - measurements (range, 10th, 85th and 90th percentiles)
DTS (Draft Technical Specification) 15007-2 (Visual Measurement)	Measurement of driver visual behavior - Part 2: Equipment & procedure	(1) evaluation and trial planning - for subject selection, trial procedures (2) recording equipments - eye-tracking, cameras, video monitors, microphones, event markers	UNK
Standard 15008 (Visual Information)	Specifications & tests for in-vehicle visual info	(1) viewing position and illumination range (2) display illumination, mode (3) alphanumerical character dimensions - height, width by height ratio, spacing (4) presentation characteristics - image instability, image blinking	- shall illumination range ≤ 10 lx (night), = 250 lx (twilight), = 5 klx (day with diffuse ambient light), = 45 klx (direct sunlight) - shall be min. contrast ratio 5:1 (night), 3:1 (twilight, day), 2:1 (direct sunlight) - shall continue at least 4 s for observation of image instability - for alphanumerical character : should ≥ 20 arc minutes for height : should be 0.6 - 0.8 for width by height ratio : shall be 0.08 - 0.2 for stroke width by height ratio
Technical	Procedure:	procedure to determine priority index	UNK

Specification 16951	determine message priority	1: appoint an examiner 2: identify and assemble messages 3: define driving context and situation 4: select the evaluators 5: evaluate criticality and urgency of a message 6: develop instructions for the examiner 7: utilize alternative method for determining message priority	
Standard 17287	Procedure: assess suitability for use while driving	procedure for assessment 1: define of assessment plan 2: select TICS representation 3: define assessment context 4: definite assessment criteria 5: select assessment method 6: perform assessment and analyze data 7: interpret results	- shall define intended use of TICS and the context of use - should include following for TICS identification: product name and version, build status, documentations - shall describe steps taken to prevent reasonably foreseeable misuse for improper use and misuse - should identify TICS failures

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APPENDIX A – OTHER SAE STANDARDS

This appendix list standards from the SAE Safety and Human Factors Steering Committee that are not concerned with warnings per se, but other human factors topics. They are listed in numeric order.

SAE Recommended Practice J2364: Navigation and Route Guidance Function Accessibility While Driving (14 pages)

1. Scope

for “both OEM and aftermarket … navigation … functions for passenger vehicles.” to determine what should be driver accessible in moving vehicles. 2 procedures, “a static method and an interrupted vision method… applies “only to the presentation of visual information and the use of manual control inputs … for.. navigation.” Voice-operated controls are excluded.

2. References

3. Definitions

accessible by the driver	occlusion total task time
computationally-interrupted task	route guidance system
control	shutter closed time
display	shutter open time
driver interface	static total task time
glance duration	task
goal	task partitionability
navigation system	total task time
occlusion interval	vehicle in motion
occlusion total shutter closed time	vision interval
occlusion total shutter open time	

4. Summary of the methods

Categories	Description
static method	- total task time including total glance time a driver looks at in-vehicle device display - shall have a static total task time <15 s for driver accessible functions in motion
interrupted vision method	- determines task partitionability using occlusion goggles or display blanking - shall use 1.5 s vision interval - shall have an occlusion total shutter open time of ≤ 20 s for function that is accessible by the driver while in motion
use either method	- not necessary to use both of methods

5. Task time compliance measurement procedure for either method

Procedure	Requirements
evaluation setup	- must be operational driver interface (prototype or simulation ok) - shall fit driver interface in design intend location in a stationary vehicle, simulator buck, mockup or equivalent
subjects	- shall be licensed drivers not familiar with the specific driver interface - shall be able to operate the driver interface, learn and complete the test procedure - shall test 10 subjects age 45 – 60
subject training	shall train subjects and give them 5 practice trials for each task, prior to testing
test trials and data analysis	- shall test each subject individually - shall complete 3 test trials for each task - not allow coaching during test trials, but feedback on errors in permitted when a task is completed
task timing	- duration: from when task is initiated by a verbal/audio command to the beginning of system confirmation that the last operation is accepted - computational interruption for calculation of task time: (see document for details)

SAE Recommended Practice J2365: Calculation of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks (23 pages)

1. Scope

This … applies to "both OEM and aftermarket route-guidance and navigation system functions for passenger vehicles." This … provides a method for "calculating the time required to complete navigation system-related tasks." These … "an aid to assess the safety and usability of alternative navigation and route guidance system interfaces to assist in their design." This … NOT consider "voice-activated controls, voice output from the navigation system, communication between the driver and others, or passenger operation."

2. References

3. Definitions

navigation system	method
route guidance system	total task time
control	static total task time
display	computationally-interrupted task
driver interface	in motion
goal	operator
subgoal	shortcut
task	pseudo code

4. Calculation method

Categories	Description
Overview	the method is based on the goals, operators, methods and selection rules (GOMS) model
Purpose	to obtain either - a working prototype of the interface - a simulation of the interface - a videotape of a user operating the interface - a step-by-step operational description
Procedure	- identify the goals - for each goal, identify the associated other subgoals to achieve it - for each goal and subgoal, identify the methods used to achieve them - convert the detailed explanation of the methods into a computer-program like format - identify the computational assumptions regarding user's knowledge of various methods of task completion - determine the proper mental, keystroke, and other operators for each step - enter the execution times for each operator - add up the execution times for each operator - adjust the keystroke times using the age multiplier as desired (e.g.

	multiply the keystroke times by 1.4 for 40-55, times by 1.7 for 55-60, times by 2.2 for > 65) - verify that the times make sense and revise as needed

SAE Information Report J2678: Navigation and Route Guidance Function Accessibility While Driving Rationale (29 pages)

1. Scope

This … provides the rationale … “for the development and content of the SAE J2364.” It provides “both the reasoning for the overall recommended practice as well as each of its elements. “

2. References

3. Definitions

accessible by the driver	occlusion total task time
computationally-interrupted task	route guidance system
control	shutter closed time
display	shutter open time
driver interface	static total task time
glance duration	task
goal	task partitionability
navigation system	total task time
occlusion interval	vehicle in motion
occlusion total shutter closed time	vision interval
occlusion total shutter open time	

3. Summary of methods

similar to J2364

APPENDIX B – OTHER ISO STANDARDS

This section list standards from ISO TC 22/SC 13/WG 8 that are not concerned with warnings per se, but other human factors topics. They are listed in numeric order.

ISO 16673: Road vehicles- Ergonomic aspects of transport information and control systems - Occlusion method to assess visual demand due to the use of in-vehicle systems (22 pages)

1. Scope

This … provides "a procedure for measuring visual demand due to the use of visual or visual-manual interfaces accessible to the driver while the vehicle is in motion." It applies to both "OEM and aftermarket in-vehicle systems." … both "permanently installed and portable systems." … any means of visual occlusion and is not dependent on one specific physical implementation.

2. References

3. Definitions

driver accessible	task
dlance duration	total shutter open time (TSOT)
goal	total task time occluded (TTT occl)
integrated system	total task time unoccluded (TTT unoccl)
occlusion interval	trial
outlier	vehicle in motion
portable system	vision interval
resumability	visual demand
resumability ratio (R)	visual occlusion procedure
system response delay	

4. Measurement procedures

Categories	Description
set-up	- intermittent viewing of an interface can be provided by various means (e.g. commonly used goggles, blanking of the visual display, a shutter in front of the interface) - regardless the means, the switching process and restoration at the end of an occlusion interval shall occur < 20ms
vision and occlusion intervals	1.5 s for both intervals
task timing	- TSOT shall be defined as duration from the beginning of the first vision interval to when the instructed task has been

	completed and the participant says he/she is “done” - ‘TTT unoccl’ shall be defined as duration from at the end of the task instruction to when the instructed task has been completed and the participant says he/she is “done” - ‘TTT occl’ shall be defined as duration from the beginning of the first vision interval to when the instructed task has been completed and the participant says he/she is “done.”
exclusion of trials	when there is a trial where the ‘TTT occl’ is more than 4 times the average ‘TTT unoccl’

5. Assessing visual demand

Categories	Description
task selection	tasks with duration less than 5s are not appropriate
participants	≥ 10 participants (+20% over 50 age) who are licensed drivers for the class of the vehicle type
training	should not train participant on all tasks before the test trial for a given task. ≥ 2 trials with occlusion procedure
test trials	should tested individually. If 2 or fewer successful trials out of 5 for ≥ 2 participants, procedure should be reviewed
experimental plan	depends on if the user is calculating only the TSOT metric, or both TSOT and R metrics
calculation of visual demand (TSOT, R)	see the original document for details.