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Road vehicles — Ergonomic aspects of transport information and control systems — Introduction to integrating safety critical and time critical warning signals

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TECHNICAL REPORT

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Road vehicles — Ergonomic aspects of transport information and control systems — Introduction to integrating safety critical and time critical warning signals

Véhicules routiers — Aspects ergonomiques des systèmes d'information et de contrôle du transport — Introduction à l'intégration des signaux d'avertissement critiques en termes de sécurité et de temps

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 12204 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics applicable to road vehicles*.

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Introduction

This Technical Report supplements the information provided in ISO/TR 16352 “MMI of warning systems in vehicles” and specifically addresses the topic of warning signal integration in automobiles.

This Technical Report contains a mixture of general guidance information where technical consensus supports such guidance, as well as discussion of those areas where further research is required to support technical consensus. It should be noted, however, that the general guidance contained in this Technical Report is informative, rather than normative, in nature.

The HMI of warning interfaces for stand-alone active safety systems is not standardized. Recently, “Guidelines on establishing requirements for higher-priority warning signals” is being developed by the UNECE/WP29/ITS Informal Group. There are, however, many different interfaces used on production vehicles. The integration of multiple stand-alone warning systems requires consideration of basic properties of the interface such as modality, timing, and redundancy. This can lead to complex trade-offs for the system designer. It may well be that over time the industry and/or governmental regulators will converge on common specifications for warning interfaces for stand-alone warning systems.

It should also be noted that a key underlying assumption for the purposes of this Technical Report is that each of the stand-alone warning system signals to be integrated has been previously validated in terms of effectiveness and acceptability. Therefore, any changes to a particular warning signal that may be suggested by evaluating the integration of multiple warning signals into a coherent HMI are intended to address an integration issue, only, and not to compensate for any deficiency that may be present in the design of one or more underlying stand-alone warning/systems.

Poorly integrated warning signals may not be noticed or could be misunderstood, confused, or ignored and could potentially impair system performance causing the driver to respond too slowly, inappropriately or not at all. Poor integration could limit the safety benefits of the warning system.

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Road vehicles — Ergonomic aspects of transport information and control systems — Introduction to integrating safety critical and time critical warning signals

1 Scope

This Technical Report provides general, informative guidance for the integration of safety critical and time critical warning signals (signals which, if ignored even briefly, could result in bodily harm to the occupant(s) of the vehicle and/or to other road users) into existing in-vehicle messages presented to a driver. Integration of non-critical signals are outside the scope of this Technical Report, except to confirm that they do not affect the driver's comprehension of safety and time critical signals.

This Technical Report provides:

1) possible approaches for determining if integration is necessary to mitigate the possibility that signals from one or more vehicle system may degrade the driver's comprehension of, or response to, safety critical warning signals from another system(s); and

2) a discussion of possible methods for assessing potential integration conflicts.

It does not provide prescriptive guidance in how to design an integrated warning HMI.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

3 Terms and definitions

3.1
abstract visual signal
simple figure such as circle or square that has no clear meaning

3.2
active safety warning system
system incorporating sensors to detect potential hazards that communicate a warning signal to the driver so that a hazard may be avoided by driver intervention

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3.3
auditory icon
auditory signal that represents an event or action without using verbal expression

NOTE This auditory signal can be a synthesized sound that gives the impression of a specific event or a recorded sound from everyday life.

3.4
ambient noise
sensory stimulus that is not relevant to the specific task of the driver in the vehicle's environment

NOTE This can include sound emanating from inside and outside the vehicle (auditory noise), reflection of sunlight, glare from headlights of surrounding vehicles (visual noise), and vibration from the vehicle (haptic noise).

3.5
comprehensibility
characteristic of a signal enabling the driver to understand the meaning of the signal in the context in which it is provided

3.6
criticality level
classification of severity of the collision

3.7
distinguishability
characteristic of the warning signal to be perceived by the driver when two or more signals share the same sensory mode, or are presented in close temporal within the driving environment

3.8
event
significant occurrence in the driving environment of a subject vehicle/driver

3.9
human machine interface
controls and displays that allow a human to interact with a manufactured device or system

3.10
integration
incorporation and organization of multiple devices or systems into a unified, coherent HMI, ensuring that all warning signals can be understood independently of when or how they are presented (individually or simultaneously) when present in the vehicle

3.11
priority
relative importance of two or more messages or signals

NOTE For warning signals, priority level can be obtained from criticality and urgency levels of a signal.

3.12
response time
time period from the onset of a warning signal to the point at which the driver starts to perform a vehicle control action

EXAMPLE The time from the onset of a forward vehicle collision warning system signal to when the driver starts to depress the brake pedal.

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3.13
safety critical signal
signal that is intended to warn a driver in time for corrective action to be taken to prevent vehicle damage or personal injuries

NOTE There are four levels of criticality, categorized based on occupant (both in the vehicle and on the road) injury and vehicle damage defined in ISO/TS16951. The four levels are:

— Criticality level 3, severe or fatal injury to occupants;

— Criticality level 2, injury or possible injury to occupants;

— Criticality level 1, no injury to occupants but with damage to vehicle involved; and

— Criticality level 0, neither injury to occupant nor damage to any vehicle.

“Safety critical signal” defined here pertains only to criticality levels 3 and 2.

3.14
scenario
driving events and situations experienced by a driver

3.15
signal
visual, auditory, or haptic stimulus information produced by an in-vehicle system or an on-road system for the purposes of communicating driving-related information to the driver

NOTE Signals include both warning and non-warning signals.

3.16
symbol
visually perceptible figure used to convey information independently of language, produced by drawing, printing, or other means.

[ISO 2575:2010, definition 3.1]

3.17
system integrator
person(s) responsible for integration of a warning device or systems in a vehicle HMI

3.18
time critical signal
signal with high urgency level that requires driver’s response to an imminent event measurable within ten seconds

NOTE Time critical signal may or may not pertain to a warning event. There are four levels of urgency, categorized based on how fast the driver needs to respond to the warning signal. The four levels are:

— Urgency level 3, respond immediately (within zero to 3 sec);

— Urgency level 2, respond within a few seconds (3 to 10 sec);

— Urgency level 1, response preparations (take action or decision within 10 sec to 2 min);

— Urgency level 0, information only (ISO/TS 16951).

“Time critical signal” defined here pertains only to criticality level 3 and 2.

EXAMPLE Signal that informs a driver of an unsafe closing distance to an object in the vehicle’s path which requires braking or evasive steering less than 10 sec.

3.19
tone
simple sound or mixture of simple sounds with fixed frequency

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NOTE Tone includes continuous sound and intermittent sound.

3.20
urgency level
classification of the time within which driver action or decision has to be taken if the benefit intended by the system is to be derived from the signal

3.21
voice message
signal with identifiable spoken terms

3.22
warning event
object, obstacle, or event in the driving environment that is likely to cause harm if ignored

3.23
warning signal
signal that is both safety critical and time critical indicating a warning event

NOTE Warning signals always pertain to risk of personal injury or death and do not include things such as navigation instructions that might also require the driver to take an action within a set time period.

4 Abbreviated terms

ACC Adaptive cruise control system

CSW Curve speed warning system

FCW Forward collision warning

HMI Human machine interface

HUD Head up display

LCM Lane change/merging warning system

5 Warning signals and situation where a warning signal is presented

5.1 Classification of warning signals

5.1.1 Background

Signals in a vehicle may communicate with the driver through auditory, visual, or haptic modalities. The signals that are candidates for integration can be classified in numerous ways, depending on which of their features are the most salient for the purposes of integration. In addition to the characteristics of signals, it is also necessary to consider the situation of the driver at the time that a given signal(s) is issued. Factors such as visibility and range of the hazard(s), e.g. other vehicle, pedestrian, roadside object, as well as necessary responses, influence how multiple warning signals should be presented. The performance characteristics that should be considered when developing an integrated HMI for multiple warning systems are classified according to the following description of warning signals and situations.

NOTE The parameters listed below are intended to identify characteristics of individual warning signals and situations in order to facilitate the identification of potential conflicts among signals. The specific values that are identified (such as the amount of response time available to the driver) have been taken from ISO/TS 16951.

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5.1.2 Criticality

5.1.2.1 Severe or fatal injury level warning signal

Warning systems that assist a driver in averting a collision that can damage the vehicle and possibly cause severe or fatal injury to the occupants.

EXAMPLE Forward collision warning that assists the driver avoiding a collision with a lead vehicle at high speed.

5.1.2.2 Injury or possible injury level warning signal

Warning systems that assist a driver in averting an intermediate or low-speed collision that can damage the vehicle and possibly risk the safety of occupants.

EXAMPLE Side collision warning signal that assists the driver avoiding a vehicle (side)-to-vehicle (side) collision at intermediate or low speed.

5.1.2.3 No injury (vehicle damaged) level warning signal

Warning signals that assist a driver in averting a low-speed collision that can damage the vehicle and does not risk the safety of the occupants.

EXAMPLE Back-up warning signal that assists the driver avoiding a collision with structure at low speed.

5.1.2.4 No injury (no vehicle damage) level warning signals

Warning signals that assist a driver in averting a very low-speed collision that does not damage the vehicle and does not risk the safety of the occupants.

5.1.3 Urgency

Time within which driver action or decision has to be taken if the benefit intended by the system is to be derived from the signal (ISO/TS 16951).

5.1.3.1 Respond immediately

Take immediate action or decision (within zero to three seconds) according to the presented warning signal.

EXAMPLE Obstacle immediately in the vehicle path. Brake immediately. Steer to avoid dangerous situations.

5.1.3.2 Respond within a few seconds

Take action or decision according to the warning signal within 3 to 10 sec.

EXAMPLE Obstacle within a few seconds in the vehicle path. Brake in a few seconds. Steer away from danger as required.

5.1.3.3 Response preparation

Prepare to take action or decision in response to the warning signal within 10 sec to 2 min.

EXAMPLE Onset of detection of an obstacle.

5.1.3.4 Information Only

No direct action or decision required by the driver.

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EXAMPLE System on.

5.1.4 Duration of signal

5.1.4.1 Background

Another aspect of the temporal characteristics of a warning signal is the length of time that a signal is provided to the driver after it is initially presented.

5.1.4.2 Continuous

A continuous warning signal persists until the end of the event and may provide a continuous update of the situation.

EXAMPLE Signal that indicates the driver is too close to the lead vehicle.

5.1.4.3 Discrete

A discrete warning signal indicates the existence of an event but is independent of the duration of the event itself.

EXAMPLE Virtual rumble strip that lasts for a predetermined period, irrespective of whether or not the vehicle returns to the roadway.

5.1.5 Direction of hazard

5.1.5.1 Background

Hazards may arise from any direction around the vehicle. Providing an integrated warning system requires a system integrator to consider the direction of the hazard and the likelihood that the driver has perceived it, especially when it appears in the presence of other hazards.

5.1.5.2 Front of vehicle

Obstacles in the forward field of view of a driver may or may not be readily perceivable by the driver the moment his or her attention is directed to the forward road scene where the hazard has been detected by a warning system.

5.1.5.3 Side of vehicle

Obstacles to the side of a vehicle may or may not be readily perceivable by the driver the moment his or her attention is directed to the side of the vehicle where the hazard has been detected by a warning system.

EXAMPLE Warning system detecting the presence of another vehicle in the driver's blind zone during an apparent attempt to merge into an adjacent lane.

5.1.5.4 Rear of vehicle

Obstacles to the rear of a vehicle may or may not be readily perceivable by the driver the moment his or her attention is directed to the rear of the vehicle where the hazard has been detected by a warning system.

5.2 Hazard perception by drivers

5.2.1 Background

Warning signals are used to direct a driver's attention to hazards in the driving environment that the driver has apparently failed to perceive (or has yet to be perceived), or assess the situation appropriately, as indicated by

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a failure to take corrective action. The driver's failure to perceive a hazard may stem from a variety of causes, which may in turn invoke special considerations for warning system designers and integrators.

5.2.2 Visible and detected by the driver

Events or situations the driver is readily able to see.

5.2.3 Visible but not detected by the driver

5.2.3.1 Background

Events that are not perceived by the driver, or not otherwise readily detectable from visual, haptic or audible cues. This is a situation where warning signals are to be utilized effectively to avoid hazards.

5.2.3.2 Driver failed to look

Warning signals regarding events/situations that could be directly visible to the driver with a brief scan of the mirrors or a glance, but have gone undetected by the driver due to failure to attend to an area where the hazard appears.

5.2.3.3 Driver looked but did not see

Warning signals provided for readily perceptible events that the driver has failed to recognize.

5.2.4 Not readily perceptible to the driver

Warning signals associated with an event/situation that is not readily perceivable by the driver. This is a situation where warning signals help the driver to detect hazards.

5.3 Description of vehicle systems that signal the driver

5.3.1 Systems requiring time critical and safety critical response

5.3.1.1 Active safety vehicle dynamic system

Active safety vehicle dynamic systems can stabilize the vehicle and help prevent accidents. They incorporate sensor systems that are capable of detecting hazardous conditions of the vehicle. Various technologies are incorporated as sensors, either individually or in combination. These include sensors within the vehicle, such as yaw rate, wheel speed, and acceleration sensors that are designed to monitor the dynamics of the vehicle. A signal (usually visual) is sometimes given to the driver during activation of the system indicating the system is stabilizing the vehicle.

EXAMPLE Electronic stability control system provides automatic braking of individual vehicle wheels to assist the driver in maintaining control in critical driving situations.

5.3.1.2 Driver assistance system with warning signal

A system that detects potential road hazard(s) and provides a timely warning signal to the driver.

EXAMPLE Lane departure warning system gives a warning signal when the vehicle deviates or is about to deviate the lane without the driver activating the turn signal.

NOTE Some active safety warning systems may incorporate multiple levels (or stages) of warning signals, which become progressively more urgent and safety critical. For example, ISO 17387 refers to “Level 1” and “Level 2 and above” warning signals, where “Level 2 and above” warning signals are more critical than “Level 1” warning signals.

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5.3.1.3 Driver assistance system with warning signal and intervention

A system that detects potential road hazard(s), provides a timely warning signal to the driver, and, if necessary, automatically manipulates vehicle control parameters to mitigate or avoid the hazard.

EXAMPLE Lane keeping system with lane departure warning that gives a warning signal when the vehicle deviates or is about to deviate outside the lane without the driver activating the turn signal and applies steering torque to help keep the vehicle inside the lane.

5.3.2 Systems requiring time critical, but not safety critical response

5.3.2.1 Vehicle condition information system

There are numerous warning signals provided to the driver regarding the condition of the vehicle. These warning signals normally do not require immediate action of the driver even though they may require urgent attention of the driver. Although there is a possibility that the failure of the vehicle system may cause an accident (if occurring while at a high speed), warning signals about the vehicle conditions are not regarded as safety critical signals. Therefore, such warning or caution signals are not under the scope of this Technical Report.

EXAMPLE Signals indicating low fuel level, low coolant level, lamp failure, etc.

5.3.2.2 Route guidance and navigation systems

Route guidance and navigation systems are special cases in that sometimes the information they present is time critical and may have implications for safety, but in other times the information presented signals a manoeuvre that is irrelevant to the immediate driving situation.

Congestion information and sharp curve warning signals provided by some navigation and route guidance systems may be safety critical and time critical, because they will be useful to avoid rear end collisions and off-road crashes, and are therefore within the scope of this Technical Report.

5.3.3 Systems requiring safety critical, but not time critical response

There are numerous signals provided to the driver to alert them of various abnormal vehicle conditions, some of which may lead to a hazardous condition if not attended to in a reasonable period of time. They do not, however, require immediate evasive action by the driver and, therefore, this type of signal requires a safety critical response, but not a time critical response.

EXAMPLE Signal indicating low oil pressure.

5.3.4 Systems requiring neither safety critical, nor time critical response

Signals from in-vehicle information systems that do not present time critical nor safety critical information to drivers are not within the scope of this Technical Report.

5.4 Possible driver responses

5.4.1 Background

The variety of responses or combination of responses by a driver to avoid the obstacle or situation identified by a warning system can be categorized as follows.

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5.4.2 Preparation

The primary response to a perceived warning signal is to direct one's attention to a certain object or event (assumed to be a hazard/threat) and to recognize the situation. Then a driver prepares to respond by deciding on an action (typically pedal and/or steering operation).

NOTE In the case of time critical and safety critical warning signals, particularly where the hazard is apparent the moment that the driver's attention has been restored, the driver's hazard assessment and decision on how to respond may occur so rapidly that the driver is not aware of having made such an assessment and decision. This type of "pre-cognitive" response (e.g. directional orientation) may point to the need for additional testing and validation of warning design, as well as for special consideration when designing an integrated warning system that must handle the possibility that multiple time critical and safety critical warning signals may occur simultaneously or in close temporal proximity.

5.4.3 Responses

5.4.3.1 Possible responses

Following the preparation as described above, a driver has a limited number of control actions that he or she may perform in an attempt to avoid or mitigate a crash. One or more of these responses may be appropriate in a given situation.

5.4.3.2 Hard braking or acceleration

Hard braking is a driver's response that is intended to slow or stop the vehicle movement as quickly as possible. Rapid acceleration is also sometimes used by drivers to avoid an imminent collision, such as when a vehicle or object is approaching the subject vehicle from the side or the rear.

EXAMPLE An urgent warning signal from a forward vehicle collision warning system that prompts a driver braking action to avoid a frontal collision.

5.4.3.3 Emergency steering manoeuvre

Emergency steering manoeuvre is intended to steer a vehicle around an object to avoid a collision.

EXAMPLE An urgent warning signal from a lane departure warning system that prompts a driver to return the vehicle to the lane.

5.4.3.4 Retake control

A warning signal for the driver to retake vehicle control is associated with systems that signal the driver when he or she must resume active control from a vehicle control system. The driver is required to re-take control of the vehicle when a vehicle control system becomes inactive or exceeds its range-of-control (but prior to the advent of a particular hazard).

EXAMPLE Warning signal from an adaptive cruise control system indicating inactivation of headway sensor because of heavy rain that prompts a driver to retake control.

6 Discussion of integration vs. prioritization

6.1 Background

This clause discusses the difference between prioritization and integration and describes the relationship between them. It is important to address these two concerns individually and jointly. It would be incorrect to assume that integration concerns can be sufficiently addressed solely through prioritization.

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6.2 Prioritization

According to ISO/TS 16951, prioritization establishes the “relative importance of two or more messages, which determines their ranking in a time sequence or emphasis of presentation.” Relative importance encompasses both time urgency and safety criticality. Using these characteristics, signals can be rated from 1-n. For a higher priority warning signal, more emphasis can be given to a signal through its spatial proximity, intensity, size, modulation and duration. Signals may be shown simultaneously or in close temporal proximity. In such a case, a signal with lower priority may be suppressed to emphasize the higher priority signal.

Prioritization essentially means choosing which of the multiple warning signals is of a higher priority (e.g. more important) for the driver.

A prioritization scheme is critical when multiple warning signals are presented simultaneously or in close temporal proximity. In this situation, a decision needs to be made whether only a single warning or multiple warnings should be presented to the driver.

Signals can be prioritized using the procedures described in the following documents: ISO/TS 16951 - Procedures for determining priority of on-board messages presented to drivers (provides formal procedures and two alternative methods for determining the priority of on-board messages) and SAE J2395 - ITS In-Vehicle Message Priority (2002).

This Technical Report is not focused on prioritization of warnings, only the integration of multiple warnings into the vehicle.

6.3 Integration

Integration of warning signals aims to organize signals into a unified, coherent HMI. Integration encompasses including all warning signals (and systems) into the vehicle and ensuring that there are no unintended consequences such as startling or confusion of the driver. It takes into account distinguishability, comprehension, and desired response(s).

The ultimate objective of the integration process is to ensure that all warning signals can be understood independently of when or how they are presented (individually or simultaneously) when present in a single vehicle. This differs from prioritization which specifies the order, or priority, for the presentation of those warning signals.

6.4 Relationship of integration and prioritization

Prioritization will guide designers in establishing the relative importance of warnings. Integration will ensure a coherent interface to avoid potential conflicts leading to misperception, lack of comprehension, startling, or an inappropriate response.

Prioritization may be imposed on given information, including safety critical and non-safety critical signals, independently of designing an integrated HMI. However, without integration, warning signals could be confused even though they are prioritized. For example, two warning signals that are visually similar could be confused even though they have different prioritization. As a second example, two tones may not be easily distinguished even though they are intended to indicate different, possibly contradictory, driver responses. The tones may be presented in such close temporal proximity that the participant has trouble comprehending them, or may become startled. Or the tones may be presented in such a way that one masks the other, causing one signal to be missed by the driver.

Simply having two warning signals prioritized does not mean integration has been achieved. Prioritization produces only a ranking for the order in which warning signals should be presented. It is still possible for the warning signals to be confusing with one another, startling for the driver or for them to perceptually mask one another unless effective integration has been achieved.

In the scenario shown in Table 1, the three warning signals have triggered simultaneously. The table illustrates the differences between prioritization and integration for this situation.

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