INTERNATIONAL STANDARD

ISO 17488

First edition
2016-10-01

Road vehicles — Transport information and control systems — Detection-response task (DRT) for assessing attentional effects of cognitive load in driving

Véhicules routiers — Systèmes d'Information et de commande du transport — Tâche de Détection-Réponse (DRT) pour l'évaluation des effets attentionnels de la charge cognitive lors de la conduite

Reference number
ISO 17488:2016(E)

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 39, *Ergonomics*.

Introduction

Driving is a complex task consisting of a range of sub-tasks such as keeping the vehicle in the lane, avoiding other traffic and obstacles, observing road signs and signals, planning and initiating specific manoeuvres, scanning mirrors and navigating. In addition, drivers often engage in secondary tasks, not directly related to driving, such as operating the media player, conversing on the phone and reading road-side commercial signs.

These different activities place varying, and sometimes conflicting, demands on the driver. In order to manage the various driving and secondary tasks, the driver thus needs to allocate different *resources*, such as the eyes, hands, feet, perceptual systems, motor control systems and higher level cognitive functions, to the different sub-tasks in a dynamic and flexible way. This allocation of resources to driving and non-driving activities may be generally conceptualized as *driver attention*. In most driving situations, attention is determined by an interaction of proactive (top-down, endogenous) processes based on anticipation of how the upcoming situation will develop and bottom-up processes (driven by exogenous stimuli) which can trigger attention to the situation when it does not develop as expected, even leading to a corrective action.

There is a need for methods that can be used to assess how engagement in secondary tasks affects driver attention. In general, the effect of a task on attention depends on the amount and type of resources demanded by the task. As outlined in further detail in Annex A, resources can be conceptualized at three general levels: *sensory-actuator resources*, *perceptual-motor resources* and *cognitive resources*. *Sensory/actuator resources* refer to the basic interfaces between the driver and the environment used to sense the environment and perform overt actions. Examples include the eyes, the ears, the skin, the feet, the hands, the mouth, the vocal cords, etc. *Perceptual/motor resources* can be regarded as brain functions for controlling specific perceptual-motor activities, e.g. visual perception, manual tracking and hand-to-eye coordination. Finally, *cognitive resources* refer to brain systems implementing higher-level cognitive operations such as planning, decision making, error detection, sustaining information in working memory, dealing with novel or difficult situations and overcoming habitual actions. These types of high-level cognitive functions may be conceptualized in terms of *cognitive control*. While sensory-actuator and perceptual-motor resources are, at least to some extent, modality-specific, cognitive control can be regarded as a single resource with strongly limited capacity, not associated with any particular sensory modality. *Cognitive load* thus refers specifically to the demand for cognitive control that a task imposes on the driver.

Several existing and draft ISO standards address the assessment of secondary task demand in the context of driving. ISO 15007-1[1] and ISO/TS 15007-2[2] provide guidance on how to measure glance behaviour and ISO 16673[3] focuses exclusively on the viewing time required to perform a task using an in-vehicle information system. Hence, these methods focus mainly on the assessment of (visual) sensory demand (i.e. the demand for the eyes). ISO 26022[4] provides a technique for evaluating the combined effect of sensory-actuator, perceptual-motor and cognitive demands on a driver's performance in a combined event detection and vehicle control task.

However, a standardized measurement method that specifically addresses cognitive load is lacking. While, for example, ISO 26022 is sensitive to cognitive load, it lacks specificity since its main performance metric (MDEV) is also sensitive to visual sensory motor interference (i.e. visual time sharing; see Annex A). A standardized method specifically addressing cognitive load is particularly needed in order to evaluate the attentional demands of new driver-vehicle interfaces designed to minimize visual interaction such as voice-based interfaces, haptic input devices and head-up displays.

The detection-response task (DRT) method defined in this document intends to fill this gap. More specifically, the DRT is mainly intended to measure effects of the cognitive load of a secondary task on attention. However, some versions of the DRT specified in this document may also be used to capture other forms of secondary task demand (e.g. visual sensory demand). The general rationale behind the DRT methodology is further outlined in Annex A.

Annex B provides guidance on how to select among the different DRT versions defined in this document. Annex C reviews factors that could potentially affect DRT performance and thus need to be accounted for when designing DRT experiments. Annex D offers a review of existing alternative DRT methodologies not covered by this document. Annex E provides an overview of the results from a set of coordinated studies with the purpose to support the development of this document. Finally, a general bibliography is provided for existing DRT-related research.

Road vehicles — Transport information and control systems — Detection-response task (DRT) for assessing attentional effects of cognitive load in driving

1 Scope

This document provides a detection-response task mainly intended for assessing the attentional effects of cognitive load on attention for secondary tasks involving interaction with visual-manual, voice-based or haptic interfaces. Although this document focuses on the assessment of attentional effects of cognitive load (see Annex A), other effects of secondary task load may be captured by specific versions of the DRT, as further outlined in Annex B. Secondary tasks are those that may be performed while driving but are not concerned with the momentary real-time control of the vehicle (such as operating the media player, conversing on the phone, reading road-side commercial signs and entering a destination on the navigation system).

NOTE According to this definition, secondary tasks can still be driving-related (such as in the case of destination entry).

This document does *not* apply to the measurement of primary (driving) task demands related to the momentary real-time control of the vehicle, such as maintaining lane position and headway or responding to forward collision warnings. However, this does not preclude that the DRT method, as specified in this document, may be adapted to measure such effects.

This document applies to both original equipment manufacturer (OEM) and after-market in-vehicle systems and to permanently installed, as well as portable, systems.

It is emphasized that, while the DRT methodology defined in this document is intended to measure the attentional effects of cognitive load, it does not imply a direct relationship between such effects and crash risk. For example, taking the eyes off the road for several seconds in order to watch a pedestrian may not be very cognitively loading but could still be expected to strongly increase crash risk.

Furthermore, interpret DRT results cautiously in terms of demands on a specific resource, such as cognitive load. Specifically, if the goal is to isolate the effect related to the cognitive load imposed by a secondary task on attention, avoid overlap with other resources required by the DRT (e.g. perceptual, motor, sensory or actuator resources). A particular concern derives from the fact that the DRT utilizes manual responses (button presses). Thus, for secondary tasks with very frequent manual inputs (on the order of one or more inputs per second), increased response times on the DRT may reflect this specific response conflict (which is due to the nature of the DRT) rather than the actual cognitive load demanded by the task when performed without the DRT (i.e. alone or during normal driving; see Annex E). Thus, for such response-intensive tasks, DRT results are interpreted with caution. This document defines three versions of the DRT and the choice of version depends critically on the purpose of the study and the conditions under which it is conducted (see Annexes A and B for further guidance on this topic).

This document specifically aims to specify the detection-response task and the associated measurement procedures. Thus, in order to be applicable to a wide range of experimental situations, this document does not define specific experimental protocols or methods for statistical analysis. However, some guidance, as well as examples of established practice in applying the DRT, can be found both in the main body of this document and in the annexes (in particular Annexes C and E).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
actuator demand
demand for *actuator resources* (3.2) imposed by a *task* (3.30)

3.2
actuator resources
human body systems used to execute overt motor actions

Note 1 to entry: Examples of actuator resources include the hands, the feet, the vocal cords, etc.

3.3
attention
allocation of resources, encompassing both bottom up and top down attentional processes, to a particular activity or activities

3.4
cognitive control
mental operations such as planning, decision making, error detection, inhibiting habitual actions, utilizing information in *working memory* (3.36), and resolving novel and complex situations

3.5
cognitive resources
brain systems implementing *cognitive control* (3.4)

3.6
cognitive load
cognitive demand
demand for *cognitive control* (3.4) imposed by a *task* (3.30)

3.7
data segment
continuous portion of data

3.8
driver attention
allocation of *resources* (3.20), encompassing both bottom up and top down attentional processes, to driving and/or non-driving-related activities

3.9
DRT stimulus
sensory signal controlled and issued to a participant during a DRT test session for the purpose of eliciting a specified *response* (3.21)

3.10
hit
response (3.21) initiated within 100 ms to 2 500 ms from the *stimulus onset* (3.29), not preceded by an earlier response in the same interval

Note 1 to entry: Hit is synonymous with valid response.

3.11
hit rate
number of *valid responses* (3.33) divided by the total number of stimuli presented in a data collection segment, excluding premature responses to stimuli

Note 1 to entry: See *premature response* (3.17).

3.12
missing response
absence of a *response* (3.21) within 100 ms to 2 500 ms after *stimulus onset* (3.29)

3.13
motor demand
demand for *motor resources* (3.13) imposed by a *task* (3.30)

3.14
motor resources
brain systems implementing the control of motor actions

3.15
perceptual demand
demand on *perceptual resources* (3.15) imposed by a *task* (3.30)

3.16
perceptual resources
brain systems implementing perception

Note 1 to entry: Perceptual functions include lower-level, modality-specific perception (e.g. visual and auditory perception), as well as higher-level cross-modal perceptual integration.

3.17
premature response
response (3.21) initiated within 100 ms from the *stimulus onset* (3.29), prior to the timing interval for a *valid response* (3.33)

3.18
primary task
driving or driving-like *task* (3.30) used in the surrogate driving, driving simulator or on-road DRT experimental setups

3.19
repeated response
response (3.21) initiated within 100 ms to 2 500 ms after the *stimulus onset* (3.29) that is preceded by an earlier response in the same interval

3.20
resources
systems in the brain or body that can be utilized to perform *tasks* (3.30)

3.21
response
signal generated by the participant pressing the response button

3.22
response time
time from the *stimulus onset* (3.29) until the response onset

Note 1 to entry: Response time is only defined for valid responses.

3.23
secondary task
task (3.30) that may be performed while driving but that is not concerned with the momentary real-time control of the vehicle

Note 1 to entry: Examples include operating the media player, conversing on the phone, reading road-side commercial signs and entering a destination on the navigation system. Thus, secondary tasks may be driving-related.

3.24
sensory demand
demand on *sensory resources* (3.24) imposed by a *task* (3.30)

3.25
sensory resources
human body systems used to sense the exterior environment or internal bodily states

Note 1 to entry: Examples of sensory resources include the eyes, the ears, the skin, etc.

3.26
stimulus duration
time during which the stimulus is turned on

Note 1 to entry: The maximum stimulus duration is set at 1 s.

Note 2 to entry: Stimulus duration depends on responses. The maximum stimulus duration represents the pre-set duration of the stimulus in the absence of a response. If the response is initiated prior to maximum stimulus duration, the stimulus is turned off.

3.27
stimulus cycle period
time from the onset of a stimulus until the onset of the next stimulus

3.28
stimulus offset
point in time when the *DRT stimulus* (3.9) is turned off

3.29
stimulus onset
point in time when the *DRT stimulus* (3.9) is turned on

3.30
task
process of achieving a specific and measurable goal using a prescribed method

3.31
trial
test of one participant undertaking one *secondary task* (3.23) one time

3.32
unrequested response
response (3.21) given later than 2 500 ms after the *stimulus onset* (3.29)

3.33
valid response
response (3.21) initiated within 100 ms to 2 500 ms from the *stimulus onset* (3.29), not preceded by an earlier response in the same interval

Note 1 to entry: Valid response is synonymous with *hit*.

3.34
visual angle
angle subtended at the eye by a viewed object or separation between viewed objects

Note 1 to entry: Measurement of visual angle is made edge to edge.

3.35
visual eccentricity
visual angle (3.34), relative to the centre of the fovea, at which a certain visual stimulus impinges on the retina

Note 1 to entry: Measurement of visual eccentricity is made from centre of eye to centre of visual stimulus.

3.36
working memory
executive and attentional aspect of short-term memory involved in the interim integration, processing, disposal and retrieval of information

4 Abbreviated terms

ANOVA	analysis of variance
B	baseline
DRT	detection-response task
HDRT	head-mounted DRT
HR	hit rate
MR	miss rate
N0	0-Back
N1	1-Back
OEM	original equipment manufacturer
R	response
RT	response time
RDRT	remote DRT
SE	easy SuRT
SH	hard SuRT
TDRT	tactile DRT

5 DRT methodology: Principles and overview

The DRT method is based on a simple detection-response task where participants respond to relatively frequent artificial stimuli presented with a specified degree of temporal uncertainty. Detection performance, measured in terms of response time and hit rate, is assumed to represent the degree to which attention is affected by the demand and, in particular, the cognitive load component imposed by the secondary task under evaluation. Longer reaction times and reduced hit rate are indicative of higher cognitive load.

The method may be implemented in several different ways, depending on the purpose of the study. The DRT versions specified by this document differ in terms of stimulus presentation modality and experimental setup, as further described below.

6 Measurement methods and procedures

6.1 Participants

Participants should be licensed drivers with a similar level of prior experience with the secondary task under evaluation. Other relevant characteristics of the participants shall be recorded, including at least driving experience (e.g. miles or km driven in the last year), similar device use experience, gender, age and previous experience with the DRT.

6.2 Experimental setup

The DRT may be used in different experimental setups as described below.

6.2.1 Non-driving experimental setup

In this setup, the DRT is performed concurrently with the secondary task under evaluation in a non-driving situation. This means that attention is divided between the secondary task under evaluation and the DRT, without simultaneous performance of a primary (driving or driving-like) task. DRT performance with the secondary task is assessed relative to a baseline condition where only the DRT is performed. The non-driving version of the DRT may be used to assess how a secondary task affects selective attention in any non-driving setting, including production vehicles, vehicle mock-ups or at a desktop.

6.2.2 Surrogate driving experimental setup

In this setup, the DRT is performed concurrently with the secondary task under evaluation while the participant performs a surrogate task that functions as the primary task of driving. This surrogate task could be a simple tracking task, watching a video of real-world driving recorded from the driver's viewpoint or a combination of such elements. DRT performance during the combined secondary task and surrogate driving is assessed relative to a baseline condition where the DRT is performed with only the surrogate driving task.

6.2.3 Driving simulator experimental setup

In this setup, the DRT is performed concurrently with the secondary task under evaluation while the participant drives a driving simulator. DRT performance during the combined secondary task and simulator driving is assessed relative to a baseline condition where the DRT is performed while only driving the simulator. The same scenario is used in both conditions.

6.2.4 On-road experimental setup

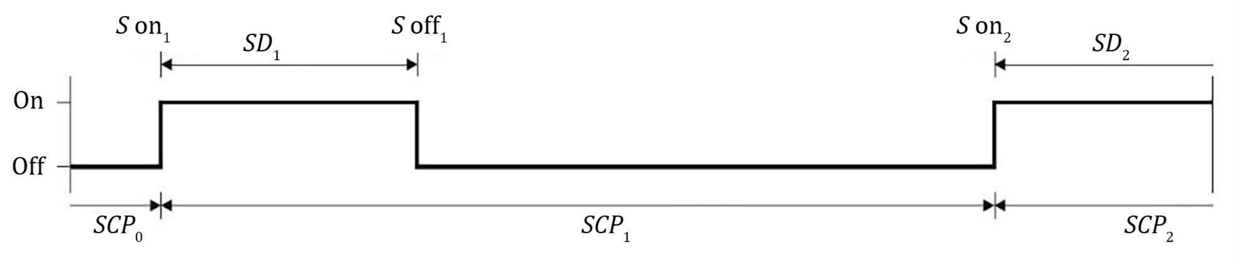
In this setup, the DRT is performed concurrently with the secondary task under evaluation while the participant drives on a closed track or an open road with traffic. Appropriate safety concerns shall be addressed for on-road testing. DRT performance during the combined secondary task and driving is assessed relative to a baseline condition where the DRT is performed while only driving.

6.3 Stimulus presentation

This document specifies three alternative methods for presenting the DRT stimulus. This includes two methods where the stimulus is presented visually and one method where the stimulus is provided by means of tactile stimulation. In the head-mounted DRT (HDRT), a visual stimulus (an LED) is presented through a fixture attached to the head of the participant at a specified visual angle. In the remote DRT (RDRT), a visual stimulus (e.g. an LED or embedded graphic in simulator scenario) is presented in the forward view of the participant. Finally, in the tactile DRT (TDRT), a tactile vibrator is placed on the participant's body. These stimulus presentation methods are described in further detail below. Guidelines for the selection of stimulus presentation mode depend on the purpose of the experiment and are provided in Annex B.

6.3.1 Stimulus presentation timing

The stimulus presentation timing is the same for all three stimulus presentation methods. Figures 1 and 2 illustrate the key principles. The stimulus onset (S_{on}) represents when the stimulus is turned on and the stimulus offset (S_{off}) when it is turned off. The *stimulus duration* (*SD*) represents the time during which the stimulus is turned on and the *maximum stimulus duration* (SD_{max}) represents the pre-set maximum duration of the stimulus. SD_{max} should be set to 1 s. The *stimulus cycle period* (*SCP*) represents the time from the onset of one stimulus until the onset of the next stimulus. The stimulus cycle period shall vary and be drawn randomly from a uniform distribution of values between 3 s and 5 s.



Key

S_{on} stimulus onset
S_{off} stimulus offset
SD stimulus duration
SCP stimulus cycle period

Figure 1 — Definition of parameters relevant for stimulus presentation specification

A signal generated by the participant pressing the response button is referred to as a response (R). If the participant responds while the stimulus is turned on, the stimulus is turned off at the moment of response (see Figure 2).

Key

S_{on} stimulus onset
S_{off} stimulus offset
SD stimulus duration
SD_{max} maximum stimulus duration
R response

Figure 2 — Illustration of how the stimulus duration is determined by the response (R)

6.3.2 Visual stimulus specifications

6.3.2.1 Head-mounted visual stimulus

In the head-mounted DRT, the visual stimulus shall be presented by means of a single LED presented on a stalk attached to the participant's head. Compared with the remote DRT, the head-mounted DRT has the main advantage that it is not affected by drivers' head motion or if drivers look away from the forward view. Figure 3 shows the setup for the head-mounted DRT. The LED should be supported by a black frame as shown in Figure 3 and should be positioned to the left if the vehicle has the steering wheel to the left and to the right for vehicles with the steering wheel to the right. For a non-driving experimental setup, the LED should be placed either to the left or right, but in a way that visual interference with the secondary task is minimized. More precisely, the LED should be positioned 20° to the left or right (depending on steering wheel position) along the horizontal meridian and 10° above the vertical meridian, using the left or right eye as reference point, as illustrated in Figure 3. The distance between the eye closest to the LED and the LED should be 12 cm to 13 cm. The position of the LED should be verified on a human or manikin head prior to beginning the experimental trials. However, it does not have to be measured individually for each subject. Recommended default specifications for the LED are given in Table 1. The luminous intensity of the LED should be adjusted to the lighting conditions in the experimental setup so that the visual stimulus is easily detectable while not inducing discomfort or harm to the participant.

Table 1 — Recommended specifications for the LED for the head-mounted DRT

Parameter	Value
Colour	Red
Dominant wavelength	626 nm
LED response time	90 ns
Diameter	5 mm
Maximum luminous intensity	0,055 cd

Care should be taken to ensure that no portion of the LED is in the blind spot of the left eye. This can be ensured by covering the right eye (when the LED is positioned to the left) and asking the test subject to fixate straight ahead with the left eye. The entire LED (when continuously on) should then be clearly visible in the peripheral visual field of the left eye (when the LED is positioned to the right, the reverse applies).

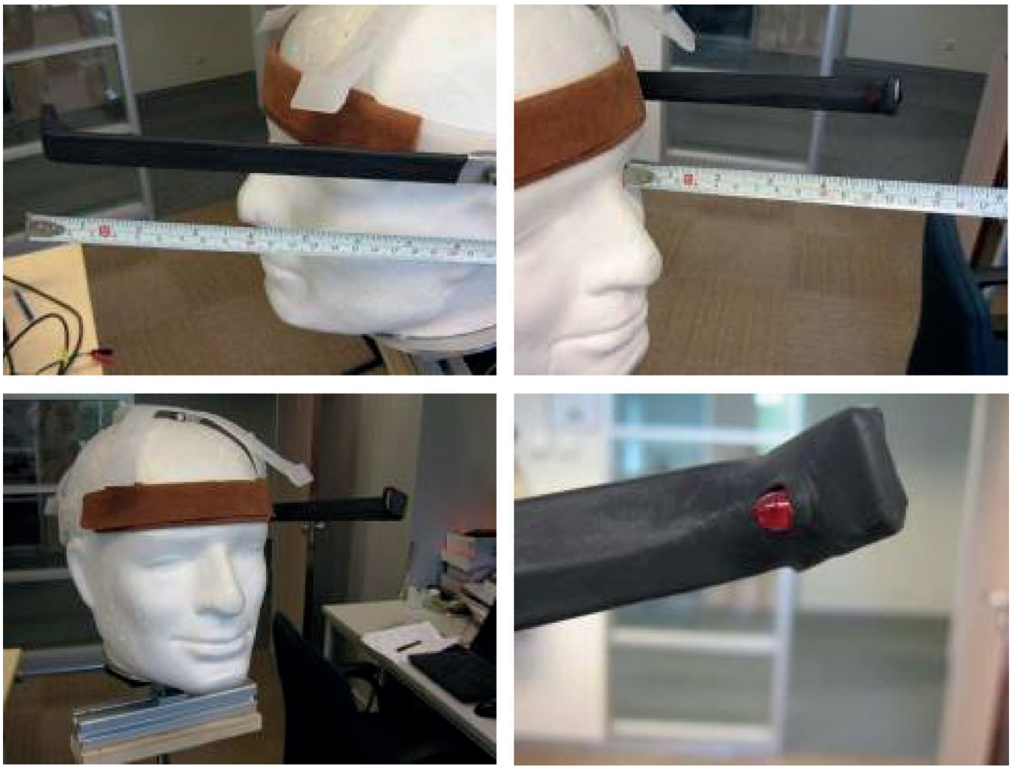


Figure 3 — Illustration of the setup for the head-mounted DRT

6.3.2.2 Remote visual stimulus

The stimulus for the remote DRT can be implemented as a single LED or, in driving simulator setups, as a graphical object displayed in a fixed location in the visual display. If an LED is used to generate the stimuli, it should be placed remotely from the participant, and should be clearly perceptible when gaze is directed straight towards the forward roadway. The LED should be directly perceived by the driver (i.e. not only indirectly perceived, for example, through reflection in the windshield). The exact positioning of the LED depends on the experimental setup. For example, in a passenger vehicle or simulator mock-up, the top of the dashboard would be a suitable position for the LED, as long as it is not occluded by the steering wheel. In outdoor conditions, care should be taken to find a position where the influence of ambient lighting on stimulus visibility is minimized (e.g. by means of shielding).

Recommended default specifications for the LED are given in Table 2. The luminous intensity of the LED should be adjusted to the lighting conditions in the experimental setup so that the visual stimulus is easily detectable while not inducing discomfort or visual impairment to the participant.

Table 2 — Recommended specifications for the LED for the remote DRT

Parameter	Value
Colour	Red
Dominant wavelength	626 nm
LED response time	90 ns
Diameter	5 mm (placed at a distance that subtends approximately 1°)
Image luminance	2 cd/m2

The exact position of the RDRT stimulus (distance from the participant, visual angle, etc.) shall be reported in each experiment. If the stimulus is presented graphically on a visual display, the stimulus