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Road vehicles — Ergonomic aspects of transport information and control systems — Occlusion method to assess visual demand due to the use of in-vehicle systems

Véhicules routiers — Aspects ergonomiques des systèmes d'information et de contrôle du transport — Méthode par occlusion pour évaluer la distraction visuelle due à l'utilisation des systèmes embarqués

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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 16673 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics applicable to road vehicles*.

Introduction

A wide range of information and communication devices and advanced driver assistance systems are being introduced into motor vehicles. These include navigation aids, emergency messaging systems and wireless communication including email and internet access, which are all accessible to the driver of a motor vehicle. Many of these features have associated visual information that can potentially both inform and distract. To help ensure that the use of such devices and features that are meant to be used by the driver while driving do not result in excessive visual demand, a consistent, verifiable and repeatable method to determine the visual demand imposed by such in-vehicle systems is needed.

Developing precise mathematical predictions of the risk of a crash due to driver distraction from using a particular driver interface is difficult. However, it can be reasonably stated that if drivers are not looking at the road (e.g. looking inside the vehicle to operate a control or read a display), then the probability for a crash is increased [1].

This International Standard is not intended to preclude direct measurement of eye glances as a method to assess visual demand. Direct measurement of eye glances is always desirable. However, direct measurements of eyes-off-the-road times, i.e. glance time measurements, are typically difficult and very costly to measure. The occlusion method estimates visual demand, including resumability, of a task using a means for intermittent viewing of the in-vehicle system. Evaluation by occlusion identifies driver interfaces that are likely to take the driver's eyes away from the road for excessively long durations. Additional data collected without occlusion can be combined with occlusion data to calculate R, a measure believed to identify whether or not tasks can be easily resumed after the driver interrupts the task to look back at the road. This procedure does not require extensive resources and can be applied if a functioning prototype of the driver interface exists.

Road vehicles — Ergonomic aspects of transport information and control systems — Occlusion method to assess visual demand due to the use of in-vehicle systems

1 Scope

This International Standard 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 Original Equipment Manufacturer (OEM) and After-Market in-vehicle systems. It applies to both permanently installed and portable systems. It applies to any means of visual occlusion and is not dependent on one specific physical implementation.

2 Terms and definitions

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

2.1
driver accessible
available to the driver such that the interface controls necessary to complete the task are within the reach of the unrestrained driver and the interface display is visible with a head movement, and the system is operable by the driver

NOTE 1 See ISO 3958 [2] for driver reach of the restrained driver, and SAE J1050 [3] for head movement.

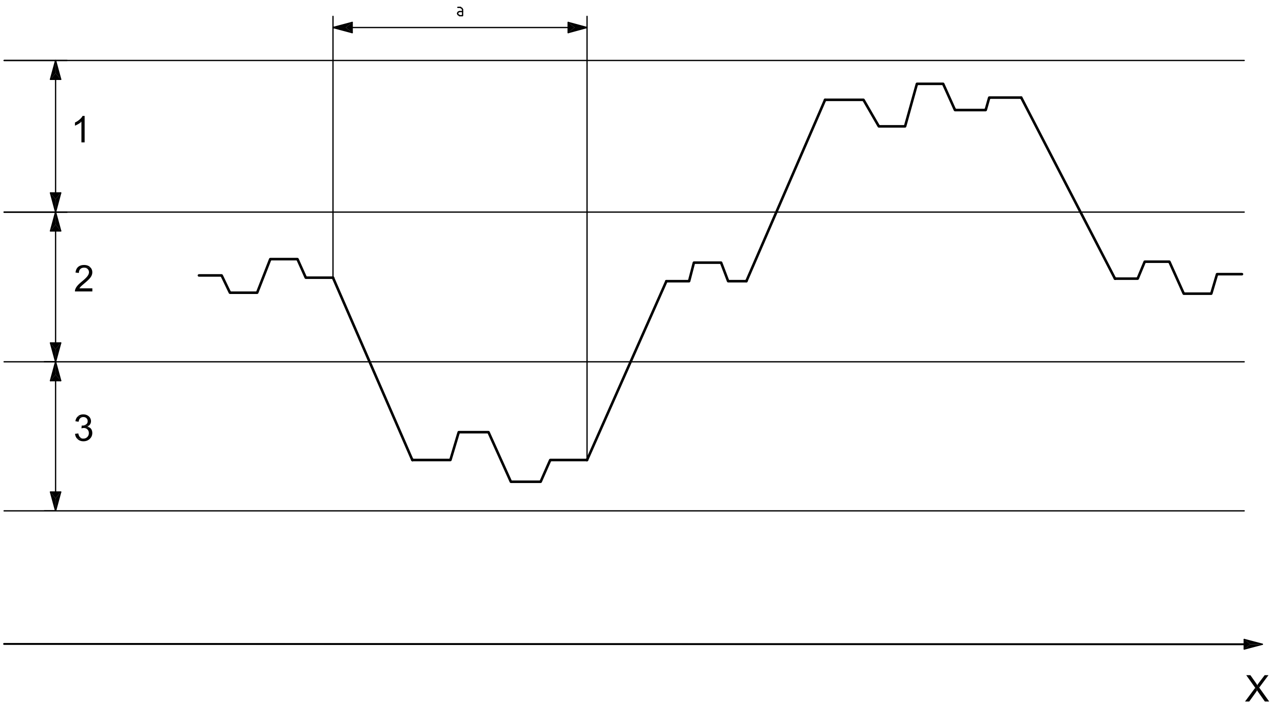
NOTE 2 The driver interface includes the visual display and any relevant controls.

EXAMPLE A nomadic or portable device such as a PDA outside of the reach of a restrained driver is still considered driver accessible if within the reach envelope of an unrestrained driver.

2.2
glance duration
time from the moment at which the direction of gaze moves towards a target (e.g. the interface display) to the moment it moves away from the target

NOTE 1 This includes the transition time to that target as shown in Figure 1 simplified from Figure A.2 in ISO 15007-1 [4].

NOTE 2 A single glance duration may also be referred to as a glance.



Key

X time

1 target B (e.g. the interior mirror)

2 target A (e.g. the roadway)

3 target C (e.g. in-vehicle display)

[a] Glance duration.

Figure 1 — Chronological relationship of driver visual allocation between target regions

2.3
goal
system end state sought by the driver and which is meaningful in the context of a driver's use of an in-vehicle system

EXAMPLES Obtaining guidance to a particular destination, magnifying a map display, or cancelling route guidance.

2.4
integrated system
two or more in-vehicle devices, which provide information to, or receive output from, the driver of a motor vehicle, whose input and/or output have been combined or harmonized

EXAMPLE 1 An in-vehicle entertainment system and route guidance system which use the same visual and manual input portals and visual and auditory output portals.

EXAMPLE 2 An in-vehicle entertainment system whose auditory output mutes when a mobile phone call is made or received.

2.5
occlusion interval
time during which the driver interface is not visible when using an occlusion procedure

2.6
outlier
observation that lies outside the overall pattern of the sample data distribution [5]

2.7
portable system
device, which provides information to, or receives output from the driver of a motor vehicle, that can be used within the vehicle without installation or can be rapidly and easily installed in and removed from a vehicle

2.8
resumability
ease with which a dialogue can be continued after it is interrupted

NOTE A dialogue is considered resumable if task performance continues without a significant degradation after an interruption.

2.9
resumability ratio
R
ratio of the duration of the total shutter open time ($TSOT$) to the total task time unoccluded (TTT_{Unoccl}), i.e. $TSOT/TTT_{\text{Unoccl}}$

2.10
system response delay
SRD
interval during which the driver has to wait for an interface to respond or update in order to continue a task

EXAMPLE Waiting for an off-board computer to be queried or waiting for a voice message to be generated.

2.11
task
process of achieving a specific and measurable goal using a prescribed method

NOTE Ultimately, it is for the users of this International Standard to determine tasks that are meaningful in the context of a driver’s use of a system.

EXAMPLE 1 Obtaining guidance by entering a street address using the scrolling list method, continuing until route guidance is initiated (visual-manual task).

EXAMPLE 2 Determining where to turn based on a turn-by-turn guidance screen (visual task).

2.12
total shutter open time
TSOT
total time that vision is not occluded when using an occlusion procedure

NOTE *TSOT* is the sum of vision intervals required for the task of interest.

2.13
total task time occluded
TTT_{Occl}
total time to complete the task of interest, including both unoccluded and occluded intervals, while using a visual occlusion procedure

2.14
total task time unoccluded
TTT_{Unoccl}
total time required to complete the task of interest without using a visual occlusion procedure and without any concurrent task

2.15
trial
investigation of one participant undertaking one repetition of one task

2.16
vehicle in motion
vehicle whose speed relative to its supporting surface is “nonzero”

NOTE Practical limitations on existing vehicle sensors may cause small velocities (typically not more than 5 km/h) to be registered as zero.

2.17
vision interval
discrete time during which the driver interface is visible when using an occlusion procedure

NOTE Vision interval is also the shutter open time (*SOT*).

2.18
visual demand
amount of visual activity required to extract information from an interface of an in-vehicle system to perform a specific task

NOTE In general, visual demand depends on the quantity of information to be extracted and the ease with which information extraction can be resumed following any interruption.

2.19
visual occlusion procedure
measurement method involving periodic obstruction of the participant’s vision or the obscuration of visual information under investigation

3 Measurement procedures

3.1 Set-up

Intermittent viewing of an interface can be provided by various means. The occlusion procedure approximates the driver looking back and forth between the forward driving scene and an in-vehicle interface, looking at each for a brief period of time. In addition to the commonly used goggles [7], occlusion can be achieved using blanking of the visual display or a shutter in front of the interface. Display blanking can be done by electronically turning the visual display on and off in accordance with the timing in 3.2. A shutter shall be opaque during the occlusion interval. This could be done electronically with a variable transmittance lens, such as that used in the occlusion goggles, or it could be done using a system of one or more mechanical shutters. In the latter case, the shutters should not interfere with operation of the manual controls. Whether using electronic or mechanical means, the switching process and restoration of the active screen display at the end of an occlusion interval shall occur in less than 20 ms. Early studies involving occlusion in the primary driving task (forward field of view) used a head mounted mechanical shutter.[17]

During the occlusion interval, neither the interface displays nor controls shall be visible, but operation of the controls shall be permitted (though most input to the interface might occur when vision is available). This protocol simulates drivers looking at the road but continuing to enter information via a manual control.

The system under investigation shall be operational and fitted to a vehicle, simulator buck, or mock-up in a design which duplicates the intended location of the interface in the vehicle (i.e. the viewing angle and control placement relationships shall be maintained). The ocular illumination levels in the vision and occlusion intervals should be comparable so that dark/light adaptation of the participants’ eyes is not necessary during the procedure.

The instruction shall be standardized and be presented either orally or in writing. The display and controls of the interface should be visible during instruction. An instruction may be repeated at the request of the participant.

3.2 Vision and occlusion intervals

The vision interval shall be 1,5 s and the occlusion interval shall be 1,5 s. These intervals are consistent with the occlusion literature (see [8] through [13]).

Periods of vision and occlusion shall automatically occur without interruption until the task is completed or the trial is terminated (see 4.6). Thus the pacing of the occlusion intervals is controlled by the system, rather than the participant.

3.3 Task timing

The total shutter open time (*TSOT*) shall be defined as follows:

— Start: Timing starts with the beginning of the first vision interval.

— End: Timing ends when the instructed task has been completed and the participant says he or she is "done".

— Duration: Tasks are timed from start to end without interruption, including errors and subtracting occlusion intervals. Individual system response delays greater than 1,5 s are accounted for by the procedure in Annex A. If the task is completed during a vision interval, then only that part of the vision interval that was used for the task should be included in the *TSOT*.

As an alternative, *TSOT* may be approximated by the number of vision intervals needed to complete the task multiplied by the 1,5 second vision interval. Another approximation is provided by $(TTT_{\mathrm{Occl}} / 3{,}0) \times 1{,}5$. Individual system response delays greater than 1,5 s are accounted for by the procedure in Annex A.

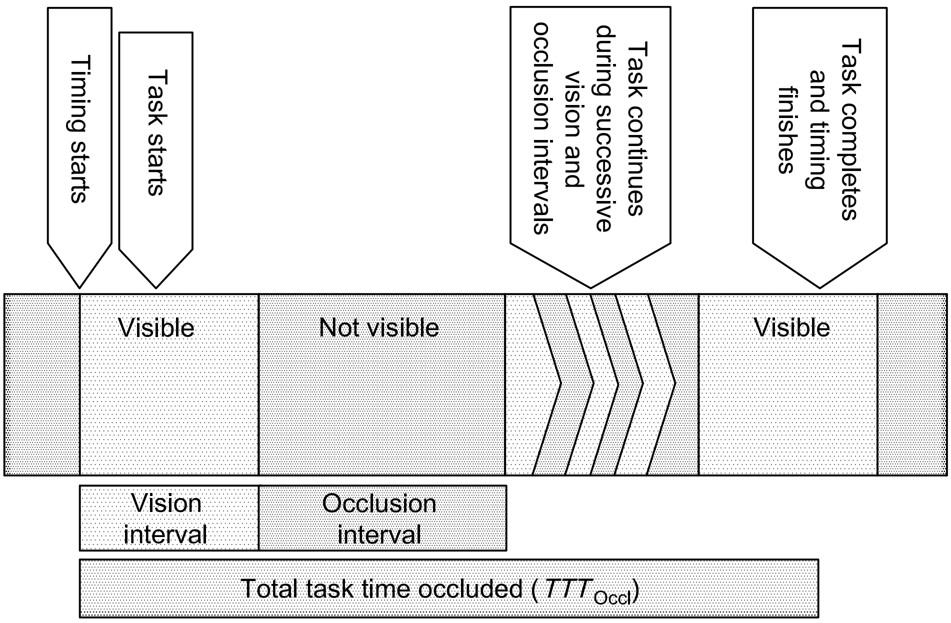


Figure 2 — Measurement of total task time in occluded conditions

The total task time unoccluded (TTT_{Unoccl}) shall be determined as follows:

— Start: Timing starts at the end of the task instruction.

— End: Timing ends when the instructed task has been completed and the participant says he or she is "done".

— Duration: Tasks are timed from start to end without interruption, including errors. Individual system response delays that are greater than 1,5 s are accounted for by the procedure in Annex A.

The total task time in occluded conditions (TTT_{Occl}) shall be determined as follows (see Figure 2):

— Start: Timing starts with the beginning of the first vision interval.

— End: Timing ends when the instructed task has been completed and the participant says he or she is "done".

— Duration: Tasks are timed from start to end without interruption, including errors. Individual system response delays that are greater than 1,5 s are accounted for by the procedure in Annex A.

3.4 Exclusion of trials

There may be occasions when a participant refuses to complete a trial, when a participant says he or she is done with a trial but they are not, when the experimenter judges that the participant cannot successfully complete a trial in spite of multiple efforts, and/or when there is a trial where the TTT_{Occl} is more than four times the average TTT_{Unoccl} for all the trials completed by that participant [15]. In such instances, the result should be documented and that trial excluded from the analysis. The participant should make a reasonable number of attempts to successfully complete five trials. If the majority of participants fail to complete five trials then the interface design should be reviewed. The experimenter may restate the task if necessary.

4 Assessing visual demand

4.1 Selection of tasks

This International Standard applies to any means of visual occlusion, but this method is not appropriate for tasks with duration less than approximately 5 s TTT_{Unoccl} 1).

EXAMPLE 1 Pressing a button to turn the audio system on or off.

EXAMPLE 2 Glancing at collision warning system/warning icon.

Once the task to be evaluated has been identified, the user should develop a number of examples of that task that are broadly the same, but ideally not identical. For example, for the task "Route guidance destination entry by postcode", there shall be a number of possibilities, e.g. RG40 3GA and GU21 6AG. Some of these are used for practice trials and the others for the test trials.

4.2 Participants

Consistent with conventional human factors practice, at least ten participants should be involved in the evaluation of each Human Machine Interface (HMI) configuration. Ten participants is a small enough sample that the evaluation procedure can be applied with reasonable effort, time and expense; yet it is large enough to provide a meaningful statistical assessment when there are five trials per participant. [15]

1) The occlusion procedure described in this International Standard does not apply to tasks shorter than 5 s, because there are not enough shutter open and closed periods. In this case, the resolution of the methodology is inadequate.

The participants shall be licensed drivers for the class of vehicle being studied (automobile, truck, etc.) whose knowledge and familiarity with the specific driver interface under investigation is typical of the general driving population. Persons who have specific technical knowledge or familiarity with the system being studied shall not be included as test participants. Other relevant characteristics of the participants should be recorded (e.g. gender, age and driving experience). At least 20 percent of the participants should be over 50 years of age.

4.3 Training

Before the first training session, each participant should be familiarized with the occlusion procedure using a similar visual-manual task. Prior to conducting the test trials per 4,4 for each task, the participant should be given a clear explanation of the system operation and the task of interest. Each participant should have at least two and up to five practice trials for each task being investigated. Fewer than five practice trials can be used if the participant is judged to be adequately prepared for the task. Participants shall be told that they may operate the controls during an occluded period. The participant should be required to successfully complete a task without intervention from the experimenter and to verbally acknowledge that he or she is “comfortable with the task”. Note that the participant should be trained on a given task just before administering the test trials for that task. The participant should not be trained on all tasks prior to the test trial for a given task. The number of practice trials should be recorded for each participant and task.

At least two of these practice trials should use the occlusion procedure.

Any data to be viewed or entered for the specific tasks in practice trials should be different from that in test trials but equivalent in difficulty. The aim should be for each practice task to be properly completed using the designated method; the experimenter should aim to ensure the appropriate completion of the task by providing coaching or assistance if the participant is having problems with the task. If participants cannot successfully complete the practice task at least once in five trials, then the interface design and training protocol should be reviewed.

The participant shall be instructed to say “done” at the moment he or she believes that the task is completed.

4.4 Test trials

After training, each participant should be tested individually. As each trial is completed, the participant should be given the next trial. Coaching should not be provided during test trials but feedback on errors is permitted when a trial is completed. “Successful” or “not successful” completion of the task shall be recorded for each trial.

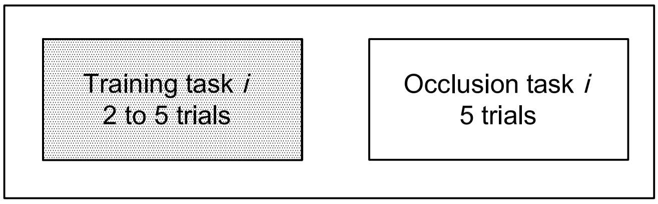
For each task, each participant shall be asked to complete five trials. The specific data to be viewed or entered for each of the five test trials should be unique but representative of the level of difficulty for that task. If there are two or fewer successful trials out of five for two or more participants, the task or interface design should be reviewed.

4.5 Experimental plan

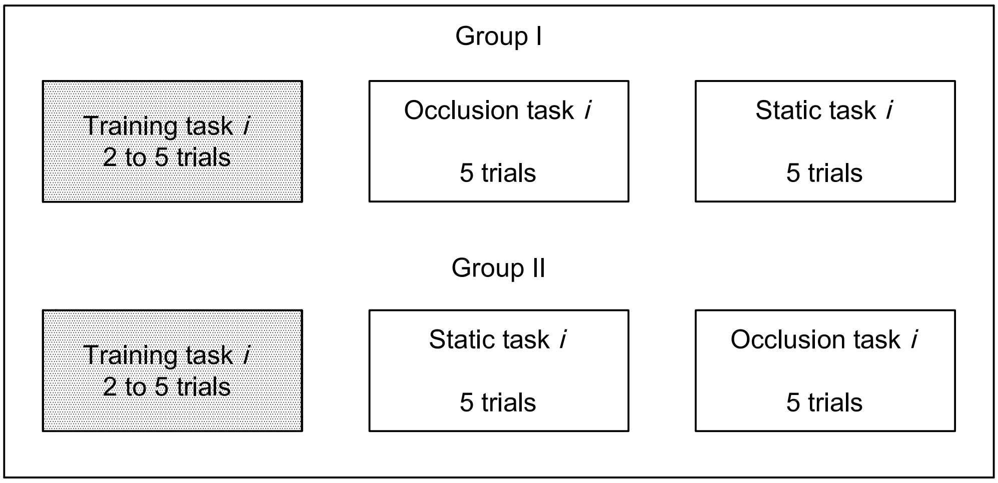
The experimental plan will depend on whether the user is calculating only the TSOT metric, or both TSOT and R metrics. These metrics are described in 4.6.

To calculate only TSOT, there is no need to conduct unoccluded (static) test trials. The test plan is shown in Figure 3 a).

Measurement of R requires a comparison of occluded and unoccluded (static) measurements. An experimental plan to accomplish such a comparison should be designed to avoid carry-over or training effects between the conditions [(see Figure 3 b)]. The plan should also ensure that instructions to participants are identical and that tasks are of equivalent difficulty (see [6] for an example).



a) When calculating *TSOT* only, static (unoccluded) condition is not needed



b) When calculating *R*, balancing occluded and unoccluded (static) conditions using two groups of participants

Figure 3 — Test plan for each task

4.6 Calculation of visual demand metrics

Testing with visual occlusion encourages the design of driver-vehicle interface dialogues that can be completed in a few, brief glances by identifying those dialogues that require more sustained visual attention. The methods for calculating *TSOT* and *R* are described in this International Standard.

4.6.1 Calculating *TSOT*

The *TSOT* value shall be recorded for each trial for a given task as described in 3.3.

If one of the *TSOT* values is an outlier [2], it should be removed from the data.

The mean value of *TSOT* for each participant shall then be calculated. If n_j is the number of usable (successful) trials completed by participant j and k is the trial number, then the mean value of $TSOT_j$ for participant j is given by the sum of the individual usable *TSOT* values from that participant j divided by n_j. See Equation (1).

$$\overline{TSOT}_j = \frac{1}{n_j} \sum_{k=1}^{n_j} TSOT_{jk} \qquad (1)$$

2) An outlier is an observation that lies outside the overall pattern of a distribution. Usually the presence of an outlier indicates some sort of problem. This can be a case which does not fit the model under study or an error in measurement.

The number of trial values for each participant may not be the same (e.g., because a different number of successful trials were completed or an outlier has been removed). This leads to N values of $\overline{TSOT}$, one for each participant, as shown in Table 1. The overall mean value of $TSOT$ for a given task is given by Equation (2).

$$\overline{TSOT} = \frac{1}{N}\sum_{j=1}^{N}\overline{TSOT}_j \tag{2}$$

Table 1 — Calculation of the $TSOT$ value for a given task from participant trial data

Participant	Trial 1	Trial 2	..	Trial k	..	Trial n	Mean
1							$\overline{TSOT}_1$
2							$\overline{TSOT}_2$
...							
j				$TSOT_{jk}$			$\overline{TSOT}_j$
...							
N							$\overline{TSOT}_N$

For a given task with N participants, four summary statistics shall be reported for the $TSOT$ metric:

a) Mean of the N values of $\overline{TSOT}_j$ [see Equation (2)]

b) Standard deviation of the N values of $\overline{TSOT}_j$ [see Equation (3)]

$$s_{\overline{TSOT}} = \sqrt{\frac{N\sum_{j=1}^{N}\overline{TSOT}_j^{\,2} - (\sum_{j=1}^{N}\overline{TSOT}_j)^2}{N(N-1)}} \tag{3}$$

c) Median of the N values of $\overline{TSOT}_j$

d) 85th percentile value of the cumulative distribution function of the N values of $\overline{TSOT}_j$

The 85th percentile value is estimated by plotting the set of values (on the Y-axis) in order of magnitude using a linear scale (on the X-axis). The 85th percentile value is that value on the Y-axis corresponding to a point at 85 % of the range on the X-axis.

It is for the users of this International Standard to determine the exact value of $TSOT$ to be used as a criterion when evaluating a given interface.

4.6.2 Calculating R

A second purpose of testing with visual occlusion is to encourage driver-vehicle interface interactions that can be easily resumed after interruption (e.g. to attend to the primary driving task) [16], [17]. The resumability ratio, R, shall be calculated as follows.

To obtain the R ratio users shall first calculate the total task time unoccluded (TTT_{Unoccl}) for each participant as described in 3.3.

If one of the TTT_{Unoccl} values is an outlier, it should be removed from the data.

The mean value of TTT_{Unoccl} for each participant is then calculated. If n_j is the number of usable trials completed by participant j, then the mean value of TTT_{Unoccl} for participant j is given by the sum of the individual $TSOT$ values from that participant j divided by n_j. See Equation (4).

$$\overline{TTT_{\text{Unoccl}\,j}} = \frac{1}{n_j}\sum_{k=1}^{n_j} TTT_{\text{Unoccl}\,j,k} \tag{4}$$

Note that the number of trial values for each participant may not be the same (e.g. because a different number of trials were successfully completed or an outlier has been removed). This yields N values of TTT_{Unoccl}, one for each participant, as in Table 1.

For a given task the ratio $\overline{R_j}$ can then be calculated for each participant as shown in Equation (5).

$$\overline{R_j} = \frac{1}{n_j}\sum_{k=1}^{n_j} \frac{TSOT_{j,k}}{TTT_{\text{Unoccl}\,j,k}} \tag{5}$$

The R value for a given task is the mean R value for all participants as given by:

$$\overline{R} = \frac{1}{N}\sum_{j=1}^{N} \overline{R_j} \tag{6}$$

If either one of the $TSOT$ or TTT_{Unoccl} values is an outlier, it should be removed from the data and the R value should not be calculated for that trial. Note that the number of trial values for a given task for each participant may not be the same (e.g. because a different number of trials were completed or an outlier has been removed). The result is N values of R, one for each participant.

For each task the following four summary statistics should be reported for the R metric:

a) Mean of the N values of $\overline{R_j}$ [see Equation (5)].

b) Standard deviation [3] of the N values of $\overline{R_j}$.

c) Median of the N values of $\overline{R_j}$.

d) 85th percentile value of the cumulative distribution function of the $\boldsymbol{N}$ values of $\overline{R_j}$.

3) Because the mean $\overline{R_j}$ is calculated for each participant, the data set per task is reduced from n_{jk} to N. When the standard deviation of this reduced data set is calculated, the intra-subject variability is removed (only inter-subject variability remains).

4.6.3 Interpretation of results

There are two options for applying the metrics *TSOT* and *R*:

a) the user may calculate only *TSOT*, or

b) the user may calculate both *TSOT* and *R*.

The mean and standard deviation are common summary statistics but have limitations when the data are skewed. Alternatively, the 85th percentile value emphasizes the tail of the distribution and represents a reasonable worst case value for the parameters.

NOTE This International Standard gives no guidance regarding specific criterion values for *TSOT* or *R*. It is up to users to establish their own criteria. Further, if both *TSOT* and *R* are calculated this International Standard provides no guidance regarding how the user should apply both *TSOT* and *R*.

Annex A
(informative)

System response delay

A.1 Introduction

TTT_{Unoccl}, TTT_{Occl} and *TSOT* measurements can be influenced by the presence of a system delay or lag in system response after an input by the participant. Thus, in terms of task timing (see 3.3), these parameters may not be correct when the participant is “idle” for part of the time, waiting for the system, which has notified the participant that it is performing some calculation or consulting a (possibly off-board) database.

When a system delay occurs while driving, the driver shall recognize that the system is busy calculating or retrieving information, and that no further dialogue is possible. If the system delay is long (more than a few seconds) the driver will look back to the road and may engage in a number of “check-glances” to the in-vehicle display to confirm the status of the system. Since several shutter open periods could occur between the onset and conclusion of the system response delay (*SRD*), *TSOT* is "artificially" increased relative to the actual total glance time (*TGT*) for the task under study. Then, when the system resumes its function and informs the driver, the driver shall recognize that the system delay is finished and that the task can now be continued.

It should be noted, however, that to date little research is available on the effects of *SRD* on driver visual demand. It is not known, for example, to what extent visual demand varies with the length of an *SRD*. It is not known to what extent drivers use the *SRD* periods to look at the road (vs. glance at the device or system). Further, the mode and content of indicators used to inform drivers that an *SRD* is active or terminated may have differing effects on visual demand and eye glance behaviour. Indicators of an *SRD*-active state that are *visual* in nature may trigger glances to a display, while auditory indicators may not. Some visual indicators may lead to very brief “check” glances, while others may lead to longer or more frequent looks. Visual indicators of an *SRD*-terminated state may lead to frequent looks, whereas auditory indicators of *SRD*-termination may allow the driver to look at the road until information is displayed on the screen after the *SRD* has ended. Thus, empirical research is limited, on *SRDs* as well as on *SRD*-state indicators, and on the effects these have on visual demand.

Given the state of knowledge on these issues, caution is advised in applying and interpreting the estimation procedures described in A.2. Users should understand that when an *SRD* is involved in a task, it may be most appropriate to set aside occlusion-based methods and instead apply direct measurement of eye glances. Direct monitoring of eye glance under these task conditions (presence of an *SRD* and *SRD*-state indicators) will yield actual measurement of visual demand (*TGT*), and actual information about the pattern of visual demand during the task. Application of the occlusion-based procedure in A.2 will yield only estimates, and those estimates may or may not correspond well with actually-measured direct eye glance data, depending on the particular types of *SRD* and indicators involved.

Recognizing the preceding caveats, users may apply the procedures given in A.2 to estimate *TSOT* when a system response delay (*SRD*) occurs while the driver is performing a task. The impact of check-glances to the display is assumed to be minimal in terms of their contribution to the driver’s visual demand, and this factor is not considered further (although it could be revisited if experimental evidence becomes available).

A.2 Including system response delay (*SRD*) within occlusion protocol

This procedure shall apply to each trial when there is a system delay greater than 1,5 s that is clearly indicated to the test participant. No correction shall be applied to individual system delays of less than 1,5 s.

An *SRD* shall be clearly indicated to the participant if the following two criteria are met:

— The system provides an indication by visual or other means that an *SRD* is active; and

— the system provides an indication by visual or other means that the *SRD* has terminated.

Generally, an *SRD* will begin during an open period (after the participant has made an input). Its duration can be assumed to be variable, depending on the request or information to be retrieved. Over a number of trials, there will be a mean *SRD*, but any particular *SRD* may finish during an open or closed period (see Figure A.1).

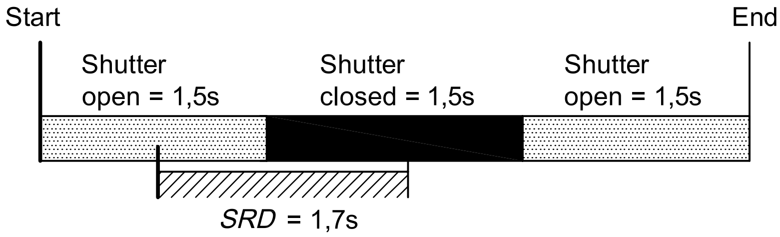


Figure A.1 — Timing of *SRD* relative to vision and occlusion intervals

The *SRD* could simply be subtracted from the total task time occluded and the *TSOT*. However, this would not be correct because with fixed occlusion and viewing intervals, in general, only part of the *SRD* will occur during a vision interval and part during an occlusion interval. The *SRD* is most likely to start towards the end of a vision interval, and on average, the *SRD* is more likely to finish during an occlusion interval than a vision interval.

Any *SRD* that occurs during an occlusion interval will not affect the determination of visual demand under the occlusion protocol (because the participant is occluded, i.e. simulating looking at the road scene). An *SRD* that occurs during the vision interval represents time that the participant does not need to attend to the in-vehicle device. Thus, the issue is to evaluate the part of *SRD* occurring during a vision interval, and a number of approaches are possible:

If the experimenter can determine with a precision of one interval when an *SRD* begins and ends, then the following protocol shall be used:

SRD start:

— The participant needs all of the vision interval during which an *SRD* starts to realize that the *SRD* is active. All of this vision interval is counted as interaction time.

SRD end:

— If the *SRD* finishes during an occlusion interval, then the participant's interaction can re-commence at the beginning of the next vision interval;

— if the *SRD* finishes during a vision interval, then all of the vision interval is counted as interaction time.

Under this protocol, the maximum error in any *individual* measurement will be one vision interval for *SRD* start, and one vision interval for *SRD* end less the time taken for the participant to realize that an *SRD* is active. On average, over a number of trials, this error is likely to be less than about one vision interval. The error will always tend to overestimate the visual demand of a system with *SRD* (but this is not unreasonable, as participants would prefer no perceptible delay).

If the *SRD* is greater than 1,5 s, and is clearly indicated to the participant, the parameters TTT_{Unoccl} and TTT_{Occl} and *TSOT* shall be replaced in the calculation of visual demand by the parameters NTT_{Uoccl} and NTT_{Occl} and *NSOT* where the new parameters are determined as follows:

Net task time unoccluded (NTT_{Unoccl}) $NTT_{\text{Unoccl}} = TTT_{\text{Unoccl}} - SRD$

Net task time occluded (NTT_{Occl}) $NTT_{\text{Occl}} = TTT_{\text{Occl}} - SRD$

Net shutter open time (*NSOT*) $NSOT = TSOT - V \times$ Vision Interval Duration

where *V* is the number of vision intervals during which the *SRD* is active, and is calculated as follows:

— *V* begins at the beginning of the vision interval during which the *SRD* starts (i.e. $N = 0$);

— *V* increments for each vision interval during which the *SRD* is active.

If the *SRD* finishes during a vision interval, then *V* is not incremented by one for that vision interval.

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