European Commission

Technical support to assess the upgrades necessary to the advanced driver distraction warning systems

Final Report

Written by Laxton, V.; Oliveira, E.; Stuttard, N.; Avis, A.; Hosten, P.
Reviewed by Hynd, D.

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Contact: Romain Ladret Piciorus

E-mail: *grow-i2@ec.europa.eu*

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List of Abbreviations

Abbreviation	Long form
ADDW	Advanced Driver Distraction Warning
AoI	Area of Interest
DDAW	Driver Drowsiness and Attention Warning
DSM	Driver State Monitoring
ELKS	Emergency Lane Keeping System
ESoP	European Statement of Principles on the design of human-machine interface
GDPR	General Data Protection Regulation
GSR	General Safety Regulation
HMI	Human-Machine Interaction or Human-Machine Interface
MVWG-DBAS	European Commission's Motor Vehicle Working Group, sub-group on Driver's Behaviour Assessment Systems (MVWG-DBAS),
ISA	Intelligent Speed Assistance
PTI	Periodic Technical Inspection

Executive summary

The regulation of Advanced Driver Distraction Warning (ADDW) systems has been mandated by the European Parliament and Council in Regulation (EU) 2019/2144 (the 'General Safety Regulation') in order to prevent distraction-based collisions and crashes. Most M and N category vehicles (passenger cars, vans, buses, coaches and heavy goods vehicles) will be included in the regulation, and it will also apply to new types from 7 July 2024 and to all new vehicles sold in the market from 7 July 2026. ADDW systems are designed to help the driver to pay attention to the driving task and warn them if they become distracted from activities that are critical for safe driving. In updating the regulation for ADDW, this report will detail the current state-of-the-art technology, support the European Commission in establishing performance requirements for ADDW systems and effective human machine interaction (HMI), and will propose testing methods for verifying performance that can be expected for a regulation of ADDW systems.

This report provides an overview of the activities undertaken and results, along with a draft proposition of system and test requirements to be covered by the ADDW regulation technical annex. The following tasks were undertaken to develop draft regulatory text covering system function and test requirements for ADDW systems in a technology-neutral manner:

- Literature review to:
    - Overview the current research on driver monitoring technology
    - Overview the current methodologies proposed for attention tracking and definition of attention threshold
    - Identify current recommendations on how the HMI of an ADDW system should be designed in order to lead to appropriate driver reactions (including consideration of intensity, modality, or escalation strategies)
    - Clarify whether an adaptive information presentation strategy would be sensible from a human factors point of view and feasible from a technical point of view
    - Provide HMI performance requirements
- Engage with ADDW stakeholders to:
    - Identify the ability of available and up-coming ADDW systems to reliably detect driver distraction
    - Collect information on design recommendations for the HMI to support the ADDW system's understandability, acceptance and effectiveness, appropriate performance requirements for the HMI to be addressed in the regulation, and test procedures applicable in verifying the performance of the HMI towards validating ADDW systems.
- Define an overall test methodology built on evidence input from the literature review and stakeholder engagement

The main outcome of the research undertaken within this phase of the project was the development of draft requirements around ADDW system testing, HMI and system function. These requirements aim to ensure that ADDW systems meet minimum standards in terms of quality (to ensure the intended safety benefit) but still allow system manufacturers to express design freedom by being technology neutral. A draft of the proposed regulatory text can be found within Appendix B: Proposed items for ADDW type approval regulation. The proposed draft text has been iterated after discussions in the European Commission's Motor Vehicle Working Group – Sub-group on Driver's Behaviour Assessment Systems.

Task 1: Propose performance requirements on ADDW systems

Within this task an initial overview was made, by literature review, on the current market situation of ADDW systems and the most appropriate threshold for attention. The overall goal was to understand the functionality, limitations and boundaries identified for these systems by either the manufacturer or road user. Two main findings were revealed in the literature review First, there are a number of ADDW systems already available or in development. Most systems in existence use cameras to monitor eye and head position, to gauge alertness, fatigue and distraction. Second, the literature was inconclusive regarding the most appropriate threshold for attention. Different metrics are used to describe attention in the context of driver distraction, these include visual measures, such as eye glances of the road, or non-visual measures, such as hands on the steering wheel. Stakeholder engagement supported the literature review findings, demonstrating that gaze detection was the most common method for assessing distraction and that there is no consensus within the industry regarding the threshold for distraction warnings.

Task 2: Propose performance requirements for an effective human machine interaction (HMI)

Within this task, an initial literature overview was also made, targeting existing distraction warning systems on the market and systems proposed and investigated by academic research, focusing on the implementation and testing of the HMI component of those systems. The literature review was complemented by consultations with stakeholders, who shared that experience with distraction warning systems on the market, albeit promising, is still limited. The overall goal of this task was to understand what aspects are considered when designing distraction warnings and what metrics can be used to verify their performance. Analysis of the inputs from the literature review and stakeholder engagements revealed two main findings. First, there is no consensus for an appropriate time threshold for driver's distraction and whether intermittent distraction should be included in the regulation. While the literature point to thresholds as strict as 2 s to characterise a driver as distracted, manufacturers are still working on getting ADDW systems to perform accurately and robustly at timing thresholds even longer than that. Second, the literature review did not point to a consensus on the design of distraction warnings, whilst stakeholders pointed out that they preferred to maintain freedom for designing the warnings emitted by their ADDW systems. Despite the freedom for warning design individualisation, technical requirements affecting the usability of warnings do exist and should be taken into account when drafting the regulatory text. They are established in normative standards regarding specifications for visual, auditory and haptic warnings.

Task 3: Propose requirements and tests for ADDW system

Within this task, the requirements for both functional components of ADDW systems, the distraction monitoring and the HMI, were specified. Results on requirements and potential test procedures obtained from the two previous tasks were summarised and compared with information collected during the stakeholder engagements. Test procedures proposed by stakeholders included naturalistic driving studies, simulation testing and stationary testing. Naturalistic driving studies hold the highest validity rates as they produce the most accurate data; however, they are also the most unsafe option when assessing true positives because it is dangerous for the driver to purposefully act distracted while operating on an open road shared with other traffic participants. Simulation testing could be used in place of road testing when too dangerous to carry out tests in real life. Stationary testing can be conducted to examine true and false positives to strengthen the system and make it more robust to a range of behaviours. It was suggested by stakeholders that the test procedures should be simple, repeatable, and reproducible across all vehicle categories. Results from Tasks 1 and 2 imposed two limitations for the work within Task 3: First, there has been no conclusive evidence about the appropriate thresholds for attention and, second, no consensus on the appropriate timing for warning emission. Also, due to the little systematic research conducted to determine validity and reliability of ADDW systems and the limited experience of manufacturers and suppliers with ADDW systems in the market, it has not been possible, by the delivery of this Final Report, to propose a test procedure for type approval authorities to validate ADDW systems for a wide enough population variety, but rather for evaluating the system's performance at a nominal situation via spot-check testing. So, the results of Task 3 comprise mainly 3 outputs: First, suggestions on what technical requirements could be specified. Second, recommendation that manufacturers should provide evidence on the performance of their ADDW systems for a representative part of the European population and type approval authorities (or technical services on their behalf) should conduct spot-check testing for inspecting the systems' basic functionality and compliance with the technical specifications for detecting distraction and warning drivers during specific conditions Third, an outlook on considerations needed to be made for the oncoming regulation in light of current and future state of distraction monitoring technology.

1. Introduction

Regulation (EU) 2019/2144 (the 'General Safety Regulation') mandates the implementation of Advanced Driver Distraction Warning (ADDW) systems (European Union, 2019, p. 30) in order to prevent distraction-related crashes. The regulation applies to most M and N category vehicles (passenger cars, vans, buses, coaches and heavy goods vehicles); it applies to new types from 7 July 2024 and to all new vehicles sold in the market from 7 July 2026 (European Union, 2019, p. 30). The scope of this project is to update previous conclusions (Seidl, et al., 2021) on the state-of-the-art technology and to support the European Commission in establishing performance requirements, testing/validation methods and realistic criteria that can be expected for a regulation of ADDW systems.

The following sections give a short overview of the purpose of ADDW systems and the Human Machine Interface (HMI) through which the ADDW interacts with a driver.

1.1. Purpose of ADDW systems

As defined in regulation (EU) 2019/2144, an ADDW system "helps the driver to continue to pay attention to the traffic situation and warns the driver when he or she is distracted". In this context, driver distraction is the diversion of attention from activities critical for safe driving to a competing activity (Seidl, et al., 2021, p. 622).

Hence, the following functional requirements on ADDW systems can be formulated:

- The system shall be able to identify situations in which the driver is distracted
- The system shall feed-back the identified distraction-related situations to the driver
- The system may also consider technical means in order to avoid distraction (additional specific technical provision defined in regulation (EU) 2019/2144, Annex II, point E3)

The regulation further defines that ADDW shall not "continuously record nor retain any data other than what is necessary in relation to the purposes for which they were collected or otherwise processed within the closed-loop system" and that "those data shall not be accessible or made available to third parties at any time and shall be immediately deleted after processing". The ADDW system shall also be "designed to avoid overlap and shall not prompt the driver separately and concurrently or in a confusing manner where one action triggers both" ADDW and the driver drowsiness warning system defined in Regulation (EU) 2021/1341.

"There are four types of driver distraction, where often a driver experiences more than one type at the same time: visual, auditory, manual and cognitive distraction. Visual distraction is considered to be the most dangerous when driving" (Seidl, et al., 2021, p. 662) and is the main focus in this study. However, this focus should not limit the scope of ADDW systems.

Visual distraction refers to the situation where the "driver takes their eyes off the road to engage in a secondary activity not related to the driving task" (Seidl, et al., 2021, p. 643) and, therefore, is no longer able to perform the driving task safely. To ensure safety, it is important that drivers maintain attention on the driving task. This requires maintaining awareness of what is happening to the side and rear of the vehicle, via observation of the mirrors. It is also important that drivers monitor information presented by the vehicle, such as current speed and any warning messages, and operate safety-critical functions such as screen demist without undue loss of attention to the driving task. This means that appropriate attention to the driving task requires multiple gaze directions, and ADDW systems must be able to take this into account, e.g. to ensure that looking in the wing mirror does not issue a false attention alert. Such false alerts risk degrading acceptance of ADDW systems and may lead to drivers switching off the alerts. Attention directed away from these driving tasks, or excessively long-duration attention to e.g. a mirror should be robustly detected and trigger alerts. An ADDW system that is able to robustly identify attention away from appropriate zones will be able to issue an alert irrespective of whether that inattention is caused by mobile phone use or other devices and distraction sources.

The literature review identified some existing driver support systems with ‘attention’ warning in their descriptions (see Table 1). On review, these were found to be primarily driver drowsiness warning systems, with system activation speeds aligned with Regulation (EU) 2021/1341 (even though some of the systems pre-date the entry into force of that regulation). While drowsiness could be considered a form of distraction (either visual distraction because the eyes are closed, or cognitive distraction because a tired driver is no longer paying sufficient attention to the driving task), this form of distraction is already covered by the regulation and does not need to be considered further here.

1.2. Purpose of the HMI for an ADDW system

As a vital component of ADDW systems, the HMI comprises the means/interaction components through which the driver is informed about their state of distraction during driving. This exchange of information happens in a two-way direction:

- Vehicle-driver direction: When the ADDW system evaluates the driver to be distracted, its HMI informs the driver about their distracted state via an appropriately designed warning.
- Driver-vehicle direction: Upon receiving the warning, the driver then changes their behaviour from a distracted to an attentive state, thus communicating to the ADDW system that they have successfully perceived, understood and acted on the warning (driver-vehicle direction) and thus are back to paying attention to the traffic situation.

According to an analysis by Karthaus et al. (2018) of Wicken’s theory of multiple resources, there should be higher interference between parallel stimuli (during processing or acting on them) when these stimuli use the same mental resources. Applying this theory in the context of ADDW systems, the inhibition of distracting stimuli or activities (which is the goal of ADDW systems, helping drivers to ward off distraction) that use similar resources should be more mentally demanding. Since driving requires intensive perception, processing, and acting on visual stimuli, “secondary visual stimuli should thus be more difficult to inhibit than additional auditory stimuli”. This could explain why most warnings inside the vehicle (from seat belt or open door reminders to emergency braking and forward collision warnings) include some auditory alert, as this type of stimulus should be less demanding when parallel to visual stimuli of the driving task.

However, Karthaus et al. (2018) also point out that the allocation of cognitive resources is limited and, thus, the “benefit of separate resources is diluted when one task requires so many cognitive resources” that the overall resource reserves are depleted and cannot be allocated to the distracting stimuli or activities anymore. The authors then conclude that “this concept of resource allocation could explain the extensive distraction effects of talking or calling, even though these tasks access quite different resources than the driving task.”

In summary, if the design of the warnings does not consider cognitive resource allocation, the alert against distraction might not be communicated effectively, and the driver may ignore the warning and thus continue their unsafe distracted behaviour, potentially resulting in collisions. Therefore, for ADDW systems to adequately support safe and efficient vehicle operation, the ADDW-HMI must be designed consistent with the driver’s expectations, capabilities and limitations (Campbell, et al., 2018). If the HMI of the ADDW system is not designed appropriately or the distraction detection, and thus the warning emission, is not sufficiently robust, it may cause distraction and even annoyance, which may lead the driver to switch off the ADDW system and thus forfeit the safety benefit.

1.3. Previous findings

TRL undertook initial research on a potential scope for ADDW systems alongside the work to support development of a draft regulation on driver drowsiness warning systems (which led to Regulation (EU) 2021/1341). The research included a review of the scientific and grey literature, and extensive stakeholder consultation. The findings are summarised below as a foundation for the present project.

All industry stakeholders had developed systems to monitor visual distraction and at least one other human factor; these systems were not in series production vehicles, although aftermarket systems, typically for heavy vehicle fleets, were available in the market. All systems monitored the driver's eyes, head and/or facial features using a camera, and each system used a minimum of one visual behaviour indicator (such as head pose, gaze direction) and one metric derived from this (such as time of gaze away from the driving task) to assess the driver's visual attentive state.

All of the distraction systems identified had at least two areas of interest defined. Simpler systems differentiated between a forward field of view (FoV - designated for attention to the driving task) and a distracted FoV; more sophisticated systems varied, but might include areas beyond the forward FoV, such as mirrors and the instrument cluster, i.e. more nuanced fields of view related to different aspects of the driving task and distraction.

All systems had at least one trigger behaviour, e.g.:

- Driver glance duration (outside FoV relevant to driving)
- Driver glance frequency (outside FoV relevant to driving)
- Driver glance duration or frequency exceeding a Total Eyes Off Road (TEOR) limit

There was no consensus among stakeholders on visual distraction thresholds. Moreover, some stakeholders suggested that visual distraction thresholds should depend on the driving context, e.g. vehicle speed, road type or external environment. Thus some open topics were identified:

- Activation speed – the driving speed at which an ADDW system should be active
- Road type – whether an ADDW system should be active on only certain road types
- Activation and deactivation – the conditions when the system will be active, and whether the driver should be able to deactivate the system

Over half of the stakeholders consulted had performed some kind of validation testing with users, although there was no consistency in number and demographics of participants, or test conditions, e.g. environmental conditions or occlusion factors. Validations targeted high true positive rates and low false positive rates, but all OEMs reported undesirable false positive and false negative rates.

There was a lack of information on suitable HMI, for instance visual alerts, visual and auditory alerts, and possible cascade or escalation of alerts if the driver does not return attention to the driving task.

Finally, it was noted that Euro NCAP were working with OEMs and Suppliers with the objective of launching an assessment of ADDW systems in 2023 for category M1 vehicles.

1.4. Glossary

In the following some terms are defined that have been used in the scope of this project:

Term	Definition
Attention	Different definitions of the term attention exist in literature. The following definitions are relevant in the context of the project: • "Attention refers to a continuously changing cognitive state characterised by a selective bias for processing certain internal or external stimuli […]. Attention anticipates on the processing of task-relevant information by way of its selective bias"(Brouwer, 2002, pp. 2-3). "The most common causes of unsafe traffic behaviour are slips of attention, when conscious attention is allocated to non-driving activities, e.g. telephoning or worrying about daily hassles (Brouwer, 2002, p. 20). • "'visual attention' refers to a set of cognitive operations that mediate the selection of relevant and the filtering out of irrelevant information from cluttered visual scenes" (McMains & Kastner, 2009).
ADDW system	'Advanced Driver Distraction Warning' system intended to help the driver to continue to pay attention to the traffic situation and to warn the driver when he or she is distracted (Regulation (EU) 2019/2144, Chapter 1, Article 3(6)).
Driver distraction	The diversion of attention from activities critical for safe driving to a competing activity (Seidl, et al., 2021, p. 623)
Visual distraction	Occurs when the driver takes their eyes off the road to engage in a secondary activity not related to the driving task (Seidl, et al., 2021, p. 643)
Field of Vision aka Field of View	Different definitions of the term 'Field of Vision' exist in the literature. The following definitions are relevant in the context of the project: • In the standardization, the driver's field of vision refers to the area that can be seen by the driver and the characteristics of this area. In order to ensure an adequate field of vision, Regulation (EU) 2018/116 (UN Regulation 125) defines requirements on the 180° forward field of vision of drivers of category N1 and M1 vehicles.
Area of Interest (AoI)	The driver's environment can be separated into areas of interest that differ in their relevance for performing the driving task, e.g. Forward AoI/FoV or Distracted AoI/FoV - compare (European Commission, 2021, p. 18).
Type 1 distraction (behaviour)	"Long glance duration to a target not relevant for driving" (European Commission, 2021, p. 23). "When a driver is visually distracted and engaged in a secondary task,

Term	Definition
	they tend to [...] glance away from the road for an extended period (Type 1)" (European Commission, 2021, p. 10). This definition does not cover situations in which the driver is engaged in activities related to multiple Distracted AoIs (e.g. multiple distraction tasks).
Type 1 trigger behaviour	"Driver's glance duration to a target in the Distracted AoI exceeds the glance duration threshold" (European Commission, 2021, p. 17).
Type 2 distraction (behaviour)	"Frequently shifting gaze between the driving task and the distraction task" (European Commission, 2021, p. 7).
Type 2 trigger behaviour	"Driver frequently glances to a target in the Distracted AoI exceeding the yet-to-be-determined threshold" (European Commission, 2021, p. 18)
Coarse visual behaviour indicators	"According to the literature, eye movement provides a direct indication of the driver's visual state and is the most sensitive at measuring visual distraction (i.e. directly assessing gaze direction by tracking the movement of the eyes). Eye movement can be indirectly measured by using coarse visual behaviour indicators such as head movement or facial feature(s) movement. These indicators provide a broad estimate of where the driver is looking" (European Commission, 2021, p. 9).
Primary metrics	Primary metrics are related to the eye gaze direction and as such provide information about the AoI, to which the driver pays (visual) attention. This metrics include coarse visual behaviour metrics – compare (European Commission, 2021, p. 17).
Secondary metrics	Next to primary metrics, the secondary metrics exploit additional information such as vehicle control metrics in order to aid reliability and robustness of the ADDW system (European Commission, 2021, p. 17).
Personal data	Any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person" (Regulation (EU) 2016/679, Chapter 1, Article 4(1)).
Biometric data	Personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics of a natural person, which allow or confirm the unique identification of that natural person, such as facial images or dactyloscopic data" (Regulation (EU) 2016/679, Chapter 1, Article 4(14)).
Human-machine interface (HMI)	The HMI comprises the aggregate of means by which drivers interact with their vehicle or any mobile tools. In the context of this project, the

Term	Definition
	aggregate of means by which the drivers can interface with the ADDW system.
Abstract threat	Driver behaviour which could lead to a crash (if it occurs in connection with a critical driving scenario) [Introduced in the ADDW ad hoc meeting on the 9 June 2022 by ACEA].
Concrete threat	Driver behaviour (‘abstract threat’) and critical driving scenario coincide [Introduced in the ADDW ad hoc meeting on the 9 June 2022 by ACEA].
Safety benefit of ADDW	The safety benefit of an ADDW system arises from the reduction of the number of situations, in which the driver shows an unsafe driving behaviour, which could lead to critical driving situations. In case of an already existing critical driving situation, the risk of a crash is further increased. Accordingly, the safety benefit of an ADDW system is even higher in these cases.

2. Performance requirements on ADDW systems (Task 1)

2.1. Introduction

The key focus of this Task was to identify the ability of available and up-coming ADDW systems to reliably detect driver distraction. Furthermore, the Task was focused on the identification of the appropriate threshold for attention shift such that the system could appropriately alert the driver when their attention is drawn away from the driving task. The overall purpose of the Task was therefore to establish the current state of ADDW technology and the most appropriate threshold for attention. This will be fed into a list of recommendations and requirements, considering also future trends in technologies.

Objectives

- Overview of current research on driver monitoring technology, with a focus on:
  - How/when attention is measured, and potential improvements proposed by the research
  - Whether and how appropriate/inappropriate attention shifts are defined and measured
- Overview of current methodologies proposed for attention tracking and definition of attention threshold
-

Research Questions

The literature review for Task 1 sought to answer the following research questions (RQs).

Main research questions

- RQ1. What are the impacts of the current implementation of ADDW technology? This could include the assessment of relevant implementations of ADDW systems, including:
  - Continuous monitoring of the driver's visual attentive state
  - The presence of secondary metrics
  - The presence of Type 1 trigger behaviour monitoring
  - Activation of the systems extended to adequate speed ranges (dependent upon road type), automatic activation and reinitiating at the ignition stage.
  - The ability to function on day and night, with all weather conditions, and on every road type
  - Ability to function with glasses (potentially sunglasses) and in varying illumination conditions

- RQ2. What are the impacts of different attention metrics and assessment methods on finding the most appropriate attention threshold?
    - The definition of appropriate and inappropriate attention shifts
    - Current studies on attention shift during driving tasks with current technologies
    - Investigation of attention metrics and their attention threshold

- RQ3. How is ADDW system performance currently tested and evaluated? This could include:
    - Follow up studies and reports outlining the validity and reliability of the technology and the procedures to test it

2.2. Methodology

The literature review had two phases.

2.2.1. Phase one

Phase one investigated RQ1 using a top-level internet search to identify and explore existing driver monitoring technology. This search was conducted on Google and Google Scholar.

This resulted in 14 sources being identified and reviewed in full. The main details that were extracted included details around visual attention monitoring, secondary metrics, and system manufacturer. Due to the lack of detail available within many of the sources, only five sources are cited within the literature review.

2.2.2. Phase two

Phase two investigated the remaining RQs and involved a systematic search of the academic literature. Part two was formed of three tasks:

- Definition of search terms to be used
- Assessment of the relevance and timeliness of identified literature
- High level review of full text literature

The search terms used in both phases are shown in Table 1.

Search Terms

A list of search terms that directly relate to the research questions were generated. First level terms targeted the search to focus on a) driver monitoring technology and b) attention threshold. The second level terms further refined the search. The search terms used are shown in Table 1 were applied systematically within the following databases: Google Scholar, TRID and PubMed. A more general internet search was also conducted, using the same search terms. The search terms were used as Boolean expressions and 'Wild card' searches (using * as a Boolean operator) allowed for variations of the term to be covered in a single search (e.g. 'camera*' generated search results for 'camera' and 'cameras') This process allowed for the most thorough search possible.

Table 1: Search terms for RQ1-5

Level 1	(AND/OR) Level 2
Driver distraction technolog* Advanced Driver Distraction Warning ADDW Visual distraction Distraction Attention shift* Monitoring equipment* Monitoring technolog* Warning system* Original warning system Aftermarket warning system Original ADDW Aftermarket ADDW Driver attention technolog* Driver attention system* Driver warning system* Driver Distraction Driving Driving Task	Regulation* Quality Cognitive distraction Continuous monitor* Camera* Gaze Gazing Gaze shift* Glanc* Trigger behaviour* Type 1 Type 2 Field of view Fov Forward Fov Distracted Fov Activation Deactivation Reinitiating Ignition Speed Road type* Day Night Weather Glasses Sunglasses Illumination Driving task* Distracting task* Long glance* Glance duration* Short glance Appropriate Attention Inappropriate Attention Validity Testing Test* Reliability Accuracy

Inclusion Criteria

In order to ensure that only literature of sufficient relevance and quality was included in the review, specific inclusion criteria were used to assess the suitability of identified sources. Each identified piece of literature was scored on relevance and timeliness (see Table 2). Though participant testing was reduced during the period of 2020 – 2022, using a cut off of less than two years for each research paper was deemed acceptable. This ensured that only the most recent literature (and research findings) were identified.

Table 2: Inclusion criteria for the literature review

	Score = 3	Score = 2	Score = 1
Relevance	Not relevant to the research objectives of the project	Some indirect relevance to the objectives of the review	Directly relevant to the objectives of the review
Timeliness	Older than 5 years	2-5 years old	Less than 2 years old

These inclusion criteria were applied two-fold; once during an initial review of abstracts and again during the full-text review. A standard abstraction document was used to collate information collected from the review. This document took the form of a spreadsheet with each identified piece of literature occupying a row and relevant details (e.g. study purpose, study approach, findings) being summarised in columns. This standardised approach allowed for a comprehensive summary of all relevant information to be collated in a single place and contributed to a more streamlined approach to reporting.

An initial search was conducted to obtain a list of titles and abstracts, which were reviewed and scored according to the inclusion criteria. A shortlist of 31 papers was then created and these 31 full text articles were then reviewed in detail. The findings have been grouped where appropriate to aid in structuring the report. In total, 15 studies were included in the literature review.

2.3. Results

2.3.1. State of the art based on literature review

Current technology

The review identified 17 examples of ADDW technology. These are summarised in Table 3. Of these 17, seven were fitted by a manufacturer to a vehicle and nine were fitted as an aftermarket system. The majority of technology identified monitored fatigue, distraction and drowsiness, through a range of methods including tracking eye and head position. Only two of the technologies identified measured only driver drowsiness.

Table 3: ADDW technology systems

Manufacturer	System name	Activation speed	Monitoring method	Limitations	Secondary metrics
Drowsiness detection exclusive systems					
Bosch	Interior Monitoring systems **Aftermarket**	Not described	Driver alertness and condition of the driver based on a camera. Driver drowsiness detection based on the driver's steering behaviour during the trip based on information from the steering-angle sensor	None described	None described
Mazda	Driver Attention Alert (DAA) **Fitted by manufacturer**	65 to 140 km/h (41 to 86 mph)	Attentiveness (primarily fatigue) alert based on lane position (forward-facing camera) and steering inputs.	DAA does not work when lane markings become obscured, the vehicle is jolted or swayed continuously, driven aggressively or frequent lane changes occur	None described
Drowsiness and / or alertness detection systems					
Aisin	Monitoring System **Aftermarket**	Not described	Detects the driver's **face orientation**, **gaze direction**, and **eye closure** with optoelectronics' driving recorder capable of recording clear, high-definition images both day and night (using infrared). If the driver monitoring system detects the driver becoming drowsy or distracted, an alarm will be activated to alert the driver.	Not described	None described
Cadillac	SuperCruise **Fitted by manufacturer**	Not described	Tracks driver head position and eye gaze and uses GPS real-time corrections and map data to determine the vehicle's location while the Lane Sensing Camera detects the marked lanes on the highway to help the vehicle steer and maintain lane position.	The system does not detect if you are drowsy or focused on safe driving	None described

Continental	Driver Monitoring System **Aftermarket**	Not described	Driver behaviour including head position, eye gaze (area and duration) and further signals from the car such as vehicle speed and traffic signs. Driver drowsiness is diagnosed based on eye blink duration and frequency as well as eye opening and closing velocity.	None described	None described
DS Automobiles	DS Driver Attention Monitoring **Aftermarket**	Activated at 70 km/h	**Alertness**, **drowsiness**, **fatigue** and **distraction** are gauged using an infrared camera mounted on the steering wheel. Vehicle position monitoring system determines where the car is in relation to road markings	Wearing dark or reflective spectacles or sunglasses or long hair interfere with the operation of the system	None described
Ford	Blue Cruise **Fitted by manufacturer**	Not described	Measures distraction Possible to drive a vehicle hands free whilst being monitored by driver-facing infrared light and infrared cameras.	Not described	None described
Gentex Corporation	Driver and cabin monitoring system **Aftermarket**	Not described	Measures distraction **Alertness**, **gaze location**, **behaviour** and **driver readiness** to assume control assessed using cameras embedded in rear view mirror.	None described	None described
Nissan Motor Corporation	Intelligent Driver Alertness (i-DA) **Fitted by manufacturer**	Activated at 60 km/h (37 mph)	Detects **drowsiness** or **reduced attention** based on changes in smoothness (roughness) of steering input by the driver, based on steering angle sensor.	None described	None described
Seeing Machines	Guardian Backup-driver Monitoring System **Aftermarket**	Not described	Not described	None described	Not described

Seeing Machines	Guardian **Aftermarket**	Not described	Measured drowsiness and distraction Guardian tracks eye, **face** and **head position** to determine whether the driver is **fatigued** or **distracted**. If there are signs of fatigue or distraction detected, the system activates in-cab alerts.	Not described	Duration of event, speed of vehicle, distance travelled, which alarms were activated, GPS location, video footage of the driver and seat vibrations sent to warn the driver
Smart Eye – Automotive	Smart Eye **Aftermarket**	Not described	Measures distraction Detects phone use, eating, drinking, smoking, and makeup application using a camera.	None described	None described
Sony	In cabin monitoring **Aftermarket**	Not described	Measured distraction and drowsiness Time of Flight (ToF) camera sensors monitor the condition of the vehicle occupants. Driver facial expressions and gestures are used to determine the driver's level of concentration and fatigue, and alerts are issued when necessary	None described	None described
Subaru	DriverFocus® Distraction Mitigation System **Fitted by manufacturer**		Measures drowsiness Infrared camera integrated into a module at the top of the dashboard monitors driver’s gaze and head position.	None described	None described
Toyota	Cabin Awareness **Fitted by manufacturer**	Not described	Measures cabin awareness Uses a 4D imaging radar sensor, mounted out of sight above a vehicle’s headliner to detect presence of a person (e.g. a child) in the vehicle, even after a driver exits. This ensures that children are not left in the vehicle by mistake.	None described	None described
Veoneer	Veoneer Driver Monitoring Systems	Not described	Measures drowsiness and distraction	None described	None described

	Aftermarket		Eye and head position, driver attention and fatigue measured using a camera.		
Harman International	Harman Ready Care	Not described	Ready Care measures both driver eye activity and state of mind. Measured using an infra-red global shutter camera with active illumination which surveys the driver’s face in low and high light environments	None described	Stress-free Routing: Compatible with multiple navigation engines, Ready Care provides an alternate route selection to lower elevated driver stress levels while on the road.

2.4. RQ1: What are the impacts of the current regulations on the ADDW technology? This could include the assessment of relevant implementations on the ADDW systems

2.4.1. Continuous driver's visual attentive state monitoring

The majority of papers reported that the driver monitoring system used involved a camera system, in many cases, an infrared camera mounted either on the steering column or rear-view mirrors. Alongside in-car cameras, computer vision, artificial intelligence (AI) and deep learning are used to improve accuracy of detecting faces, gaze direction and eyelid closure *(Seiki & Suwa, 2019)*. These systems, including what is measured (drowsiness or attention, is summarised in Table 3.

2.4.2. Presence of secondary metrics

Only one source discussed the presence of secondary metrics in the ADDW system. The system, from Seeing Machines, which measures drowsiness and distraction, records the duration of the driving event, speed of vehicle, distance travelled, which alarms were activated, GPS location and video footage of the driver.

2.4.3. The presence of Type 1 trigger behaviour monitoring

Four of the sources reviewed described Type 1 trigger behaviour monitoring. These sources describe using gaze direction to assess driver distraction events.

2.4.4. Activation of the systems extended to adequate speed ranges

Three of the sources reviewed mentioned using activation or reactivation in their respective ADDW system (see Table 3). In the DS Automobiles system, which measures drowsiness, alertness, fatigue and distraction, as soon as the speed of the vehicle drops below 70 km/h (43 mph), the system goes into standby. The settings are changed via the driving/vehicle touch screen menu. The status of the system stays in the memory when switching off the ignition. In the case of Nissan's Intelligent Driver Alertness, which assesses drowsiness and driver attention, the system resets and starts reassessing driving style and steering behaviour when the ignition switch is cycled from the ON to the OFF position and back to the ON position. In Mazda's Driver Attention Alert (DAA) system, which measures fatigue, the system activates when speed is about 65 to 140 km/h for about 20 minutes. Note, though included in the review, Nissan and Mazda's systems are specific to fatigue detection, rather than distraction detection per se. Additionally, the activation speeds described here are from the drowsiness systems described in Commission Delegated Regulation (EU) 2021/1341. In the DAA system, the driving data will be reset under the following conditions: The vehicle is stopped for 15 minutes or longer, the vehicle is driven at less than about 65 km/h (41 mph) for about 30 minutes or the ignition is switched off.

2.4.5. The ability to function on day and night, with all weather conditions, and on every road type

Several of the ADDW system sources reviewed described how issues may arise when the system was used in conditions of darkness. In DS Automobiles, wearing certain types of spectacles or sunglasses that are very dark or reflective, or face partially obscured (hair, hands) could interfere with the operation of the system. Similarly, Mazda's DAA may not operate normally if the lane lines are less visible because of dirt or fading/patchiness. Finally, Ford's BlueCruise, which is a distraction detection device, uses cameras to monitor the vehicle's lane position and applies steering support to keep the vehicle centred. A driver facing camera and infrared lighting is used to monitor eyes and head position to detect distraction; this ensures that distraction can be detected even in times of darkness *(Ford, 2022)*.

2.5. RQ2: What are the impacts of different attention metrics and assessment methods in finding the most appropriate attention threshold?

2.5.1. The definition of appropriate and inappropriate attention shifts for the driving task

This research question examined the definition of appropriate and inappropriate attention shifts during the dynamic driving task. This was explored from two perspectives: the definition of appropriate attention shift from the National Highway Traffic Safety Administration (NHTSA) guidelines and the findings from the published literature. It should be borne in mind that the evidence base for these guidelines is unclear and the guideline is also intended as an aid to manufacturers in designing in-vehicle devices.

NHTSA defines distraction as "the diversion of a driver's attention from activities critical for safe operation and control of a vehicle to a competing activity" (NHTSA, 2014, p. 9). The NHTSA guidelines specify three criteria which must be fulfilled for a task to count as safe to perform while driving. For 21 out of 24 (87.5%) of participants, the following criteria applied (note this refers to when performing the task in question):

- No more than 15% of each participants' total number of eye glances away from the road scene have durations greater than two seconds
- The mean duration of all eye glances away from the forward road scene is less than or equal to two seconds
- The sum of the durations of each individual participant's eye glances away from the forward road scene is less than or equal to 12 seconds

Glance means a single ocular fixation by a driver; an ocular fixation refers to when the eye remains still for a brief period over a stimulus. If the eye glance characterisation method being used cannot distinguish between different nearby locations of individual fixations, "glance" may also be used to refer to multiple fixations to a single area that are registered as one ocular fixation.

Whilst the NHTSA guidelines provide a clear definition of driver distraction, the literature indicated that no clear consensus exists regarding an appropriate or inappropriate attention threshold. For instance, Moslemi, Soryani, & Azmi (2021) consider each and any action that diverts driver's attention from driving to be a distraction. These actions include mobile phone use (texting, dialling) and smoking. Furthermore, attention is defined using a range of metrics, which in itself, makes it difficult to define a single attention threshold. Other studies (Noble, Miles, Perez, Guo, & Klauer, 2021) have described attention in terms of the following visual measures:

- Number of off-road glances – the number of glances away from the road scene during the 10- second sample interval
- Mean off road glance duration – the mean glance off road is the average duration of all off road glances during the 10-second sample interval

- Total eyes off-road time (TEORT) – the summation of all glance durations to all areas of interest other than the road scene during a sample interval in seconds
- Single longest off-Road Glance (SLG) – the duration of the single longest glance away from the defined road scene during the sample interval
- Fixation (duration) and count – a fixation when the eyes stop scanning the visual scene and hold central foveal vision, typically lasting 250 ms

2.5.2. Current studies on attention shift during driving tasks with current technologies

Several papers provided examples of how these eye movement metrics are operationalised. Noble et al. (2021) investigated the prevalence of driving automation complacency behaviours that occur whilst the vehicle is in a state of conditional automation. The study used data from the Virginia Connected Corridors Naturalistic Driving Study, which took place from October 2016 to June 2018. The vehicles used in the study were fully instrumented with GPS, lane tracking, and six video cameras mounted to allow natural observation of the drivers' behaviour. The cameras were designed to unobtrusively record the driver's face, shoulder, footwell and rear roadway. Number and mean duration of off-road glances, TEORT and SLG were recorded continuously throughout the drives. Four measures of eye glance behaviour were used to assess driver monitoring during the 10-second matched-paired epochs; the on-road glance locations included the forward windscreen, instrument cluster, left mirror, rear-view mirror, and right mirror. The results showed drivers spent more time looking away from the road while the driving automation systems were active and that drivers were more likely to be observed browsing on their mobile phones while using driving automation systems. This engagement in secondary tasks caused the drivers to take more frequent glances away from the roadway.

Similar findings were reported by Amini et al. (2022). In this study, a driving simulator was used to investigate driving behaviour in a controlled environment and test safety-critical events that would otherwise not be possible to test in naturalistic driving conditions. Driver responses to different risky events on the road (e.g. a pedestrian stepping out into the road and tailgating) and the impact of distraction on driving performance was assessed. Eye tracking, a technique used to gauge the visual attention allocated to a particular stimulus, was used to examine where participants were looking during the critical events and in the distraction scenario. This involved creating areas of interest (AOIs) on the road ahead, the steering wheel area, the i-DREAMS display and the mobile phone screen. The i-DREAMS display consisted of a small screen containing a head-up display.

A significant change in drivers' gaze patterns during the distraction drives was observed, with significantly higher gaze points towards the i-DREAMS intervention display (designed to reduce driver distraction). The i-DREAMS interventions consisted of headway, pedestrian, forward collision, and lane departure warnings which occurred when drivers completed unsafe driver manoeuvres. These safety warnings were audible and visual and were delivered through the clock display of the vehicle changing to the i-DREAMS display.

The statistical significance in the average fixation duration and fixation count indicated a change of drivers' gaze patterns during the intervention and distraction scenarios. During these scenarios, drivers' gaze behaviour was reduced significantly with respect to the road ahead and dashboard area. This reduction may be associated with drivers' attentional shift from the road ahead and dashboard area to the mobile phone screen during the distracted driving and possibly to the i-DREAMS warning display during the intervention scenario. Other studies have used similar metrics to gauge drivers' allocation of attention (Khan & Lee, 2019) (Zhang, Ma, Pan, & Chang, 2021).

2.5.3. Investigation of attention metrics and their attention threshold

In a literature review conducted by Kashevnik, Shchedrin, Kaiser, and Stocker (2021), the scientific literature on driver distraction detection methods was reviewed. Based on the findings, the authors created a driver distraction framework to detect three types of distraction: manual, visual and cognitive. The authors highlighted, based on their synthesis of the literature, that the exact threshold for distraction types is unclear. For instance, the authors highlight that two seconds of 'eyes off road' time (when the driver is looking away from the forward roadway) may constitute distraction, though it is unclear how fast the vehicle was driving when the eyes off road time was measured. Other papers report that a driver whose eyes are off the road for 46 metres in distance are distracted. For hand position on the steering wheel, the authors did not note a consensus within the literature. The findings of Kashevnik et al. are partially supported by that of El Khatib et al. (2019), who surveyed inattention detection within the literature. The consensus from the studies reviewed was that looking away from the forward road for more than two seconds, regardless of the reason, increases the risk of crashes or near-crashes.

One study described the use of a model to conceptualise driver distraction. Kircher and Ahlstrom (2016) as cited in Halin et al. (2021) argue that existing definitions of driver distraction are limited, as they are difficult to operationalise and only consider eyes off road time and engagement in non-driving related activities (Halin, Verly, & Van Droogenbroeck, 2021, p. 22). Instead, Kircher and Ahlstrom propose a theory named MiRA (Minimum Required Attention), that defines the attention of a driver in the driving environment, based on the notion of situation awareness (SA). Instead of trying to assess distraction directly, one does it indirectly, by first trying to assess attention, based on the premise that distraction is a form of inattention. MiRA theory states that a driver is considered attentive at any time when they sample sufficient information to meet the demands of the driving environment. This means that a driver should be classified as distracted only if they do not fulfil the minimum attentional requirements to have sufficient SA. This occurs when the driver does not sample enough information, whether or not simultaneously performing an additional task.

MiRA theory is unique, in that it does not operationalise distraction in terms of manual, visual, auditory or cognitive distraction. Rather, it is operationalised using, a context dependent algorithm (Ahlstrom, Georgoulas, & Kircher, 2021), which uses eye-tracking data registered in the same coordinate system as an accompanying model of the surrounding environment and multiple buffers. Each buffer is linked to a corresponding glance target of relevance. Such targets include windscreen, left and right windows, (rear-view) mirrors, and instrument cluster. Some targets and their buffers are always present (like the roadway ahead via the windscreen), while some other targets and their buffers appear as a function of encountered traffic-regulation indications and infrastructure features. Each buffer is periodically updated, and its update rate can vary in time according to requirements that are either "static" (e.g. the presence of a specific on-ramp that requires one to monitor the sides and mirrors) or "dynamic" (e.g. a reduced speed that lessens the need to monitor the speedometer). At each scheduled update time, a buffer is incremented if the driver looks at the corresponding target and decremented otherwise; this is a way of quantifying the "sampling" (of the environment) performed by the driver. A buffer running empty is an indication that the driver is not sampling enough the corresponding target; he/she is then considered to be inattentive (independently of which buffer has run empty). Until declared inattentive, he/she is considered attentive. The theory, whilst providing an operational definition of distraction and attention, fails to provide actual metrics alongside its definition, limiting its wider application.

Driver distraction has also been measured using a convolutional neural network (CNN)[1] approach, using eye movement measures. Zhang and Abdel-Aty (2022) used dashboard mounted cameras to record the events of 289 drivers. Head pose was taken and used by a CNN to predict drivers' distraction. The authors defined distraction in the following way. Each frame of each second was examined. If the frame involved eye activity (the driver's eyes are off road), it was identified as distraction; if not, the frame is identified as no distraction. Other studies have been conducted into the effects of driver distraction and attention shift. For instance, Gaspar and Carney (2019) conducted a naturalistic driving study to investigate how drivers deploy visual attention in a partially automated vehicle. During the study, ten participants drove a Tesla Model S for 1 week during their daily commute. Drivers were instructed to use Autopilot, a system that provides both lateral and longitudinal control, as much as they felt comfortable while driving. Driver-facing video data were recorded and manually reduced to examine glance behaviour. Drivers primarily allocated their visual attention between the forward roadway (74% of glance time) and the instrument panel (13%). With partial automation engaged, drivers made longer single glances and had longer maximum total-eyes-off-road time (TEORT) associated with a glance cluster.

Similar findings were observed by Morris, Reed, Welsh, Brown and Birrell (2015) who investigated the glance behaviours of drivers, assessed from video data, when using a navigation device (study one) and a green-driving advisory device (study two). The main focus was to establish the number of glances of two seconds or more to the systems and relate this to driver safety (as stipulated in new guidelines for use of in-vehicle systems proposed by NHTSA). Study 1 tested a Blom Ndrive G800 navigation device whilst study 2 tested the Foot-LITE device; a Smart' driving system which incorporates Green Driving Support (GDS). In study one, the subjects were specifically requested to drive a prescribed route of approximately 25 km and were directed by an experimenter who was present in the front passenger seat (baseline condition phase). After approximately eight months, the same 10 subjects were requested to perform the same drive but using the navigation device to guide them around the route (experimental condition phase). In study two, all subjects were asked to drive a prescribed route first without using the Foot-LITE device (baseline condition phase) and then some days later, with the Foot-LITE device (experimental). In study one, the percentage of eyes off road time for drivers was much greater in the experimental (with device) condition compared to the baseline condition (14.3 % compared to 6.7 %) but whilst glances to the navigation device accounted for the majority of the increase, there were very few which exceed two seconds. Drivers in study two, spent on average 4.3 % of their time looking at the system, at an average of 0.43 s per glance; no glances exceeded 2 s. As the duration of the glances did not exceed two seconds, this suggests that the distraction caused by the infotainment system for navigation or green driving advice did not impair the drivers' safety.

2.6. RQ3: How is ADDW system performance currently tested and evaluated?

While there is documentation of ADDW systems being assessed under both real-time and simulated environments, there is little systematic research conducted to determine validity and reliability of the systems. In the literature referenced in this paper, the most commonly used method is to engage drivers in non-driving tasks and monitor whether the system identifies these behaviours as inattentive. Findings from stakeholder interviews state that user experience tests are conducted with the main aim to minimise the number of false positives, and often assessed by the annoyance reported by the drivers.

[1] A CNN is a deep learning neural network designed for processing structured arrays of data such as images.

A common limitation mentioned in the literature and by stakeholders was challenges presented by the use of cameras. This included identifying distractions occurring in areas outside the camera's view as well as impacts of accessories like face masks and other occlusions. Another challenge was the lack of a clear threshold between the different distraction levels. This made it more difficult to accurately determine whether the person was performing a driving task or a non-driving task as well as the potential severity of any distraction.

Metrics and methods for the assessment of driver attention: current state of the art

The review identified several research efforts made to monitor drivers' state of attention to provide support to drivers. Various methods, both invasive and non-invasive, have been applied to track driver's attentional states; however, most of these methods can cause discomfort, or are unrealistic to use in natural driving environments, or are too costly. For this section, papers that identified a parameter for observation and an approach to test or set the baseline were reviewed.

Invasive methods of assessment of driver attention often involve sensors that monitor driver's physiological state and infer their state of attention. Physiological measures include brain activity using electroencephalography (EEG) signal, heart rate using electrocardiogram (ECG) signal, skin conductance using electrodermal activity signal, muscle current using electromyography (EMG) signal, or cornea-retinal standing potential using electrooculography (EOG) signal. Because of the nature of these methods, they are typically tested in simulation trials and cannot be carried out in real world scenarios. They can also be used to validate the findings from non-intrusive detection methods.

Non-invasive methods of driver attention assessment typically use imaging sensors to collect visual information on the driver's movement and can be easily used to monitor real road traffic scenarios. Movement such as gaze direction, frequency of yawning, blink duration, percentage of eyelid closure, and other body movements such as head turns, or lack of movement (unresponsive) are widely used to detect inattention in drivers. Image sensors are typically installed with predefined 'maps' or zones' of the face that are used to determine movement and severity of distraction. There are various algorithms developed and employed by researchers to utilise eye, gaze, head, and body data for detection of a driver's alertness and intentions. These algorithms use fuzzy logic (logic-based model integrating information from multiple sensors to indicate different level of distraction); neural networks; unsupervised, semi-supervised, and supervised machine learning techniques (information from multiple detecting systems and machine learning algorithms to reach a decision); and combinations of multiple techniques (Khatib, Ou, & Karray, 2020) (Khan & Lee, 2019). Table 4 below defines the different metrics and methods used for the different non-invasive parameters, noting that some parameters are related to drowsiness and driver unresponsiveness, which are out of scope for ADDW.

Early studies on determining driver distraction found in the literature were based on driver monitoring (Kashevnik, Shchedrin, Kaiser, & Stocker, 2021). In such studies, drivers are not required to do anything other than their regular driving tasks and their behaviour is monitored and compared with other drivers to create a baseline. There is no consensus found in the literature on a suggested threshold to be used for different distraction levels.

Another way of determining the threshold of attention is by assessing the driver's degree of distraction caused by engagement in non-driving related tasks while driving. There are various ways of implementing different levels of distractors in the form of different secondary tasks. Driver's movements are monitored and the time the driver is considered to be involved in a secondary task is recorded and compared across difficulty levels.

Findings from the stakeholder engagement echo the above and note that gaze detection is the most common method of assessing distraction. It was also stated that systems that focus on measuring distraction through gaze alone show a potential for lowered performance in cases where the driver is wearing sunglasses (especially infra-red blocking sunglasses) or is seated in an extreme seat position. Many systems try to mitigate this by using additional methods of measuring distraction.

The stakeholder engagement also found that there is currently no consensus within the industry regarding the threshold of distraction warnings. Most systems are customisable, and the thresholds are often determined by the OEMs. Another area of inconsistency is the overall number of driver states that an OEM monitors and the predefined ‘zones’ used to detect and determine the level of distraction.

Table 4: Description of non-invasive attention parameters observed

Parameters observed	Metrics used	Method for capturing data
PERCLOS	Percentage of duration that the eye is closed over a time interval of 60 seconds.	Eye Tracker Webcam Wide-angle cameras
Gaze direction or Off-road glances	Degree of movement of the centre of the eyes away from the baseline/frontal orientation	
Blink frequency	Frequency of blinks within 60 seconds	
Blink duration	It is the total time from the start to the end of a blink. It is typically measured in the units of milliseconds (around 200–400 ms)	
Micro sleep	If the duration of a detected eye blink exceeds 500 ms (and less than 10 s), this situation corresponds to a microsleep	
Head detection	Degree of movement of head away from frontal orientation within 60 seconds	
Yawning frequency	Mouth or lip movement	
Body movement	Lack of movement/ Unresponsiveness	
Hand detection	When the driver takes the hands off the steering wheel	
Feet detection	Driver’s feet movement and readiness to step on pedal	

Several limitations of eye trackers are noted (Sharafi, Soh, & Gueheneuc, 2015). These include:

- Precision and accuracy - head movement makes it difficult to estimate the eye gaze of a subject
- Hard contact lenses, glasses or makeup (e.g. mascara) may interfere with the path of infrared light of the eye tracker

The literature largely focused on vision-based monitoring systems. Studies using eyes off-road detection as their method of assessment generally used 2 seconds of off-road glances as a threshold. The analysis of eye-glance behaviour by NHTSA (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006) suggested that total duration of eyes-off-road scenarios of greater than 2 seconds significantly increased individual near-crash/crash risk. In contrast, eyes-off-road scenarios of less than 2 seconds did not significantly increase risk relative to normal baseline driving. The paper noted that not all glances off the road ahead are inattentive behaviour. Behaviours such as checking the side or rear-view mirror are considered behaviours that enhance safety and occur at least 44% of the total driving duration. While such behaviours are essential for safe driving when done systematically and under two seconds, it can be picked up by attention monitoring systems and flagged as inattentive. This raises difficulty in discerning what is a safe and unsafe threshold.

(Bucsuházy, et al., 2020) observed drivers took longer off-road glances to engage in safe driving behaviour. They analysed durations of selected off-road glances captured in real road traffic while drivers were instructed to follow the direction of the navigation system. Two types of tasks were analysed – only visual information, and combination of visual-audio information on the navigation system. A video-based eye tracker was used to capture driver behaviour in normal city traffic for a total route length of 16 kilometres. Glances considered off-road were in situations where the driver looked away from the road towards something and fixated their glance on the object before looking back at the road. They found that the average duration of total off-road glances conducted to check the situation using the vehicle mirrors was 1.2 seconds. Additionally, the average duration of off-road glances while using the navigation system with and without audio information was 0.6 and 0.9 seconds, respectively. Similar findings from analysis of results from field operational tests (FOTs) in UK highlight the impact of different levels of distraction on levels of attention and off-road glances. Morris et. al. (2015) investigated the effects of distraction of navigation and green driving systems. These studies highlight the inconsistent off-road glances threshold level based on different level of distractions and draw attention to the need for creating less distracting in-vehicle interface (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

It is important to note that the two second threshold advised by (NHTSA, 2014) pertains to manually driven vehicles. While in manual driving situations, a standard threshold could be applicable to trigger an alert system, it may not be entirely transferable to automated vehicles attention detection systems. There are six levels of vehicle automation to provide a common interface for research and development among different stakeholders within the industry, ranging from no automation to fully automated vehicles. Given that an automated driving system can control the vehicle, this creates the opportunity for drivers to reduce their attention to the road and engage in secondary none driving tasks such as texting. As such, any draft regulation will need to account for whether a vehicle is in automated driving mode or not. The requirements may be different for a Level 2 partial automation, where the driver is expected to maintain full awareness of the driving situation, and Level 3 or 4 automation systems, which may have specific requirements for driver availability monitoring systems. It may be possible to deactivate ADDW warnings when a driving automation feature is engaged and a suitable driver availability monitoring system is active.

(Yang, Kuo, & Lenné, 2019) and (Gaspar & Carney, 2019) compared off-road glance pattern in drivers on a test track while engaging in different secondary tasks. There were three levels of distraction monitored while driving a manual vehicle and an additional fourth level of distraction monitored while driving an automated vehicle. As the level of distraction increased, participants' off-road glances became longer, less frequent, and less consistent. The overall higher eyes off-road glances observed in drivers in automated vehicles raises concerns about slower take-over behaviour when inattentive in automated vehicles and setting appropriate trigger points. (Gaspar & Carney, 2019) gathered similar results in their analysis of driver visual attention during partially automated driving in real-world conditions. Participants were more likely to over-rely on automated driving and hence make longer glances away from the road to attend to secondary tasks. Such studies restate the finding that there is currently no consensus within the industry regarding the threshold of distraction warnings.

2.6.1. Definition of most common alerts used and their effect on driver behaviour, as well as their perception/ratings

The literature review did not reveal a set of common alerts used in ADDW systems. However, a study by Alam et al. (2021) described the use of a vision-based ADDW system. The system comprises four major modules: cue extraction and parameter estimation, state of attention estimation, monitoring and decision making, and level of attention estimation. The system estimates the driver's state of attention and classifies the attentional states based on the percentage of eyelid closure over time (PERCLOS), the frequency of yawning and gaze direction (see Section 1.4 for a definition of these metrics). The system makes the decision based on the driver's estimated state of attention (SoA) for the previous frames. Based on the value of the drivers' state of attention, this module generates an alert (sound and message signal) for the driver. The system generates an alarm if the driver is found in any of the inattentive states (i.e. drowsy, fatigue, and distracted). The alarms deactivate automatically when the driver gets back to the desired SoA (i.e. attentive). The three alarms consist of beep sounds, which are used to indicate drowsiness, fatigue, and distracted SoA.

Further, Ahir and Gohokar (2019) conducted a review of the current driver alertness systems and methods of detection and describe the following systems. Note, these are drowsiness detection systems, not distraction detection systems per se. Whilst these systems may catch some of the effects of distraction, such drifting out of a lane, this will only be once it has happened and will not be captured if the vehicle does not have a lane centring function.

1. **Ford's** driver alert calculates an alertness level for the driver using a front camera which faces the driver.
2. **Volkswagen's** driver alert system continuously evaluates the results such as drivers' characteristics and steering patterns at the initiation of every new trip.
    - If the system detects a lapse in concentration, it gives the drive a five second audible tone warning. This involves a warning sign being displayed on the instrument panel, which requests that the driver takes a break.
3. **Volvo** detects failing driving ability via a camera which monitors the edge markings painted on the carriageway and compares the alignment of the road with the driver's steering wheel movements.
    - When the driving behaviour starts to become inconsistent; the driver is alerted by a symbol in the driver display, together with the text message "Time for a break soon?"

Khan and Lee also describe a number of alert types offered across several makes of vehicle. These alerts were used by Audi, BMW, Cadillac, Ford, Mercedes-Benz and Toyota and all use audio, visual alerts (which appear on the instrument display), with Audi, BMW and Ford also using vibration-based alerts.

3. Performance requirements on ADDW systems - State of the art based on stakeholder engagement (Task 1)

3.1. Introduction

Similar to the literature review the key focus of the Task 1 stakeholder engagement was to identify the ability of available and up-coming ADDW systems to reliably detect driver distraction. The following overview presents the findings from the engagements in relation to Task 1, including the methods and metrics for the assessment of driver attentions and driver monitoring systems, and views on the regulation of ADDW systems. As with the Task 1 Literature review, this will be fed into a list of recommendations and requirements, similarly considering future trends in technologies as well.

3.2. Method

An initial list of stakeholders was generated. The stakeholders were then contacted and asked to participate. In total, 18 consultations took place over a three-month period (Table 5). An additional 3 written summaries were provided by stakeholders who were unavailable for consultation.

Table 5: Overview of stakeholder engagements

Authority	Number
OEM	5
Tier 1	4
Tier 2	2
Aftermarket	3
Technical authority	3
Academic	2
NGO	2
Total	**21**

All stakeholders were invited to attend an individual consultation, which was facilitated by staff from TRL and fka. During the consultations, the stakeholders were given an opportunity to present an overview of their system and answer the questions presented in the topic guide. The questions in the topic guide differed slightly for each stakeholder group, but were all based around the example topic guide in Appendix A: Stakeholder consultation topic guide. Vehicles from categories M1-M3 and N1-N3 were represented in the stakeholder engagements.

3.3. Results

3.3.1. Overview

The majority of systems were designed to measure the drivers' distractions, although some have the capability to monitor driver attention to the driving task as well. Out of the stakeholders with developed or in-development systems, three had the capability to monitor attention and this was measured through eye and gaze tracking. Systems were designed to detect drivers looking away from the road, browsing or otherwise using a phone as well as interacting with other systems or passengers in the vehicle. Most systems also mention the capability to measure fatigue, microsleeps and drowsiness, noting that this form of inattention is already covered by the DDAW regulation (Commission Delegated Regulation (EU) 2021/1341).

- The installation of systems (especially the positioning of cameras) differs across vehicle categories due to differences in the vehicle design, e.g. seat and steering wheel positions, cabin geometry and so forth.
- Most systems work on a closed loop system, without storing any personal data. Where such data is stored, this is done with the consent of the driver. This stored personal data typically supports comfort features within the vehicle, such as automatic seat position adjustment for individual drivers via face recognition.
- Most systems use infrared (IR) technology, mitigating the effects of harsh ambient lighting and darkness. In cases where such a system is unable to detect e.g. eye gaze direction due to unfavourable lighting or other constraints, most systems are designed to provide an alert to the driver.

3.3.2. Metrics and methods for the assessment of driver attention

- Gaze direction detection was the most common method of assessing distraction. Other methods include head movements, face orientation, object or people detection and body movements. The systems also usually measure behavioural distraction factors like unresponsive drivers (sickness), drowsiness and fatigue.
- The overall number of driver states monitored by the system often depends on OEM specification and therefore varies. Some driver states monitored include distraction type, distraction level, cognitive load and closed eye.
- Most systems use defined 'zones' to determine the possibility and severity of distraction, though these zones can differ across OEMs and vehicle categories.
- Systems that focus on measuring distraction through gaze alone show a potential for lowered performance in cases where the driver is wearing sunglasses (especially IR blocking sunglasses) or is seated in an extreme seating position. Many systems try to mitigate this by using additional methods of measuring distraction, such as monitoring head positioning and direction.
- There is currently no consensus within the industry regarding the threshold for distraction warnings. Most systems are customisable and the thresholds are determined by the OEM.

3.3.3. Metrics and methods for the assessment of attention monitoring systems

- ADDW systems are currently assessed through a combination of stationary, on road driving and simulated driving tasks. Some systems also use synthetic data. Most systems also assess performance in daytime as well as night time settings.

- The most commonly used method is to have the drivers look at the designated distraction areas in the car or perform specific non-driving tasks and monitor whether the system identifies these as 'distractions'.
- During user experience testing, the main aim is to minimise the number of false positives, often by assessing annoyance from the drivers.
- A common challenge during the development of most of these systems were the limitations imposed by the use of cameras. This included identifying distractions occurring in areas outside the camera's view as well as impacts of accessories like face masks and other occlusions.
- Another challenge was the lack of a clear demarcation between the different distraction zones. This made it more difficult to accurately determine whether the person was performing a driving-related task or a non driving-related task, as well as the potential severity of any distraction.

3.3.4. Views on regulation of ADDW systems

1. The general recommendation from stakeholders was that the regulation should focus on setting only a minimum level of performance requirement. ADDW systems are still in the early stages of development and stakeholders indicated that there is a risk of the regulations putting limitations on their future improvement.
2. There is also a concern regarding strict regulation having negative impacts on the end user experience, again because this could restrict future improvements in HMI as experience with ADDW systems increases.
3. The regulation should also consider the presence and future development of distraction prevention systems and their synergy with the existing drowsiness monitoring systems.

From the stakeholder engagements, expectations and suggestions regarding the following technical requirements were gathered:

1. Areas of Interest
2. Position of the camera
3. Seating position
4. Variability in human appearance
5. Activation speed of the system

Area of Interest

With regards to the Area of Interest, stakeholders noted that it is important to define specific AoI in order to establish test criteria. This definition does not need to correspond with the AoI used when developing a system. During the consultations, stakeholders expressed their views on the different technical requirements they recommend for the regulation.

When asked how a camera-based system should deal with glances into places other than the road, but that are still relevant to the driving task, such as the instrument cluster or side mirrors, most stakeholders had a similar suggestion of using 3 levels of distraction areas. Level 1 is areas the driver sees often while driving (front windscreen, high difficulty to avoid false positive as located close to the attentive zone), Level 2 is areas of distraction between level 1 and 3 (side mirrors and instrument cluster, medium difficulty to avoid false positive), and Level 3 is areas of distraction higher than level 2 (down at lap and passenger footwell, low difficulty to avoid false positives). Warnings are mainly issued for level 3 areas, with the intensity of the warning dependent on the areas to avoid false positives. An image of these levels can be seen in Figure 1 below. Stakeholders also raised some concerns regarding false positives in the level 2 distraction zone. There were some worries that it may be difficult to distinguish between eye glances to the instrument panel and mirrors that a relevant to the driving tasks and those that are not (e.g., someone looking at a phone placed in a cradle on the instrument panel or someone looking at digital entertainment playing on the infotainment system) and this could increase the number of false positives for this zone.

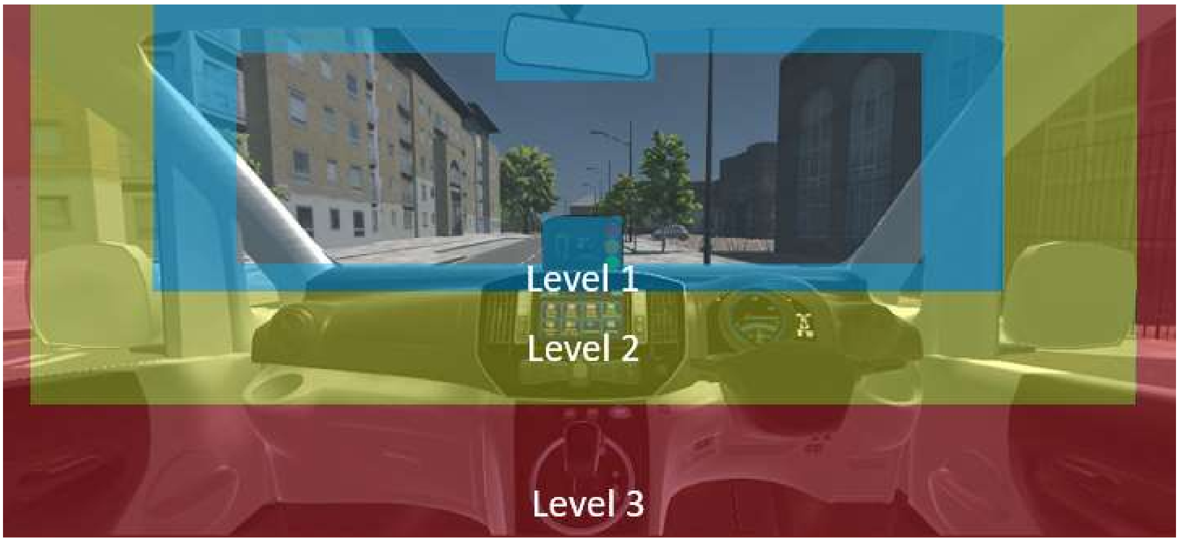

Figure 1 The three levels of distraction recognised in camera-based systems

One stakeholder highlighted that a proposal of 2 distraction zones is not robust enough against different cockpit designs, because it suggests that drivers can look at the instrument cluster for a long period, with attendant risk, and not be issued with a warning. The 3-zone approach is therefore more appropriate, but this may need to be adapted for intermittent distraction.

Position of the camera

With regards to the optimal position for the mounting of the camera, stakeholders highlighted that the camera position depends on the vehicle category the system is implemented in due to the differences in interior geometries and cabin layout between e.g. passenger cars and heavy goods vehicles. The difference in interior between vehicle categories, such as passenger cars compared to trucks, causes challenges in the effectiveness of detecting the eye gaze of the driver.

Furthermore, one stakeholder highlighted that a difference between cars and trucks is the hydraulic seating in trucks and buses, which may cause difficulties for the camera to detect eye gaze if the driver is moving, or the seat is moving.

Moreover, stakeholders proposed that an example of where the camera could be positioned in a passenger car is on the steering column; however this would not be feasible in a truck as the view towards the driver would be obscured and limited due to the different geometry. Similarly in a passenger car, the way the driver holds the steering wheel such as in a 12 o’clock position, their face and eyes would be covered, at least temporarily. Therefore, the camera would need to be positioned in an alternative location, such as on the dashboard, secondary display or on the interior rear-view mirror, which may affect the performance of the system at detecting distraction through the driver's eye gaze.

Seating position

Similarly, the seating position varies between vehicle categories, thus the performance of the ADDW also depends on the seating position of the driver. The seating position of the driver is important as this impacts the angle from the camera to the eye and any occlusions. Furthermore, one stakeholder highlighted the importance to consider hydraulic seats that are commonly used in buses and trucks.

Variability in human appearance

With reference to the variability in human appearance, accessories such as infrared blocking sunglasses causes performance issues for the detection of the eyes, therefore this should be considered in the regulation. Most stakeholders reported that their systems work with a wide range of physical appearances and accessories such as face masks and spectacles but understand there may be use cases where the system does not perform to its optimal capability. An example of this would be if the frame of the driver's glasses blocks the camera from detecting eye gaze. In this situation, stakeholders suggested for head movement to be used as the secondary metric.

Activation speed of the system

The activation speed of the system received mixed views from stakeholders during the consultations. Activation speeds for individual systems can be found in Table 3. One stakeholder believed that a 10 km/h threshold is suitable for the system to be able to differentiate between manoeuvring situations and 'normal' driving situations; beyond the 10 km/h threshold, the driver should be attentive to the forward view of the road. Other stakeholders reported that the minimum activation speed should be 20-30 km/hh to avoid annoyance of the driver during slower driving tasks such as parking or manoeuvring, which they considered less dangerous than driving at speeds over 30 km/h. However, one stakeholder highlighted that regardless of speed, urban environments are much more dynamic, and suggested that lower speeds do not mean lower risks and that the risks across all driving settings are similar for different reasons.

Time threshold for a distraction warning

The time threshold for a distraction warning was discussed in the consultations, with reference to both long and intermittent distraction. For long distraction, there was a mix of responses ranging from under 2 seconds to 4 seconds based on research they have conducted. Several stakeholders believed that the time threshold for long distraction should be decided by the manufacturers to allow for the users to accept the system and prevent annoyance by false positives; however, the most suggested time threshold was 4 seconds, or 3+1 seconds.

With reference to intermittent distraction, multiple stakeholders referred to the '30 second window' threshold, which implies that during a 30 second time period, there should be a 10 second threshold regarding the cumulative period eyes off road, then when the driver looks back to the road for 2 seconds, the window resets. This type of distraction is particularly important if the driver is interacting with the infotainment system or mobile phone device while driving, and they are intermittently glancing away from the road. Some stakeholders believed that intermittent distraction detection should be dependent on the context and driving situation.

Distraction indicator

Stakeholders were asked their views on a distraction indicator, which received mixed results. Some stakeholders expressed that their systems could have different levels of distraction, which they recommended having, and highlighted that the manufacturers should have the freedom to use different levels and design their strategy of warning escalation if they desire so. One stakeholder said that communication with the driver about their behaviour and distraction state could make a difference to their day-to-day driving.

However, a number of other stakeholders responded that a distraction indicator could draw the driver's attention away from the road to look at the indicator, causing more distracted behaviour thus having an adverse effect on the safety benefit the system is trying to achieve.

3.4. Task 1 Summary and conclusions

The purpose of Task 1 was to establish the current state of ADDW technology and the most appropriate threshold for attention. The review revealed two main findings. First, a number of ADDW systems exist, with the majority of these using cameras to monitor eye and head position, to gauge alertness, fatigue and distraction. Several systems describe using Artificial Intelligence (AI) algorithms to detect driver drowsiness. Second, the literature was inconclusive regarding the most appropriate threshold for attention. Whilst the NHTSA guidelines clearly define distraction in terms of glances away from the road, the literature review revealed that different metrics are used to describe attention in the context of driver distraction. These metrics tend to be visual, e.g. off-road glances (this finding is supported by the stakeholder engagement findings), but also non-visual metrics such as the hands on the steering wheel. Not only are metrics used to gauge attention differently, but the thresholds of attention used within these metrics also vary. Some studies report that two seconds of eyes off road time (when the driver is looking away from the forward roadway) may constitute distraction, whilst others examine individual frames of video footage to gauge distraction. The stakeholder engagement, conversely, showed that gaze detection is the most common method for assessing distraction. Furthermore, in line with the findings from the literature review, the stakeholder engagement showed that no consensus exists within the industry regarding the threshold for distraction warnings.

4. Performance requirements for an effective human machine interaction (Task 2)

It is important for a safe and convenient interaction between driver and vehicle that the HMI is designed to be efficient and effective at achieving the system's goals. Specifically, for ADDW systems, once attention is monitored and thresholds characterising distraction have been detected, it is necessary to examine how the ADDW system's HMI can alert the driver to inattention, resulting in the driver to refocus on the driving task, without the alerts themselves causing more distraction. Therefore, the driver needs to perceive the alert successfully, understand its purpose promptly, and react appropriately without delay.

4.1. Introduction

The activities under Task 2 were carried out to gather information not only on the technical preconditions to help drivers avoid distraction while driving and to identify additional means that could help drivers to regain focus once their distraction has been confidently identified. The overall purpose was to establish the current state of HMI used for ADDW technology and their appropriate performance requirements. This will, as in Task 1, be fed into a list of recommendations and requirements, similarly considering future trends in technologies.

Objectives

- Identify current recommendations on how the HMI of an ADDW system should be designed in order to lead to appropriate driver reactions (including consideration of intensity, modality, or escalation strategies)
- Clarify whether an adaptive information presentation strategy would be sensible from a human factors point of view and feasible from a technical point of view
- Provide HMI performance requirements that feed into Task 3

4.2. Methodology

For the derivation of performance requirements for an effective HMI of ADDW systems, the search for evidence under Task 2, following an approach similar to Task 1, consisted of two methods to gather information on the current state of the art: Literature review and consultations with stakeholders.

4.2.1. Method 1: Literature review

Warnings emitted by collision preventing systems (e.g., FCW, AEBS, ELKS, ISA), as well as by drowsiness and fatigue monitoring systems were out of scope of the literature review of Task 2, because the requirements for the HMI of those systems have already been established in the Regulation (EU) 2021/1341 (European Union, 2021).

The literature review comprised three parts:

- Available technology: Review of OEMs' public announcements about driver distraction warning systems released on the consumer market in the last 10 years. The intention was not to perform an exhaustive analysis of all existing systems but to provide an overview of the HMI implementation for distraction warning systems currently available in the market.
- Ongoing research: Analysis of scientific papers that could provide performance requirements and assessment procedures for the HMI of ADDW systems. The evidence review focused on technology and empirical literature specific to the development of driver distraction warning HMI applied in the absence of an external hazard or imminent collision, because systems focused on hazards and imminent collisions are designed for intervention rather than preventive warning.
- Relevant normative standards and design guidelines:(Seidl, et al., 2021), relevant normative standards on the ergonomic aspects of transport information and control systems of road vehicles, as well as established guidelines for the design of driver-vehicle interaction, should be taken into consideration to develop minimum performance requirements for the HMI of ADDW systems.

(a) Research questions

In order to derive minimum performance requirements for the HMI of ADDW systems, the work undertaken during Task 2 looked for evidence to answer the following research questions (RQ), clustered under three topics:

Cluster 1) Available approaches

RQ1.1. What approaches implemented via the HMI are currently available to alert the driver about their distracted state?

- What sensory modalities are used to convey distraction warnings?
- Escalation strategies: Are there approaches adopted for the design of distraction warnings in case the driver fails to comply with the behaviour the system requires?
- Is it possible to identify trends in the design of distraction warnings?

RQ1.2. How is HMI in distraction warning systems currently being tested and evaluated?

- Are there published results about studies on the performance of the HMI of driver distraction monitoring and warning systems?
- Based on the results from RQ1.1, how are escalation strategies being tested and evaluated?
- How does the Euro NCAP address distraction-warning systems in their assessment protocol for safety assist?
- What performance metrics or assessment methods could be used to evaluate the effectiveness and efficiency of the HMI for ADDW systems?

RQ1.3. Are there approaches to guide attention or help the driver to focus on the driving task?

Cluster 2) Adaptive warnings

RQ2.1. What strategies to adapt the emission of distraction warnings are there?

- In what context could the emission of distraction warnings benefit from adaptation strategies?
- How are adaptive warning strategies implemented via the HMI?

RQ2.2. What are the potential benefits and risks associated with adaptive warnings?

- From a human factors perspective?
- From a technical perspective?

Cluster 3) Relevant normative standards and design guidelines

RQ3.1. What aspects of relevant normative standards should be considered for the HMI of ADDW systems?

RQ3.2 What aspects of relevant normative standards should be considered for testing and validating the HMI of ADDW systems?

RQ3.3. What information is already included in established design guidelines on avoiding driver distraction?

RQ3.4. Are there any specific recommendations or guidelines for guiding the driver's attention?

As with the method used in Task 1, the evidence review for the research questions under Clusters 1 'available approaches' and 2 'adaptive warnings' took a 3-step approach:

- Definition of search terms, listed in Table 6 and Table 7;
- Assessment of the relevance and timeliness of the identified literature;
- High level review of full text literature.

For the Cluster 3 'relevant normative standards and design guidelines' research questions, the following Standards were considered relevant:

- ISO/TR 12204: 2012 – Road vehicles – Ergonomic aspects of transport information and control systems – Introduction to integrating safety critical and time critical warning signals
- ISO/TR 16352:2005 – Road vehicles – Ergonomic aspects of in-vehicle presentation for transport information and control systems – Warning systems
- ISO 15005: 2017 – Road vehicles – Ergonomic aspects of transportation and control systems – Dialogue management principles and compliance procedures
- ISO 15006:2011 – Road vehicles – Ergonomic aspects of transport information and control systems – Specifications for in-vehicle auditory presentation
- ISO 15008:2017 – Road vehicles – Ergonomic aspects of transport information and control systems – Specifications and test procedures for in-vehicle visual presentation
- ISO 17287:2003 – Road vehicles – Ergonomic aspects of transport information and control systems – Procedure for assessing suitability for use while driving

Also for the Cluster 3 research questions, the following guidelines were considered as established in the automotive industry and thus analysed:

- European Commission: the updated version of the “European Statement of Principles” (ESoP) (European Commission, 2008)
- NHTSA: the “Human Factors Design Guidance for Driver-Vehicle Interfaces” (Campbell, et al., 2016)
- NHTSA: the “Human Factors Design Guidance for Level 2 and Level 3 Automated Driving Concepts” from 2018. (Campbell, et al., 2018)

Despite also being well-known design guidelines for the development of automotive HMI systems, the “Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems” from the Alliance of Automobile Manufactures (AAM), published in 2006, was not investigated during Task 2 since it consists of design principles for systems involving visual-manual interaction. The “Guidelines for In-vehicle Display Systems” from the Japan Automobile Manufacturers Association, published in 2004, was likewise not analysed in Task 2 due to only regarding the design of visual displays and having all listed principles already covered in the ESoP.

Finally, overarching all three clusters of research questions regarding HMI for ADDW systems, the latest version of Euro NCAP’s Assessment Protocol (Euro NCAP, 2022), which will come into implementation in 2023, was also included for analysis. The aim was to avoid HMI performance requirements proposed within Task 2 unnecessarily constraining or contradicting elements checked during the scoring process, which could otherwise end up penalising manufacturers.

(b) Search terms (specific to literature review of ongoing research)

Two lists of search terms were generated. Table 6 lists the search terms for the RQs under Cluster 1 regarding available approaches. Five “Level 1” terms target the search to focus on a) automotive field, and b) driver attention or c) driver distraction, and d) HMI, and e) Performance Requirements. The “Level 2” terms further refine the search. For the research questions under Cluster 2 regarding adaptive warnings, the terms listed in Table 7 were added. These search terms have been applied systematically within the databases Scopus, Web of Science, and Google Scholar.

Table 6: Search terms for evidence gathering under Cluster 1 of research questions

Level 1	Level 2 (Synonyms / Different spellings / Alternatives)
Automotive Field	Car Cars Vehicle* Automotive Automobile Transportation Driver* Driving Driving Task
Distraction	Distraction + avoidance + technolog* + warning
Attention	Attention Focus Guide / Maintain + attention + focus

Table 6 (continued)

Level 1	Level 2 (Synonyms / Different spellings / Alternatives)
HMI	HMI Human machine interface* / Human machine interaction Driver vehicle interface* / Driver vehicle interaction Visual / Acoustic / Haptic + warning* Display* Sound* Vibration*
Performance Requirements	Performance + behaviour / behaviour Response* False + warning* + positive* + negative* Warning* + implementation* + impact* + effect* + influence* Efficient / Efficiency Effective / Effectiveness Reliable / Reliability / Reliably Robust / Robustness

Table 7: Search terms for evidence gathering under Cluster 2 of research questions

Level 1	Level 2 (Synonyms / Different spellings / Alternatives)
Adaptive Warning	Adaptive + warning* + alert* + strateg* Escalation / Escalated Warning* / Alert* + timing + interval* + filter* + inhibit* Road type*

(c) Inclusion and exclusion criteria (specific to literature review of ongoing research)

In order to ensure that only literature of sufficient relevance and quality was included in the review, only peer-reviewed papers were considered and also specific inclusion and exclusion criteria were used to assess the suitability of the identified sources (see Table 8). The timeliness for the inclusion of HMI studies was longer than the one used for Task 1, as HMI performance characteristics had not been investigated on the previous Report on ADDW systems (European Commission, 2021).

Table 8: Inclusion criteria for the literature review

Criteria	Inclusion	Exclusion
Relevance	Addressing HMI in the contexts relevant to the research objectives of the project	No addressing of HMIs in the contexts relevant to the research objectives of the project
	Reports of user studies offering parameters to technical and/or subjective HMI performance	No studies with reports on performance parameters
Timeliness	Published in the last 10 years	Published longer than 10 years ago.

An initial search was conducted to obtain a list of titles and abstracts, which were reviewed and scored according to the Inclusion Criteria. A shortlist of 20 papers was then created and they were all reviewed in detail. The findings have been grouped where appropriate to aid in structuring the report for the reader. In total, 8 studies have been included in the literature review.

4.2.2. Method 2: Consultation with Stakeholders

The consultations with stakeholders were carried out via teleconference to gather information on the types of systems that OEMs and suppliers currently have on the market or in development. The stakeholders were engaged using a standardised series of structured questions to guide discussion (see “Topic Guide” in Appendix A) and ensure that relevant information was captured from each stakeholder in a consistent manner. The research questions used in the Literature Review under Method 1 were taken into consideration when formulating the questions within the Topic Guide, which ultimately aimed to collect information on:

- Design recommendations for the HMI to support the ADDW system’s understandability, acceptance and effectiveness
- Appropriate performance requirements for the HMI to be addressed in the regulation
- Test procedures applicable in verifying the performance of the HMI towards validating ADDW systems

4.3. Results

The Results section within Task 2 consists of three comprehensive tables containing all the consolidated information during the literature review of published materials (press releases, manufacturers’ websites, scientific papers, norms, and guidelines).

In compliance with confidentiality agreements, information obtained during the stakeholder engagements relating to ongoing developments, specific innovative technologies or competitive know-how have not been disclosed.

4.3.1. State of the art based on literature review

This section presents the results from the literature review, which comprised three parts: available technology, ongoing research in the academic field, and review of relevant norms and guidelines.

Available HMI technology for distraction warning systems

The review identified 7 examples of distraction warning systems' HMI currently implemented in serial passenger vehicles available in the market and 1 example of an aftermarket system installed in commercial vehicles. These are summarised in Table 9. All of the identified systems provided visual and auditory warnings, while only one example for passenger vehicles and one for commercial vehicles provided haptic warnings. Some HMIs apply repetition or escalation of the warnings in the event that the system detects continued distraction.

Ongoing research in the academic field

From the 7 papers summarised in Table 10, 6 presented recommendations regarding design of HMI applied for distraction warnings as well as some performance results from empirical studies. The study presented by Muvihill et al. (2021) reported on the evaluation of the system presented by Horberry et al. (2021) which addressed the design of an HMI concept for intermittent distraction.

Review of relevant norms and guidelines

All documents were analysed with focus on collecting relevant norms and design principles applicable in the derivation of technical requirements for the HMI of ADDW systems. When mentioned by the norm or design guideline, performance requirements and test procedures recommended for validating the identified technical requirements were also taken into consideration. The results are summarised in Table 11.

distraction): until system detects that gaze is redirected to the road een e during 1st stage): until system detects that driver took over control of the steering wheel rts the driver to redirect gaze towards the road and to take control of the steering wheel d during 2nd stage): until system detects that driver took over control of the steering wheel (otherwise Super ol) nd stage ontrol of the vehicle now!" ding to an interview with a General Motors Engineer (LeBeau, 2017): 4 seconds if at 75 mph (ca. 120 km/h) or longer than that when at 10 mph (ca. 16 km/h)	long as speeds are above 20 km/h and below 137 km/h (85 mph)	
prises both monitoring of driver's visual attention to the forward road and driver drowsiness monitoring additional bar graphics displaying level of drowsiness and level of distraction are shown	Activated at 25 km/h	Indirectly, via menu
forward road during hands-off ADAS BlueCruise is additional to monitoring of driver drowsiness (which as o redirect attention to the road, the BlueCruise systems engages the brakes and slows down the vehicle g control, the driver is requested by the system via visual message on the instrument cluster to press the	Activated when BlueCruise system is active. BlueCruise is geofenced to specific highways in North America, where it can be enabled at speeds up to 136 km/h (85 mph)	Not possible, requires deactivation of the BlueCruise system
	Activated at 60 km/h (37 mph)	Indirectly, via menu
y: standard or sensitive, in which the warnings are triggered earlier tion can be accessed via menu	• Activated after 30 min. of consecutive driving • Between 60 km/h (37 mph) and 200 km/h (124 mph)	Indirectly, via menu
vehicle will begin to slow itself and even come to a full stop. the system will call for help from emergency responders by using connected services technology.	System will not alert the driver if: • Turn signals are on • Vehicle is in reverse	Depending on vehicle model: • Directly, via physical button, or • Indirectly, via menu
iour does not improve.	Activated at 65 km/h (40 mph) and remains active as long as speeds are above 60 km/h (37 mph)	Indirectly, via menu

	• Warning inhibited when driver pressed the brake or performed severe steering manoeuvres • Warning inhibited when occurred within 15 s from the onset of an earlier warning	3. Time from warning to fully attentive 4. Visual time-sharing duration 5. Visual time-sharing intensity 6. Time duration to next buffer empty	• Variables 1 through 5 with tendency of reduction ○ for (1): a slightly reduced frequency of dangerously long off-road glances in relation to the complete trip; and a reduced percentage of off-road glances and of long glances within the off-road glances ○ for (2) and (3): both with tendency for slight decrease ○ for (4): as the sum of (2) and (3), consequently decreased ○ for (5): reduction of 7,5% • Variable 6 slightly (but not significantly) longer
n bus ted ssing o be ng ated ns not	None described	Not tested yet, previewed for future work.	Not tested yet, previewed for future work.
ces", when rts. 2 s nply es / river ing free e	None described	• Activation rates per hour ○ In the case of this study, activation rates of each of the 3 stages were aggregated separately • Driver's responsiveness to warning alerts (executing the system's required response to be not considered distracted anymore) • Response to silent driving system failures (lane drift) • Driver's understanding of system prompts and alerts (via subjective questionnaire)	• Compliance to stage 1 warnings averaged 92.6% (only 7.1% of warnings emitted were stage 2 warnings and 0.2% were stage 3 warnings) • On average, drivers were found to look up and detect the lane drift within 3.54 s of the onset of the event. ○ Drivers detected the lane drift before stage 1 was triggered in 59% of cases ○ Alert interventions increased detection rates by 35% • Differentiation between untrained drivers and drivers previously trained on the system functionalities ○ 90% of trained drivers and 64% of untrained drivers understood correctly the system functionalities and the escalation strategy ○ 14% of untrained drivers misunderstood warnings as alerts to the presence of hazard.
e luded and	• Study about the influence of drowsiness and distraction on the take over request (TOR) of highly automated vehicles	• Qualitative: ○ Visual recognition of TOR alarms ○ Auditory recognition of TOR alarms • Quantitative: ○ Reaction time between emission of request and taking over control ○ Blink count during reaction time ○ Acc. to author's literature review, blink count is positively correlated to cognitive load) ○ Gaze distance per second during reaction time ○ Author argues that visual distraction increases gaze	• Results suggest that auditory information, particularly the alarm sound, was recognised more quickly than visual information for TOR, regardless whether driver was distracted or drowsy. • Reaction time was longer for distracted drivers in comparison to drowsy drivers, but not due to fail in noticing the emission of the alarms ○ Drowsy participants could not identify the traffic situation when alarm sounded; being thus startled when reassuming control ○ Distracted participants, although engaged in secondary task, could identify the traffic situation sufficiently fast and prepare themselves for the take-over, exhibiting a relatively larger safety margin • Distracted drivers had higher blink count than drowsy drivers, indicating a higher increase in cognitive load.

Table 11: Relevant normative standards and design guidelines for the HMI of ADDW systems

Technical requirements applicable to ADDW HMI	Recommendations on performar
one mentioned is technical report proposes approaches for facilitating driver's comprehension and discusses methods r assessing possible integration conflicts between concomitant signals (e.g. distraction warning nflicting with an incoming call or warning from another ADAS).	None mentioned
Design of visual warnings: (for more details, please consult the referenced source) o Sizing o Colours o Use of symbols vs. text based on the information conveyed o Blinking frequency, etc. Design of auditory warnings: o Loudness: 50-70 dB (comfort range) and 70-90 dB (emergency range) o Frequency: 500-3 000 Hz (tonal warnings) and 200-8 000 Hz (speech warnings) Design of tactile/haptic warnings: o Vibration frequencies: 100-300 Hz (most sensitive to humans, and high enough to not be covered by road-induced vibrations and to be away from the human-body Eigen-frequencies around 3 Hz)	• Effectiveness: o Detection rate, and o Response time. • Efficiency: o Alert impairment (e.g. startling effect); o Reliable detection and identification (cons clearness); o Intelligibility: - by psycho-acoustical parameters (com characteristics of the signal against ba - by psychological metrics (parameters and/or behaviour, e.g. perceived mear o Compliance, i.e., transition from unsafe o
Visual warnings should be presented in a defined place, orientation and format; When multiple information delivery systems are installed within a vehicle, the integrated designs should consider the relative priority of their functions	Information presentation should be designed to • Maximise understanding • Facilitate operation
In-vehicle auditory signals specifications o Recommended frequency range: 200-8 000 Hz o Frequency range specific for tonal warnings: 400-2 000Hz (due to age-related audibility decrease) o Time from onset to full loudness: ≥ 30 ms The urgency of a situation should be reflected by the character of the signal If a corresponding visual warning is emitted, it should be displayed at the same time	• Audibility: as high as possible whilst still suit sudden/surprised reflexes or defensive reac
Visual warnings: (for more details, please consult the referenced source) o Contrast ratio between symbol and background differs according to external lighting conditions o Character styling and sizing (for textual messages) o Colour combinations (presented in pair-wise combinations, distinguishing between preferred, recommended, acceptable with high saturation differences, and not recommended) o When applicable, image flashing: frequency range of 11 Hz5 1-5 Hz with a duty cycle of 50-70%	For visual warnings: • Contrast ratio between symbol and backgrou requirements in all external lighting conditior • Luminance of symbols/messages, when sta
Suitability of the ADDW system: depends on their compatibility with the primary task, which in turn is dictated by the driver's performance and the corresponding subjective and objective usability metrics her requirements System failures should be identified (e.g. failure modes and effects analysis, or FMEA)	• Suitability focuses on: o Interference with the driving task o Controllability o Efficiency o Ease of use while learning about the syst • Usability aspects: o Driver's workload o Driver's performance of the driving task o Any behavioural adaptation induced by th o Learnability

4.3.2. State of the art based on stakeholder engagement

The acquisition of information from stakeholders for Task 2 was made during the same stakeholder consultations described under Task 1. Regarding the activities under Task 2, the stakeholders were consulted about the implemented HMI on their respective versions of ADDW systems, either existing or undergoing development, as well as about their perceptions, concerns and recommendations regarding the oncoming regulatory text.

Overview of attention monitoring systems and Human-Machine Interface

- Decisions regarding HMI customisations are usually made by OEMs.
- There is agreement within the industry that the HMI for ADDW systems should be able to interact well with retrofit/after-market systems targeted towards vehicle adaptations for drivers with disabilities and impairments. It was suggested that such adaptations should not affect the possibility for the driver to deactivate the system.
- Visual and auditory warnings were the most applied sensory modalities for manufacturers of passenger vehicles.
- In case of a lack of driver's compliance with the distraction warning, some manufacturers adopted escalation strategies while others opted for repeating the same warning.
- While there is an acknowledgement of the importance of adapting the warning strategy based on the use case, there is also an understanding of the lack of evidence to support the specifications of what these customisations should be.
- The alternative of employing distraction warnings via haptic modality has been deemed relevant for manufacturers of commercial vehicles, especially for buses, where auditory alerts could disturb the passengers.

During the consultations, stakeholders were asked what their recommendations would be for HMI with reference to the ADDW system:

- Being understood by the driver
- Being accepted by the driver
- Not causing distraction.

Being understood by the driver

It is crucial for the system to be understood by the driver. Multiple stakeholders suggested that the warnings should be standardised, simple, and consistent across all systems to avoid confusion. One stakeholder recommended that the system use generic icons and/or text that are consistent with similar warning systems currently used in vehicles. Another stakeholder suggested that the system should have a distinct sound that can be recognised, and a minimum volume and consideration about ambient noise, e.g. passenger conversations, radio noise, and external noise such as roadworks or emergency vehicle sirens.

However, one stakeholder expressed that although standardisation of warnings would facilitate understanding, it may hinder freedom in future development and innovation. Standardising the system while in the early stages of development may impede upon new trends and regulations.

Most stakeholders recommended that the primary warning should be audible, the secondary warning to be visual, and an optional warning of haptic. The reason for this is in the case of a visually distracted driver; they may miss the visual warning on the dashboard;

therefore an audible warning should always be given. A number of stakeholders suggested that a haptic warning, such as steering wheel or seat vibration, be considered in the case of buses, as audible warnings would cause disturbance or annoyance of the passengers on board.

Being accepted by the driver

With regards to ensuring acceptance of the system, stakeholders proposed that the HMI should be customisable to suit the preference of the driver, to minimise annoyance and maximise the time of the system being active/switched on. An option suggested by some stakeholders could be that the driver can choose the volume and type of the warning emitted if audible (e.g., a sound such as a beep, or a spoken-out phrase), or what phrase to display on the dashboard or windscreen if visual. Another recommendation would be for the system to configure the option for the warning to disappear automatically following re-attention to the driving task.

Stakeholders identified other aspects that should be considered when developing the regulation for the HMI of the ADDW system. They emphasised that the confidence rates of the warning should be relevant and accurate, to avoid the system being switched off by the driver as a result of false positives.

Lastly, one stakeholder argued that the HMI should lean strongly on the information portrayed to the driver, specifically the value and benefits of such a warning system to allow the driver to understand why the system is implemented.

Not causing distraction

It is important that the HMI does not cause distraction to the driver, because this would produce the opposite to the intended safety benefit of the system. Most stakeholders believed that visual warnings could distract the driver further as their eyes would not be on the road but would be on the dashboard instead. One stakeholder highlighted that the system should be implemented with confidence, relevance, and limiting false positives as, simply speaking, any warning is a distraction.

4.4. Discussion

The evidence presented in Table 9, Table 10 and Table 11 collectively provided insights for the research questions presented in Section 4.2. These insights are summarised below.

Cluster 1) Available approaches

4.4.1. RQ1.1. What approaches implemented via the HMI are currently available to alert the driver about their distracted state?

What sensory modalities are used to convey distraction warnings?

All the HMI of systems presented in Table 9 offer a variety of simultaneous visual and auditory alerts. Among the reviewed solutions, the only one to apply a purely visual warning was the Driver Attention System (DAS) (Cadillac, 2021), during the first stage of the escalation strategy, by only having the steering wheel light bar flashing green. All other systems always present visual and auditory warnings simultaneously. The DAS system was also the only solution in passenger vehicles to employ haptic warnings by vibrating the driver’s seat at the second stage of the escalation strategy, with the aim of increasing the warning's saliency. The after-market solution by (Seeing Machines, 2022) utilises the haptic modality for increasing the saliency of distraction warnings in environments where auditory alerts could be masked by the external and in-vehicle noises.

Manufacturers did not disclose the technical specifications regarding implementation, e.g. brightness and contrast for visual warnings or frequency and volume for auditory warnings. Therefore, the work under Task 2 turned to the literature to explore possible HMI implementations, which are described in detail in Table 10.

Empirical research mostly studied visual and auditory warnings. Haptic warnings were investigated in some studies, albeit mostly for the purposes of multi-modality investigation (for more details, please refer to the discussions under RQ1.2 and RQ1.3 below). Among the selected papers, only Ahlstrom, Kircher, & Kircher (2013) investigated purely haptic distraction warnings, in which four actuators integrated into the driver's seat vibrated simultaneously when a distraction warning was triggered. Based on a time-buffer approach, the vibration would stop when the driver looked at the road again, or after 2 s. However, in a later publication about the update of their distraction detection algorithm, Ahlstrom, Georgoulas, & Kircher (2021) modified the HMI approach of the system, now opting for a combination of visual and auditory warnings. The reason for the specific change in the HMI modality was not disclosed. An assumption is that it could have been a decision based on what other research results have also suggest, that a combination of visual and auditory warning is more effective in comparison to haptic warnings.

Escalation strategies: Are there approaches adopted for the design of distraction warnings in case the driver fails to comply with the behaviour the system requires?

Most manufacturers currently adopt some escalation strategy for the emission of distraction warnings when the driver fails to comply with the expected change of behaviour, for example if a driver does not return their gaze toward the road in front of the vehicle. Current strategies available in the market and from respective manufacturers are summarised in Table 9.

The effects of escalation strategies have also been investigated in empirical studies. The different strategies adopted for warning escalation are described below, while the technical implementation of the warnings are described in Table 10. The results of studies conducted for evaluating these escalation strategies are described under RQ1.2 in Section 4.4.2.

Llaneras, Cannon, & Green (2017) evaluated test drivers' capabilities of detecting lane drift upon being warned of their distraction while driving with assistance systems corresponding to a level 2 of automation. If the drivers failed to comply with the first stage warning and depending on how long they took to eventually change their distracted behaviour to not distracted, the warnings would progress into two more salient stages of escalation. Also, depending on the escalation stage reached, the vehicle required increasingly more demanding responses from drivers. On the 1st stage after 2 s of the driver not looking to the forward road, the warning counter would be simply reset when driver redirects gaze back to road. On the 2nd stage, after 7 s accumulated of distraction, the drivers needed to look back to the road and grab the steering wheel. The 3rd stage was reached if the driver would be continuously distracted for 12 s, after which the driver would be required to stop the vehicle and recycle the ignition if they wanted to restart driving with level 2 assistance.

Horberry et al. (2021) designed the HMI concept of a 2-level distraction warning system for commercial trucks. The first level warning, named "cautionary" level, would be emitted when the system detected the driver to be distracted. A more intense, or "urgent" level, warning would be emitted when the driver failed to comply with the cautionary warning. Besides evaluating the distinction between the cautionary and the urgent warnings, the authors also exposed the participants to two different timings for the escalation, a "short timing" of 1.5 s and a "long timing" of 4.0 s, to verify which timing strategy the test participants would prefer.

Han & Ju (2021) did not investigate escalation strategies on their study, but did suggest the adoption of an urgency progression of distraction alerts for future work.

Among the reviewed systems available in the market and the ones studied under research, an example of after-market solution for heavy and commercial vehicles (Seeing Machines, 2022), employed in fleet management services, goes beyond the escalation of warnings in case drivers fail to comply. When fatigue or specific situations of distraction (e.g. phone use or attention-off-road) are detected, the data and video capture of the event are sent to a management centre for review and verification by an employee, who, in turn, analyses the series of events occurrences and can decide to apply managerial measures for ensuring that either the driver reduces distraction occurrences or takes a break from driving.

Is it possible to identify trends in the design of distraction warnings?

Even though it was not possible to detect a general pattern or standardisation for advanced driver distraction warnings, some trends were noted:

- Visual warnings: There were no standard displays, symbols, or colour patterns identified for the steady state (or system active without emitting warnings), but a general trend of using saliency progression for escalation was identified, entailing the adoption of one or both of the following strategies:
    - Colour progression: graphics or plain light sources would follow the colour convention of traffic lights, progressing from green, to yellow/orange and lastly to red when the warnings were deemed more urgent.
    - Increase of flashing rate: graphics or plain light sources would start static for a certain amount of time and, upon escalation, would flash in increasing rates, in an effort to attract the driver's attention with progressively more urgency.
- Auditory warnings: No standard sound was identified for the first distraction detection, but as with visual warnings, a general trend of using saliency progression for escalation was identified, entailing the adoption of one or both of the following strategies:
    - Volume progression: increase in dB levels, although without concrete recommendation for variation ranges.
    - Increase in duty cycle: sound alerts would start at lower duty cycles, i.e. shorter pulses with longer intervals, and would grow in urgency by increasing the duration of the pulses and shortening the interval between them.
- Haptic warnings: It was not possible to identify trends for haptic warnings emission since little evidence was found about the investigation of this modality.

Also, specific technical requirements for visual, auditory and haptic warnings used in transport information and control systems of road vehicles were found on normative standards, and these are addressed later in RQ3.1 and RQ3.2, in Sections 4.4.6 and 4.4.7, respectively.

4.4.2. RQ1.2. How is HMI in distraction warning systems currently being tested and evaluated?

Are there published results about studies on the performance of the HMI of driver distraction monitoring and warning systems?

No studies about the evaluation of HMI components of distraction monitoring and warning systems was made public by OEMs or Tier-1 suppliers. Thus, the evidence search was supported with the review of empirical literature. The details of the investigated papers are summarised in Table 10.

A naturalistic study was published by Ahlstrom, Kircher, & Kircher (2013), who evaluated a driver distraction monitoring system on an extended field study comprising 7 participants who drove, on average, 4 351 ± 2 181 km. The distraction warnings were emitted using only the haptic modality, via four actuators installed in the driver's seat. The authors aimed to investigate the effects of a distraction warning based on a time-buffer approach for assessing the driver's distracted state. Following this strategy, drivers would have a time buffer of 2 s that depleted in real-time when meeting one of the two situations: When the driver looked away from the forward road or when the driver looked at mirrors or speedometer – the latter with a latency period of 1 s, as these glances off-road are deemed necessary for driving safety. When the system registered the driver to be looking at the forward road again, the time buffer started to fill up after a latency period of 0.1 s. The tactile distraction warning was triggered when the time buffer depleted fully. Their study aimed to analyse how distraction warnings could affect drivers' behaviour, not only in periods close to the warning but also on a more global scale.

The experiment in the study by Ahlstrom, Kircher, & Kircher (2013) was conducted using a regular passenger vehicle equipped with the distraction monitoring system. 7 participants were recruited as test drivers, and they were instructed to use the car as they would in their regular routines, without any restriction on where, when or how to drive. Each driver drove the vehicle for 10 days without knowing about the distraction monitoring system, which would be actively monitoring but would not be emitting distraction warnings during this period. This period was named "baseline case", with no distraction warning. After 10 days, the test drivers would be instructed on the system's functionality. Then, the drivers would continue to use the equipped vehicle for another 3 weeks, this time knowledgeable of the system. This period was named "treatment case", with the distraction warning activated. Having each participant driving the vehicle continuously during their participation, the whole experiment conduction panned out approximately 8 months. Six objective parameters were assessed: (1) total time with eyes-off-road, (2) time from fully attentive to warning, (3) time from warning to fully attentive, (4) visual time-sharing duration, (5) visual time-sharing intensity, and (6) time duration to next buffer empty. The test drivers also filled out questionnaires to evaluate their subjective experience with the system. The limited number of participants did not allow for a generalisation of the results. However, this naturalistic study could still descriptively reveal a trend to slight behavioural changes, which were more observable in the short-term than on the experiment's longer global time scale. When the objective parameters measured in the baseline case were compared with the ones measured during the treatment case, parameters (1) through (5) presented tendencies for reduction, whilst parameter (6) was deemed slightly but not significantly longer. The subjective evaluations pointed to a general high acceptance of the warning system.

A study with 36 participants conducted by Roberts, Ghazizadeh, & Lee (2012) using a high-fidelity driving simulator evaluated the effects of visual and auditory distraction warnings on mitigating driver distraction. The test participants experienced the following three drives in the simulator. (a) A baseline drive performing procedural visual-manual tasks (touching a specific arrow on a random sequence of arrows on a centre display) without receiving distraction warnings; (b) three short training drives to familiarise themselves with the distraction warnings, and (c) a proper drive performing distracting tasks with the emission of the corresponding distraction warnings. Driver acceptance was assessed in terms of perceived usefulness (PU), perceived ease of use (PEOU), unobtrusiveness (which the authors define as the opposite of "annoyance") and behavioural intention to use (BI). Results revealed that, although unobtrusiveness did not present a significant effect on BI, it did present a substantial influence on PU and PEOU. Moreover, PEOU was found to be the primary determinant of BI, whilst PU was deemed the secondary determinant of BI. The authors, however, whilst arguing that achieving the actual distraction mitigation depends on the driver acceptance of the system, they also pointed out that PU might in reality be a better predictor of BI, since during the experiment, drivers were obliged to use and evaluate the distraction mitigation system.

Considering the overlap between drowsiness and distraction, Han & Ju (2021) investigated how warning strategies for take-over requests (TOR) on vehicles with Level 3 automation could be adapted to the driver's conditions, depending on whether they are drowsy (related to fatigue) or distracted (related to engagement with non-driving related tasks). The goal was to investigate how the different types of distraction generated different reactions by the drivers depending on the design of the warnings. 38 test subjects participated in a driving simulator study, where they experienced one scenario for distraction and one for drowsiness. The measured objective parameters were reaction time and gaze indicators (blink count, gaze travel distance, and changes in pupil-diameter), whilst subjective evaluations were obtained via questionnaires. The drowsy state was specifically monitored with electroencephalography (EEG). Moreover, the authors adopted the number of eye blinks, changes in gaze distance, and variations in pupil diameters as relative indicators of cognitive load. Upon evaluating questionnaire results, the authors concluded that, although no statistical difference could be detected between alarm perception during drowsy and distracted states, the cognitive processing of auditory alarms received higher scores than that of visual alarms in both states. Based on this study's results, the authors highlight the importance of auditory notifications and point out the need for visual notifications to deliver supplementary information. Also, their analysis of cognitive load revealed that because drivers engaged in non-driving related tasks perceived the alarm while engrossed in these tasks, their cognitive load increased instantly. As a result, they recommend that alarms for the distracted state should be more intense and simpler compared to that in the drowsy state. They also intended to investigate the effects of escalation strategies for gradually increasing the intensity of the visual and auditory warnings for both states in the future.

In a study conducted by Mulvihill et al. (2021), test subjects performed a post-hoc evaluation of the distraction warnings developed by Horberry et al. (2021), ranking each individual modality type – visual, auditory tone, auditory speech, and haptic seat – as well as two intensity levels for the warnings, “cautionary” and “urgent”. The details of the warnings' designs are described in Table 10. Results from this study point out that multimodality is considered relevant for warning redundancy, in case the driver misses a visual warning for being visually distracted or an auditory warning due to loud noises in their environment. Furthermore, it was found that acoustic modality is most effective for warning perception in comparison to the other two modalities, while visual modality is the least effective, since it can be easily overlooked in case of distraction or cause more distraction by pulling visual attention to the message instead of towards the forward road.

Overall, as pointed out in Section 4.4.1, most ADDW systems available in the market and investigated under academic research use multimodality for distraction warning emissions. A majority of the systems use combinations of visual and auditory warnings, which provided promising results towards the effectiveness and efficiency of the HMI of ADDW systems. Design guidelines establish that, whilst information modality should be matched with the driver's tasks, needs, and expectations so that their comprehension and performance is enhanced, they also point out the visual modality can convey more information compared to auditory or haptic modalities (Campbell, 2016). Conversely, the studies by Han & Ju (2021) and Mulvihill et al. (2021) investigated the effects of each modality separately and suggest that acoustic information is potentially more efficient, as drivers can recognise auditory warnings more quickly, and that visual modality is less effective, since visual warnings can be easily overlooked or even cause more distraction by pulling attention towards the message.

Based on the results from RQ1.1, how are escalation strategies being tested and evaluated?

In the study performed by Llaneras et al. (2017), 25 participants drove for up to two hours on a test track using level 2 ADAS and would be evaluated based on a standardised scenario. Once drivers were deemed distracted, the test vehicle would, on purpose, start manoeuvring towards drifting out of the lane. At this moment, the first stage of a distraction warning would be triggered. The drivers experienced distraction warnings emitted according to an escalation strategy that aimed to serve as an incentive for drivers to respond to the alerts. Results from this study found that the HMI concepts that introduce consequences for driver nonresponse increased compliance to system alerts. For example, when exposed to a situation of lane drift, 59% of drivers were able to detect this ACC system failure before stage 1 warnings were triggered, while the alert interventions increased detection rates in 35%, thus achieving a detection rate of lane drifts of 94%. Nevertheless, the authors concluded that compliance with the primary stage of warnings were already high. Only 7% of the warnings generated during the conduction of their experiment reached the 2nd and 0.2% reached the 3rd stage of warning escalation. The authors also noticed a significant effect regarding the driver's experience with the system, in which 90% of trained drivers versus 64% of untrained drivers understood correctly the system functionalities and the escalation strategy.

The study conducted by Mulvihill et al. (2021) compared two intensity levels for warnings, "cautionary" and "urgent", and also compared two intervals for escalating the warning to "urgent" when the driver failed to comply with the first "cautionary" warning. The shorter escalation happened in 1.5 seconds, the longer escalation happened in 4 seconds. While all warnings' designs and both levels of intensity scored high for usefulness and acceptance, the shorter escalation strategy of 1.5 s ranked descriptively more effective than the longer timing for escalation of 4 s, albeit this effect did not present statistical significance and can only be interpreted in a descriptive manner.

How does the Euro NCAP address distraction warning systems in their assessment protocol for safety assist?

The Euro NCAP assessment protocol (Euro NCAP, 2022a) provides some variables that can affect the performance of Driver's State Monitoring (DSM) systems, which are presented in Table 12. Alongside those variables, the assessment protocol specifies the respective range variations within which system performance should not be degraded. As evidence of an adequate system performance and submission into the point scoring system from Euro NCAP, the OEMs should present a dossier demonstrating that the sensing system's performance is not degraded within the specified ranges. Additionally, in case the system's performance is degraded when operating outside of the specified ranges, the OEM should appoint actions from the system that could still ensure some degree of safety or awareness to the driver, in order to be awarded the respective scoring points for the DSM system. The aim of the summary presented in Table 12 is to, later in Task 3, aid the derivation of requirements and measurements towards ADDW systems performance. For the complete specification, please refer to the original assessment protocol.

Table 12: Requirements for Driver's State Monitoring (DSM) systems HMIs according to Euro NCAP (Euro NCAP, 2022)

Requirement	Variables and operating ranges		Action in case of failure
Population coverage	• Age	• 16-80 years old	• OEM must demonstrate that system performance does not deviate strongly with different noise variables • However, a tolerance for "strong deviation" was not defined
	• Sex	• All	
	• Stature	• Between female 5-Percentile (AF5) and male 95-Percentile (AM95)	
	• Skin complexion	• Fitzpatrick Skin Type (1 - 6)	
	• Eye lid aperture	• 6.0-14.0 mm	
Occlusion of driver's facial features	• Lighting	• Daytime (100 000 lux) – night-time (1 lux) measured outside of the vehicle	• OEM must demonstrate that system performance is not degraded • If such demonstration is not possible, the driver should be informed within 10 s about system not being available (in case of eye occlusion, also the cause of unavailability) via a visual and/or an audible alert.
	• Eyewear	• Clear glasses and sunglasses with >70% transmittance including those with thick rims	
	• Facial hair	• Short facial hair (< 20mm in length)	
Driver behaviour	• Eating • Talking • Laughing • Singing • Smoking / vaping • Eye scratching / rubbing • Sneezing	• There is no performance requirement.	• OEM must demonstrate how the DSM system performance is affected by these driver behaviours.

What performance metrics and/or assessment methods could be used to evaluate the effectiveness and efficiency of the HMI for ADDW systems?

An ADDW system is defined in the Regulation (EU) 2019/2144, Chapter 1, Article 3(6), as a system that intends to help the driver to continue to pay attention to the traffic situation and to warn the driver when he or she is distracted. *Effectiveness* is determined by the accuracy and completeness with which users accomplish their goals, and *efficiency* is determined as the ratio of resources used in relation to the accomplished results (DIN Deutsches Institut für Normung e. V., 2018).

In the context of ADDW systems, the HMI is effective when two things happen. First, the user is successfully warned about their state of distraction once the distraction monitoring component of the system has appropriately detected such a condition. Second, the user comprehends their state of distraction and changes their behaviour from the unsafe state of distraction back to paying attention to the driving task. The HMI is thus efficient when the user understands the warning as quickly as possible and spends less attention on the warning themselves instead of the driving task. The system's efficiency can also be influenced by its acceptance by the drivers. When they understand the value of the ADDW system and are subjectively satisfied with its performance (high accuracy and low false-positive rates), the higher is the likelihood that they will not be annoyed and will keep the system activated, allowing the system to achieve its goal of helping the driver to pay attention to the road and ultimately increasing driving safety. The performance parameters listed in Table 13 summarise the ones found in the more comprehensive Table 11 and can be applied for the performance evaluation of the HMI of ADDW systems.

Table 13 : Potential performance parameters for ADDW-HMI evaluation

Qualitative parameters: Subjective perception of the warning system	• Perceived usefulness • Perceived ease of use • Acceptance towards the system or intention to use the system • Annoyance with the system (alternatively, unobtrusiveness) • Comprehension of the system functioning • User's compliance with the distraction warnings (executing the system's required response to be not considered distracted any more)
Quantitative parameters: Objectively measurable effects of the warning system	• Warning's activation rates per hour • Reaction time • Blink count • Gaze travel distance • Pupil diameter • Rate of user's compliance with the distraction warnings (executing the system's required response to be not considered distracted any more) • Time eyes-off-road (TEOR) • Time from fully attentive to warning emission • Time after end of warning and fully attentive

Campbell et al. (2018) list factors that influence the effectiveness of vehicle automation design. These influencing factors can be interpreted in the framework of advanced driver assistance systems and their influence on the driver's ability to perform the driving task. Therefore, since distraction warnings arguably affect the driver's condition to execute the driving task, the factors listed in Table 14 should be taken into consideration for designing the warning elements of ADDW systems.

Table 14: Factors influencing the effectiveness of ADDW HMIs (Campbell, et al., 2018)

Influencing factor	Best practice for designing the HMI of ADDW systems
Driver understanding of automation	The distraction warnings should not degrade a driver's mental model of how the ADDW system functions
Automation-induced errors	The distraction warnings should not introduce new sources of driver distraction.
Behavioural adaptation	The distraction warnings should not lead drivers to adopt "bad habits" (i.e. not paying attention to the road) that can lead to unsafe driving in some situations or in different vehicles.
Status display availability	Display of system status should be available on demand (i.e. a persistent visual notification).
Status display modality	Status display modality should be consistent with or complement the type of information presented (i.e. visual for persistent information, auditory or conspicuous for change information).
Change in automation status	Display of system status should indicate changes in system status. Status changes in critical tasks should be adequately conspicuous, but not disruptive to the driving task.

4.4.3. RQ1.3. Are there approaches to guide attention and/or help the driver to focus on the driving task?

The two previous research questions addressed the emission of warnings after the system detects driver distraction and how the driver can be successfully warned about it. It is also the scope of Task 2 to investigate whether there are means that could help drivers regain focus once their distraction has been confidently identified. This could entail a further step toward improved safety, in which distraction is not only detected and the driver warned, but the effects are also mitigated.

The design guidelines presented in Table 11 provide principles for designing in-vehicle information and control systems that take into account safety aspects such as facilitating operation by the driver and minimising distraction. When manufacturers adhere to these guidelines and their design principles during the development of their vehicle's HMI (in general, not only for ADDW systems), this can be considered already an approach to guide the driver's attention to the forward road. Still, none of the reviewed solutions for ADDW systems currently present in the market claims to apply any approach for attention guidance. This could be understood as a likely cautionary measure from the side of the OEMs and Tier-1 suppliers. They argue that with the current state of the technology, distraction measurement available in serial vehicles is not yet capable of reliably assessing the actual state of cognitive attention in-vehicle and why most market solutions focus on measuring visual attention instead. The emission of warnings based on evaluating cognitive distraction could be interpreted as a means to help the driver keep their focus on the driving task. The literature research under Task 2 could find two examples of suppliers that claim to be able to recognise cognitive distraction, but it has not been disclosed whether those systems are already available in serial vehicles. Harman Automotive claims to be able to detect cognitive distraction with their "Ready Care" system and uses this assessment to, in conjunction with the vehicle's navigation engines, provide an alternate route selection to lower elevated driver stress levels while on the road (Harman Automotive, 2022). DTS AutoSense is a system by DTS Inc. that provides in-vehicle sensing and analytical solutions. The supplier claims their system is capable of, among other functions, detecting certain distracting activities (e.g. driver is eating, drinking, smoking or using the phone while driving), detecting various types of distraction (besides drowsiness and fatigue, also visual, manual, and cognitive distraction), and detecting the driver's state of mind, which enables the adjustment of comfort features according to the system's interpretation of the driver's emotion (DTS Inc., 2022).

Besides evaluating mitigation of driver distraction in real-time through emission of distraction warnings, Roberts, Ghazizadeh, & Lee (2012) investigated an approach for post-drive feedback. The authors invited the test drivers to compare their driving performance to their peers, with the goal of encouraging them to direct their attention on the primary driving task in the future. The drivers were presented with three screens after experiencing the test drive. The first screen provided a graphical information of the participant's distraction levels, divided into low, medium, and high levels of distraction along the y-axis. The participant's personal distraction levels were plotted alongside the average distraction levels of the other test participants over the complete duration of the experiment, along x-axis. On a second screen, the drivers were presented a 15-seconds video of their distracted driving during the test. The video was accompanied by classification of the detected types of distraction (e.g. "tunnel vision – staring at the same area", "eyes off road" or "too frequent glances off road"). The criteria for the presentation of a video was determined by a scoring algorithm that considered the occurrence of hazard events, namely lane departures, maximum lateral accelerations, and collisions. The last screen presented other performance and behaviour measures using bar graphs, also comparing the driver's performance with their peers. These behaviour metrics were related with driving errors, such as "distraction-related critical incidents" and "number of lane drift", and with attention to driving, such as "number of unsafe glances" and "percentage of drive time not looking at the forward road". Results from this investigation on post-drive feedback revealed that the test participants found this type of feedback less obtrusive and simpler to use than real-time feedback (namely, emission of distraction warnings). This approach of post-drive feedback could be implemented with optional applications additional to in-vehicle ADDW systems to encourage drivers to pay attention to the driving task in the future. The drivers could, for example, access such types of feedbacks after ending their journeys, either on the vehicle's infotainment system or on their smartphones. Another example would be to compare their performance on the last drive with their own past performance, instead of comparing with other drivers as in the experiment by Roberts, Ghazizadeh, & Lee (2012).

A study performed by Llaneras, Cannon, & Green (2017) suggests that introducing consequences to the driver for distraction, such as needing to look back to the road (between 2 and 5 s) or eventually needing to grab the steering wheel in case of longer distraction (> 7 s), could potentially "assist drivers in maintaining their attention to driving, keeping drivers focused on the forward roadway and traffic environment" (Llaneras, Cannon, & Green, 2017, p. 26) (2017).

DeGuzman, Kanaan, & Donmez (2022) investigated attentive user interfaces (AUIs) as an approach to modulate driver attention in automated vehicles. The automation level itself can be considered an influencing factor on the adaptation strategy, because with increasing levels of automation the driver's attention resources can be turned away from the driving task. Nevertheless, the adaptation strategies may have to be implemented differently according to the level of automation; the insights provided by this research can be analysed in the context of SAE Level 2 and below for attending to our research questions. AUIs are "interfaces that adapt based on the operator's state and task/environmental demands to manage and direct the operator's attention" (DeGuzman, Kanaan, & Donmez, 2022, p. 305) The implementation of AUIs is analysed in more detail under the research question RQ2.1. Regarding approaches to guide attention and/or help the driver to focus on the driving task, the authors present a literature review on strategies that can be used to adapt built-in and carried-in device displays used in driving. The adaptation strategies can be split into two categories, based on how they manage attention: "optimizing attentional demand" or "reorienting attention", which are listed in Table 15.

Table 15 : Adaptation strategies for in-vehicle interfaces (DeGuzman, Kanaan, Donmez, 2022)

	Strategy	Description
Optimising attentional demand	1. Limiting	Blocking some (or all) functions of a non-driving task
	2. Simplifying	Reducing the complexity of the interface and/or notifications
	3. Filtering	Suppressing alerts and/or notifications based on priority
	4. Delaying	Postponing alerts to a later time
	5. Activating	Initiating a task to increase arousal
Reorienting attention	6. Advancing	Issuing alerts earlier than they would typically be issued
	7. Supplementing	Providing additional warnings
	8. Augmenting	Changing the way the information is presented to make it more salient to the driver

Cluster 2) Adaptive warnings

4.4.4. RQ2.1. What strategies are there to adapt the emission of distraction warnings?

In what contexts could distraction warnings benefit from adaptation strategies?

The report on ADDW systems (Seidl, et al., 2021) mentioned the possibility to adapt alerts with escalation in case of repeated distraction. The corresponding context for an escalation is the lack of response from the driver to the distraction warning, with the saliency of the warning being progressively increased with the aim to emphasise the urgency of the situation and demand from the driver the appropriate action (e.g. to look back towards the forward road or take over the steering wheel). Such urgency progression could improve the safety benefit of ADDW systems.

Both the literature review and the consultation with stakeholders have been providing insights into further contexts in which an adaptive activation or deactivation of ADDW systems could be beneficial. In order to avoid user annoyance by reducing the possibility for occurrence of false-positive warnings (which likely reduces system acceptance), the Report on ADDW systems (Seidl, et al., 2021) mentioned the possibility of adaptive activation and deactivation of ADDW systems, for example according to the following functions: (1) Activation speed, (2) time-to-activation, (3) road type, (4) weather, and (5) system activation/recycling/deactivation: The report also acknowledged the need for more investigation on ADDW technology around these five functions to determine appropriate potential performance requirements.

An example of such research is demonstrated on a study conducted by Ahlstrom, Kircher, & Kircher (2013), in which three criteria were used to inhibit distraction warnings: (1) vehicle speed below 50 km/h, (2) driver had stepped on the brake pedal or performed severe steering manoeuvre, or (3) a distraction had been detected within 15 s from the onset of an earlier distraction warning. The authors declared that these criteria were implemented for reducing the number of warnings, claiming that this could affect driver's acceptance. However, this claim was not particularly verified, as the specific effects of warning inhibitions on system acceptance were not investigated.

As Campbell, et al. (2018, p. 2) stated, "safe and efficient operation of any motor vehicle requires that the driver-vehicle interaction be designed in a manner that is consistent with the driver's limitations, capabilities, and expectations." Therefore, even if distraction warnings could benefit from adaptation strategies, constraints of, from and around the driver must be considered to derive appropriate performance requirements for safe and efficient vehicle operation. Considering that drivers present different limitations, capabilities and expectations, DeGuzman, Kanaan, & Donmez (2022) investigated how the implementation of HMI adapting to a driver's state and task/environmental demands could aid in the modulation of the driver's attention. The authors argue that once the system is able to collect information about the user's level of distraction, it should thus be capable of adapting the interface to manage the user's attention by following at least one of the two approaches: (1) Changing the information provided to the driver (for example content quantity, level of details, graphical features, etc.) or (2) changing the way that information is provided to the driver (for example sensory modality, changing presentation conduit, etc.). A few examples for the different adaptation strategies listed in Table 15 are mentioned by the authors, such as sending incoming calls directly to voicemail under the "limiting" strategy for "optimising attentional demand", or emitting alerts in auditory and vibro-tactile modalities under the "augmenting" strategy for "reorienting attention" (DeGuzman, Kanaan, & Donmez, 2022, S. 315). These approaches to adaptation could be considered for future developments. When distraction monitoring technology is able to reliably assess the driving situation as well as the driver's condition, it could thus change the type of warnings to the currently required levels of cognitive demand of the driver and ensuring that the warnings are conveyed most effectively. As the authors conclude, “with more sensitive and/or accurate measures of driver state, the probability of false alarms may be reduced, addressing potential issues with user acceptance” (DeGuzman, et al., 2022, p. 329).

How are adaptive warning strategies implemented via the HMI?

Overall, the two adaptation strategies most mentioned by academics and the industry were, first, warning escalation by repetition or progressive increase in salience, and second, situation-dependent warning inhibition. Strategies for warning escalation were already addressed in RQ1.1. Under the assumption that frequent emission of warnings could potentially cause the driver to feel annoyed and less accepting of an ADDW system, thus deactivating the warnings and not enjoying the safety benefit of the system, manufacturers have employed various adapting metrics dictating which warnings are inhibited.

As presented in Table 9, there is a consensus among OEMs’ that the HMI implemented for distraction warning systems allows the driver/user to turn, if not the system, at least the warnings off when desired, and that the system is reactivated when the vehicle is turned off and on again. This possibility is also in accordance with the general requirement for driver monitoring systems according to Euro NCAP (Euro NCAP, 2022a) and is covered by the item 3.1.1. of the DDAW Regulation (EU) 2021/1341 (European Union, 2021).

Considering the findings presented in Table 10, from a human factors perspective, it is recommended that system understandability and acceptance should be further investigated in future research regarding the design of adaptive warnings for ADDW systems. Ahlstrom, Kircher & Kircher (2013) presented a distraction warning system based on a 2-second accumulative time-buffer, which was depleted when the driver looked away from the road and filled back up the driver redirected their gaze to the road. This approach could thus distinguish between distraction caused by long glances as well as visual timesharing behaviour, i.e. an approach to account for Type 1 and Type 2 trigger behaviours. Eight years later, Ahlstrom, Georgoulas, & Kircher (2021) presented the further development of the distraction detection algorithm, now implementing multiple time-buffers and incorporating context-dependent analysis to the time-buffer computation. The context-dependent analysis considers the role of vehicle velocity, geographical and map data for the emission of warnings, which could potentially improve user’s acceptance of the system and which, according to the authors, will be investigated in the future. However, as pointed out by stakeholders during consultations, the complexity of such warnings adaptation does not lay on the HMI itself, but rather on the fact that these capabilities are still under research and there is no prediction when they would be available in the market.

There has been no consensus about the minimum vehicle speed considered for system activation: Some manufacturers adopted 60 km/h and others adopted 65 km/h, while the draft Euro NCAP assessment has recommended that driver-monitoring system be activated at 10 km/h whilst the warnings’ emission be activated at speeds starting at 20 km/h. There is also a lack of consensus on the period of activation. Some manufacturers report that their systems are always active as long as the vehicle speed remains above 20 km/h, while others deactivate their system once vehicle speed reduces below 40 km/h. During consultations, none of the stakeholders argued for a maximum speed, above which the distraction monitoring system should be deactivated.

In different road and environment conditions, different vehicle speeds incur change in the mental effort required for the driving task and should thus be considered for strategies in adapting distraction warnings. However, no evidence was found about the how the combination of environment and vehicle speed can be adopted as an influencing parameter for warnings adaptation. Whilst considering the potentially more complex learnability of the warnings, there is indeed a need for research by academics the industry about the effects of distraction warnings under different vehicle speeds and traffic situations. It is assumed that this could lead to higher acceptance of the system, which would lead to an even higher safety benefit.

4.4.5. RQ2.2. What are the potential benefits and risks associated with adaptive warnings?

From a human factors perspective?

According to the literature review performed by Mulvihill, et al. (2021), there is relatively little published research about the design of warnings applied to driver monitoring systems. According to DeGuzman, Kanaan, & Donmez (2022), strategies that limit access to non-driving tasks and force drivers to monitor only the vehicle behaviour for extended periods – for example in case of SAE Level 2 automation – may result in a state of underload leading to a degraded monitoring and take over performance. Considering this level of automation, the authors present two arguments:

- More research is needed towards finding an optimal level of engagement in non-driving tasks while using SAE Level 2 of automation
- Frequent unexplained interface adaptations may be confusing or frustrating to drivers, which may bring issues with user acceptance.

Nonetheless, considering the different approaches to adaptive interfaces presented in the previous research questions, it is important to consider whether it is relevant how the user would form mental models to understand that the system works differently depending on the context or the conditions in which it is operating. For instance, the ADDW system may be only activated at a certain velocity V_1, remaining active until velocity V_2 ($V_2 > V_1$) is surpassed and only staying active as long as velocities do not drop below velocity V_3 ($V_3 < V_2$, but without a restriction of V_3 being lower or higher than V_1) – and here some stakeholders added the parameter of travel duration to influence this activation strategy. It could thus be beneficial to investigate whether such adaptation strategies affect the way the drivers perceive the ADDW system. If case of negative effects, mitigating measurements would need to be researched. However, in case there is no change in the subjectively perceived performance of the system, then there would be no need for extra measures.

From a technical perspective?

DeGuzman, Kanaan, & Donmez (2022) argue that, for adaptive HMIs to be effective, driver state monitoring algorithms should have high accuracy and a low false-positive rate. However, no suggestion about threshold values or potential implications on the HMI implementation were made.

All reviewed manufacturers provide systems that can be optionally deactivated by the user. Such option is in accordance with the following general requirement of the Euro NCAP Assessment Protocol, version 10.1:

> *"To be eligible for scoring points in Driver State Monitoring (DSM), the system needs to be default ON at the start of every journey and deactivation of the system should not be possible with a momentary single push on a button"* (Euro NCAP, 2022, p. 11).

This requirement has been in vogue since the version 9.0.3 (Euro NCAP, 2020, S. 10). Vehicle models presenting a physical button for deactivating the driver monitoring system were released before the implementation of the updated version of the protocol.

In systems in which driver distraction monitoring is associated with higher levels of automated driving (e.g. General Motor's SuperCruise, Ford's BlueCruise), there is no option to deactivate the driver monitoring system without deactivating the level-2 automated driving system.

Cluster 3) Relevant normative standards and design guidelines

4.4.6. RQ3.1. What aspects of relevant normative standards should be considered for the HMI of ADDW systems?

When covering the specification of warning signals, the investigated normative standards mainly refer to alerts emitted due to an imminent hazard or collision, while distraction warnings are characterised only as informative or as a design guideline. Therefore, the requirements for the nature of visual and acoustic warnings specified in the DDAW regulation (European Union, 2021) could be taken over, except for the reference to the ISO 2575:2010+A7:2017, which has been withdrawn and updated in 2021. Thus visual symbols to be developed for the purpose of ADDW systems should keep coherence with the recommendations from ISO 2575:2021, which specifies a convention for symbols and tell-tales, with indications of colours, applied to passenger cars, light and heavy commercial vehicles and buses depending on the type of information provided.

Since the DDAW regulation did not mandate haptic warnings, the work under Task 2 then looked for recommendations on specifications for this modality. The technical report number ISO/TR 16352:2005 (International Organization for Standardization, 2005) provided evidence from experimental research on hazard and collision warnings presented via a combination of modalities. Even though warnings to alert the driver about their distraction were not mentioned, the scientific evidence about the sensory capabilities of the human body can still be taken into account. For example, the report recommends that in-vehicle tactile warnings should introduce vibration frequencies in the range of 100 Hz to 300 Hz, to which humans are most sensitive. These values are also high enough to be away from the resonating frequency of human organs (~ 3 Hz) and from road-induced vibration frequencies.

Complementing the information presented on ISO/TR 16352:2005, the standard ISO 15005:2017 (International Organization for Standardization, 2017a) states that when multiple information delivery systems are installed within a vehicle, the integrated designs should consider the relative priority of their functions. Another technical report, number ISO/TR 12204:2012 (International Organization for Standardization, 2012), provides guidance on the integration of safety- and time-critical warnings signals into vehicles. The report points out that warnings originated from different systems must follow a prioritisation chain based on urgency and criticality of the information, which also implicates in trade-offs for the systems' designers. The report also proposes approaches for facilitating driver's comprehension and discusses methods for assessing possible integration conflicts between concomitant signals. Such recommendations in this report should be taken into account for the future development of distraction warnings, especially for the cases in which visual distraction overlaps with drowsiness detection or with time-critical warnings by hazard and collision avoidance systems.

4.4.7. RQ3.2. What aspects of relevant normative should be considered for testing and validating the HMI of ADDW systems?

The columns "recommendations on performance requirements" and "recommendations on testing procedures for validation" in Table 10 summarise information on what aspects can be considered when testing and validating ADDW HMI.

The technical report ISO/TR 16352:2005 (International Organization for Standardization, 2005) recommends that user studies with human test drivers are conducted, to evaluate the warnings' effectiveness (through testing with human test driver's for evaluating their detection rate and response time) as well as the warning's efficiency (through looking into aspects such as alert impairment, reliable detection and identification, intelligibility and compliance). However, no specific value or acceptance range, neither for effectiveness, nor for efficiency has been indicated.

The norm ISO 15006:2011 (International Organization for Standardization, 2011) presents a method that can be consulted for specifically measuring and evaluating the loudness of auditory signals.

The norm ISO 17287:2003 (International Organization for Standardization, 2003) recommends that user studies are used for testing a system's compatibility with the driving task by evaluating its suitability (aspects related to Interference with the driving task and ease of use while learning about the system) and usability (driver's workload, performance of the driving task, behavioural adaptations induced by the system, and the system's learnability).

4.4.8. RQ3.3. What information is already included in established design guidelines on avoiding driver distraction?

The three design guidelines considered relevant for analysis under Task 2 present numerous principles for the safe design and use aspects to be considered for developing efficient and effective in-vehicle HMI. In general, all these design guidelines require that manufacturers design their in-vehicle information and control systems to avoid driver distraction and not divert attention from the driving situation.

The first two "Overall Design Principles" of the ESoP (European Commission, 2008) summarise the general goals of this design guideline:

> *Design goal I: The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.*
>
> *[…] Systems that are not designed with this principle in mind are unlikely to be in accordance with the other principles.*
>
> *Design goal II: The allocation of driver attention while interacting with system displays and controls remains compatible with the attentional demand of the driving situation.* (European Commission, 2008, p. L 216/7).

The two NHTSA guidelines (Campbell et al., 2016), (Campbell et al., 2018) also aim to aid researchers, designers, and OEMs and Tier-1 suppliers in ensuring the compatibility of in-vehicles HMI with the drivers' limitations and capabilities.

> *Design goal: Design in-vehicle tasks and messages that do not divert attention from activities critical for safe driving.* (Campbell et al., 2016, p. 3-2)

4.4.9. RQ3.4. Are there any specific recommendations or guidelines for guiding the driver's attention??

Considering that distraction warnings are conceived to reduce distraction once it has been detected, a higher safety benefit would be achieved if ADDW systems could help guide the driver's attention towards the driving task. The investigated norms and guidelines present various recommendations on how to avoid driver distraction, identifying many best practices applied to in-vehicle HMI design (see Table 11), and some of them can be interpreted as measures for guiding the driver's attention.

For each design principle, the ESoP presents explanations and examples of systems developed with the good design practices in mind. For ADDW systems, the "Installation Principle IV: Visual displays should be positioned as close as practicable to the driver's line of sight" is particularly interesting, since it recommends that "displays containing information relevant to driving and all displays requiring long sequences of interface [shall] be placed within approximately 30° downward viewing angle of the driver's normal forward view." (European Commission, 2008, p. L 216/12). This principle, despite being valid mostly for passenger vehicles only, could indeed guide the definition of relevant areas of interest for the ADDW system to monitor the driver's visual attention during driving. Since areas below this 30° doward viewing angle should not contain information relevant for the driving task, the system could classify the driver as distracted upon detecting the driver's fixation gaze in this area for a to-be-defined threshold duration.

Furthermore, there is a consensus that the effectiveness of the warnings is highly dependent on various human factors, such as limitations of attention, perception, and memory related to e.g. age and inter-person variability. Also, according to the ISO/TR 16352:2005, external factors such as context, education, and fatigue can also influence the effectiveness of warnings (International Organization for Standardization, 2005). This high variability of human factors is possibly why no specific recommendation on how to guide the driver's attention to the driving situation has been found other than best practices for in-vehicle HMI design.

Moreover, as pointed out by (Wickens, 2008), attention is a limited resource that, once depleted (partially or entirely, depending on the level of distraction), requires mental effort to be replenished – thus it could be potentially counterproductive to spend scarce mental resources to redirect attention when these should be used to paying attention to the driving task. Nevertheless, it is expected that, after some time experiencing the system, drivers initially prone to being less attentive during driving could reduce the occurrences of distraction events. As pointed out by Campbell et al. (2018, p. 42), "after exposure and extended use, drivers can learn to comprehend virtually any message. While even "bad" messages can eventually be effective, however, they may promote errors, require training, or involve extensive trial-and-error learning." Thus to avoid "bad" messages, this guideline established the following design goal: "Design Goal (L2, L3): Develop and present messages that support accurate and timely comprehension by the driver." (Campbell et al., 2018, p. 41)

4.5. Summary and conclusion

The main goal of ADDW systems is to help the driver to continue to pay attention to the road. The system achieves this goal by warning drivers when they are distracted. When drivers are distracted from the driving task, but no assessment of the appropriate duration for the driver's deviation of attention is made, the general safety of the vehicle's passengers and other road users end up relying on the driver's own awareness of their state. For instance, they would need to notice their distraction eventually and then turn their attention back to the road by themselves, or worse, not even notice the distraction and only return to monitor the traffic situation after finishing their distractive task. In the best case, the vehicle does not deviate from the driving lane and no hazard is encountered. However, this lack of formal restriction on distraction implies that attention is technically allowed to be inadequate for monitoring the external traffic situation, which often leads to collisions, as reports on statistics of traffic accidents have shown (European Commission, et al., 2021), (National Center for Statistics and Analysis, 2022, May). ADDW systems thus intend to increase the probability that drivers will behave more safely in traffic by reducing the duration and occurrence of distraction events and, ultimately, helping drivers to change their behaviour and more continuously pay attention to the driving task.

Among factors influencing the effectiveness of automation design, Campbell et al. (2018) mention that behavioural adaptation should be taken into consideration. In the case of ADDW systems, a severe case of behavioural adaptation after some period of time experiencing the system would be the driver assuming it is safe to be distracted until a distraction warning is emitted, thus purposefully engaging in distracting activities and waiting until the emission of the distraction warning to return their attention to the road. It should be further investigated by research in academia and the industry whether drivers should be warned against such misuse of the ADDW system.

The European Commission published on 16/06/2021 the Report on Advanced Driver Distraction Warning Systems (Seidl et al., 2021, p. 661), which presents the following list of some functional and performance requirements for the HMI of ADDW systems that could potentially be integrated into the new ADDW regulation:

- The HMI shall present a visual and auditory visual distraction alert when the driver exceeds at least one of the yet-to-be-determined distraction threshold(s)
- It shall be possible to easily supress audible warnings, but such action shall not at the same time supress system functions other than audible warnings
- The alert shall be representative of the level of visual distraction, appealing to repetition, cascading or escalation of the warnings when the driver continues the unsafe behaviour of distraction.
- The driver shall be able to deactivate the alert

These requirements are refined and complemented by the recommendations for requirements specifications and test procedures for verification of performance towards ADDW system validation in Section 5.3.2.

5. Propose requirements and tests for ADDW systems (Task 3)

An ADDW system is defined by the General Safety Regulation (EU) 2019/2144 as "a system that helps the driver to continue to pay attention to the traffic situation and that warns the driver when they are distracted" (European Union, 2019). From this definition, two functional components are identified: The driver distraction monitoring technology and the HMI to emit the distraction warnings. Each component was reviewed during the previous Tasks 1 and 2 of this project respectively, and served as input to Task 3.

5.1. Introduction

The overall purpose of Task 3 was to derive test procedures for validating ADDW systems within the scope of requirements specifications for both components, distraction monitoring and HMI. For this general purpose to be achieved, the following objectives for Task 3 are outlined:

Objectives

- Identify requirements for description and specification of ADDW systems
- Review how ADDW systems are currently being tested, identifying where there is consensus and where there are still challenges
- Review how other validation testing methods could complement ADDW testing procedures
- Derive requirements for test procedures for validating ADDW systems
- Recommend test procedures for verifying the performance of ADDW systems and how they can be used for validation

5.2. Methodology

For achieving the outlined objectives, the search for evidence under Task 3 for derivation of requirements and test procedure recommendations consisted of the following methods: Detailed analysis of the outputs from Tasks 1 and 2, consultations with stakeholders, and review of complementary literature.

Method 1: Analysis of outputs from Tasks 1 and 2

A systematic analysis of the outputs from Tasks 1 and 2 provided a list of requirements for describing and specifying ADDW systems (namely the distraction monitoring and the HMI components) and also provided findings on potential approaches to testing towards system validation.

Method 2: Consultation with stakeholders

The consultations with stakeholders were carried out in conjunction with the consultations within the previous Tasks 1 and 2. The questions attending to the objectives of Task 3 aimed to collect how suppliers and OEMs currently define metrics for verifying ADDW system performance, how they verify the effectiveness of their system, whether they have conducted tests with human participants, and if that was the case, whether they could provide information on the procedures adopted for these tests.

Method 3: Complementary literature

After summarising the information collected through the previous methods, it was possible to establish general requirements for the scope of the to-be-recommended test procedures. The outputs from Tasks 1 and 2 and from the stakeholder consultations were then complemented by a review of literature related to tests used for ADDW system validation, after which recommendations on testing procedures for verifying the performance and validating ADDW systems were made.

This three-step methodology provided the results presented in Section 5.3. A discussion of these results with subsequent recommendations for the specification and testing of performance parameters for ADDW systems is laid out in Section 5.4. Both Sections provided the foundation for elaborating a draft proposal for the contents of the ADDW regulation under the framework of the General Safety Regulation (European Union, 2019). The draft of the regulation is presented in Appendix B, which has been refined and updated after discussions with the European Commission's Motor Vehicle Working Group (MVWG), as well as with its sub-group on Driver's Behaviour Assessment Systems (MVWG-DBAS), up to the 3rd meeting of the sub-group on 29 November 2022.

5.3. Results

5.3.1. Outputs from Task 1, review of driver distraction technology for ADDW systems

Task 1 provided recommendations on metrics and corresponding thresholds for monitoring driver distraction, although the literature was inconclusive regarding the most appropriate time threshold for differentiating the driver between being attentive or distracted.

(a) Recommendations on metrics and devices for measuring driver distraction

A consensus on adopting visual distraction for ADDW systems has been identified between academics, suppliers and manufacturers. It has been found that, although research on detecting cognitive distraction is ongoing, the technology for this type of detection is not yet robust or reliable enough. The driver's gaze direction is the most commonly adopted metric applied in visual distraction monitoring systems, both in the market and in academic research. The gaze detection functionality is usually realised using camera systems. The optimal position and number of cameras is highly dependent on the type of vehicle and the cockpit geometry. It needs to be chosen by the OEM so that the system is effective for the driver population in combination with the complete range of available seat positions. Also, a wide variability in human appearances needs to be taken into account, especially face masks, glasses and contact lenses. When eye gaze can temporarily not be detected, using the head pose has been suggested as a fallback metric.

(b) Recommendations regarding system activation

For the activation of ADDW systems, the vehicle speed has been adopted as an influencing parameter. When performing low-speed manoeuvres, drivers are expected to have gaze directions that would not be appropriate at higher speeds. For example, when parking, a driver may look over their shoulder for an extended period, which would not be safe in most regular driving scenarios. Therefore, a minimum vehicle speed for activation of the ADDW is a simple way to avoid false positive distraction warning during low-speed manoeuvres. Systems currently available in the market use threshold speeds of 60 to 70 km/h. These systems are often partly or primarily drowsiness warning system, and the activation speed is related to that in the DDAW regulation (Commission Delegated Regulation (EU) 2021/1341). During consultations, several stakeholders expressed that the velocity threshold for ADDW should be lower, at 30 km/h. In discussions within the MVWG-DBAS, stakeholders have proposed activation speeds ranging from 5 to 60 km/h.

(c) Recommendations on Areas of Interest (AoI) for determining driver distraction

In order to classify the driver's gaze direction and apply the to-be-designated appropriate time thresholds, Areas of Interest (AoI) have to be defined in relation to their relevance to the driving task. Some stakeholders were in favour of establishing only one area of interest for the sake of system simplicity. However, considering the potential safety benefit of ADDW systems, it is suggested that the AoI are distinguished between the following areas, in order to associate the driver's gaze fixation with their possible attentive or distracted states:

- "Attentive areas", where driver is most likely attentive:

  Mainly covers the windscreen, and could also cover the frontal side windows (depending on the driving situation)

  This definition of "attentive areas" is directly applicable to detecting visual distraction. However, the evaluation of cognitive distraction would imply on potentially more complex definitions of AoI and attention thresholds.

- "Distracted areas", where driver is very likely distracted:

  Covers the vehicle footwell, the areas behind the driver, the vehicle roof, and areas below the instrument cluster and other driver information systems (approximated by the MVWG-DBAS by a projection plane of 30° downward from the forward view driver's eye point)

  According to the ESOP, there should be no driving-critical controls or driver information systems in these areas

- "Transition areas", where the driver may need to look for short periods of time for driving-relevant information or controls, but where long gaze durations may still be considered distracted:

  Covers the interior and wing mirrors, instrument cluster, secondary controls (e.g. HVAC controls), and infotainment display

  Depending on the interior configuration of the vehicle cabin, the location of some of these elements may fall into the "attentive" or into the "distracted" areas, thus making their boundaries relatively irregular and potentially increasing the complexity of gaze-monitoring algorithms

The definition of AoI enables the derivation of three use cases for establishing warning triggers based on the location of the driver's gaze within those areas:

Use case 1: Driver's gaze fixation lies within "attentive areas":

When the driver's gaze is located in these areas, which represent the regular view direction during driving, ADDW systems shall not trigger any distraction warning.

Use case 2: Driver's gaze fixation lies within "distracted areas":

When the driver's gaze is located in these areas, which represent areas in which the driver likely does not have the forward road in their peripheral view and does not have controls or information critical to the driving task, ADDW systems shall trigger a distraction warning after an appropriate period of time – refer to next item (d).

Use case 3: Driver's gaze fixation lies outside "attentive" and outside "distracted", but within "transition areas":

When the driver's gaze is located in these areas, it is very likely that they are engaging in secondary activities, which various sources from the literature suggest should require a maximum of 2 s of time of eyes-off-road (TEOR). However, there has not been consensus among the stakeholders for establishing in which cases a warning should be triggered or not when the driver is gazing into “transitions areas”. In discussions with the MVWG-DBAS, on the one hand, some stakeholders suggested a “grey zone” for covering the dashboard area and interaction zones, for which a warning could be emitted, but not as a regulatory requirement. On the other hand, other stakeholders suggested not considering any transition zone at all and only emitting warnings when the driver has their gaze located in what has been here defined as highly likely “distracted areas”. Nevertheless, a balance may be considered between the time a driver needs to look away from the road for driving related information and controls in these “transition areas”, and a time that is excessive and causes an unnecessary risk to themselves and other road users.

(d) Recommendations regarding time thresholds for classifying the driver as distracted

Whilst various sources from the literature suggest secondary activities should not have a duration of TEOR greater than 2 s, they also point out that not all glances off-road are inattentive behaviour. It is argued that driving-related inattention, e.g. checking the side or rear-view mirrors, despite occurring on average 44% of the total driving duration, is necessary for enhancing driving safety (Klauer, et al., 2006).

More specifically, an analysis of the data collected during the 100-car Naturalistic Driving Study (Klauer et al., 2010) revealed that TEOR lower than 2 s did not significantly increase risk relative to baseline driving (i.e., driver constantly looking to the forward road). Furthermore, results pointed out that alert drivers typically glance at mirrors and at the traffic in a rather systematic and brief (for less than 1 s) manner. However, the data did support the 2-second distraction threshold, estimating that the risk of a crash or near crash doubles for TEOR greater than 2 s within a 6-second period. The following conclusion was extracted from executive summary of the report containing the 100-car data analysis, presented by NHTSA in 2010:

> *For the 15-second total TEOR analysis, the results indicated that as total* ***TEOR increased past 3 s (or 20 percent of the total time)****, the odds ratios also showed statistically significant* ***increased crash/near-crash risk****. While previous results showed statistically significant results in total TEOR greater than 2 s out of 6 s (or 30 percent of the time), this comparable analysis shows that* ***as task duration increases, lower percentages of total TEOR time increase crash/near-crash risk****. This is an important finding, indicating that the Alliance of Automobile Manufacturers (AAM) rules regarding* ***a single glance duration of 2 s is not stringent enough****. Risk of crash/near-crash involvement increases far more quickly than this rule suggests.* (Klauer et al., 2010, p. iv)

Considering the established consensus on the 2-second threshold to classify a driver as distracted and the breadth and relevance of the 100-car Naturalistic Driving, such a conclusion should be taken into account for the development of robust driver monitoring technology. Some stakeholders were in favour of the 2-second threshold.

Pointing out the wide variety of drivers’ characteristics, the variability of seating positions, and the relative market immaturity of the existing technologies, others stakeholders indicated, during discussions with the European Commission’s MVWG-DBAS, that a 2-second threshold for distraction would be too challenging for short-term realisation. They proposed a longer time threshold between 3.5 and 5 s for detecting continuous visual distraction when the system assesses the driver to be looking exclusively into “distracted areas”. Moreover, these stakeholders argued that the time threshold should be extended by 1.5 s in case non-nominal situations occur, i.e. when the system encounters noise factors. Some of these stakeholders were also opposed to defining any time thresholds for distraction when the driver is looking into areas other than the ones designated as “distracted areas”. All these concessions would arguably reduce the likelihood that too many false-positive events occur. However, no results from internal studies or evidence that further justified the longer threshold for distraction or the simplification of AoI were provided.

Ultimately, stakeholders pointed out that successfully integrating ADDW systems into serial vehicles and validating the performance of the warnings, in which the timing for emissions plays a significant role, is complex. In the steps of system development prior to the serial phase, testing environments are controlled and use case situations are prescribed. Such configurations pose a challenge in balancing the delivery of useful information to the driver and its effects on the driver's experience with as well as usability and acceptance of the distraction warnings in the real world. For now, current Level-2 ADAS in the market, described in Table 9, address the exceedance of distraction intervals and continuous non-compliance of drivers with the distraction warnings by deactivating the automated driving system until the next vehicle start cycle. Further aspects regarding in-vehicle technology and driver distraction will be discussed in Section 6.1

5.3.2. Outputs from Task 2, review of ADDW systems HMI

Task 2 reviewed the current state of the art regarding the HMI component of ADDW systems and recommend functional and technical requirements. However, Task 2 did not point to a consensus on test procedures to evaluate the performance of the HMI.

(a) Recommendation on requirements for the HMI of ADDW systems

Functional requirements

So far, there is no consensus on an appropriate definition of long distraction and there is also no consensus on whether intermittent distraction should be taken into account at this moment, as the technology is not ubiquitously robust enough for this use case. So, the following functional requirement can be specified, without any specification of timing:

- Distraction warnings should be emitted as soon as possible after the occurrence of the trigger behaviour. Trigger behaviour means that the system evaluated the driver as positively distracted.

In case the driver fails to comply with the warnings and continues to be distracted, the manufacturers may choose to repeat, cascade or escalate the warnings.

Technical requirements

While manufacturers reported that they preferred to maintain freedom for designing the warnings emitted by their ADDW systems, there are technical requirements regarding the usability of the in-vehicle warnings that are specified in normative standards and should be taken into account when drafting the regulatory text:

- In case visual warnings are used:
    - Their design should be consistent with the instructions and requirements from ISO 2575:2021 concerning symbols for controls, indicators, and tell-tales of road vehicles.
    - The contrast of the symbol with the background in sun light, twilight and night conditions are recommended to be in accordance with ISO 15008:2017.
- In case auditory warnings are used:
    - Their design should not be consistent with the instructions and requirements from ISO 15006:2011 concerning in-vehicle auditory presentation.
    - A majority of the acoustic warning shall fall within the frequency spectrum of 200-8000 Hz and amplitude range of 50-90 dB, in accordance with ISO15006:2011.

- In case of haptic warnings:
    - Vibration frequencies of 100-300 Hz should be used. Humans are most sensitive to this range of frequencies, which is high enough not to be covered by road-induced vibrations in the cabin. This range is also considerably distant from the ranges around ca. 3 Hz, considered to be spectrum of Eigen frequency of the human body that, when matched, could case discomfort or nausea. (ISO/TR 16352:2005).

(b) Recommendation on approaches for validation of the HMI of ADDW systems

Based on the evidence gathered under Task 2, the following parameters should be considered for verifying the performance of ADDW systems during validation testing:

- Effectiveness: through testing with human test driver's for assessing:
    - Warning activation rate, e.g. per hour
    - Warning detection rate, in percentage values
    - Rate of driver's compliance: Transition from unsafe to safe behaviour, by executing the system's required response to be not distracted any more
    - Time eyes-off-road (TEOR)
    - Time from fully attentive to warning emission
- Efficiency: through testing with human test driver's for assessing aspects such as
    - Alert impairment (e.g. startling effect)
    - Intelligibility or understandability: by psycho-acoustical parameters, by comparing physical characteristics of the signal against background noise, or by psychological metrics, through parameters of correct understanding and/or behaviour, e.g. conspicuousness, clarity, perceived meaning or perceived urgency.
    - Reaction time: Interval between the stimulus of the warning and the driver being considered not distracted any more

However, no specific value or acceptance criteria for any parameters measuring effectiveness or efficiency have been indicated. Stakeholders have suggested that manufacturers and suppliers need more time and experience with ADDW systems, as well as more feedback from customers while using the system on the road after some time, to be able to suggest appropriate acceptance values for these parameters. Nevertheless, manufacturers should be able to provide evidence on the performance of their system based on tests they have conducted to guarantee that their ADDW systems are reliable and robust enough to be released into the market.

5.3.3. Outputs from stakeholder engagements specific for Task 3

This Section summarises the information gained during consultations and written feedback from 21 stakeholders on existing requirements and test procedures for ADDW systems. In addition to the questions that served as input for Tasks 1 and 2, stakeholders were specifically asked how they assess the effectiveness of their systems and to describe the challenges regarding technical feasibility and system validation that they have encountered while developing their systems.

(a) Proposed test procedures to evaluate ADDW system performance

During consultations, the stakeholders reported on their experiences with assessing the effectiveness of their ADDW systems. The following test procedures have been mentioned by manufacturers and Tier 1 suppliers as having been used or as recommended to be used, while also suggesting the appropriate testing conditions to be adopted:

- Spot-check tests
- Naturalistic tests
- Repeated tests using a range of subjects

Many stakeholders held the view that the test procedures should be simple, repeatable, and reproducible across all vehicle categories. Specifically, one stakeholder expressed that the approach should be kept simple to allow suppliers to reduce the number of false positives. With time, as the technology develops, experience is gained and the systems are improved, technical requirements can eventually become more complex.

Spot-check tests

Several stakeholders proposed to check the basic functionality of ADDW systems with spot-check tests, by assessing the system's sensitivity, i.e. true positive rate, and specificity, i.e. true negative rate, under a prescribed condition representing a specific nominal situation. Evidence about reliable system performance for a wider range of conditions would still need to be provided by more comprehensive documentation, such as a system validation dossier.

Stakeholders suggest measuring true positive rates by assessing the accuracy of defined distraction-related situations. True negative rates are then measured by verifying whether the system does not emit distraction warnings when the driver is instructed to drive normally and look to the forward road. This kind of test procedure could be conducted by the driver being instructed to look into certain zones for longer than the defined threshold times and according to instructed orientations on how to get distracted, e.g. using a mobile phone, picking an object from the passenger's footwell or turning back towards the rear passenger seats. Spot-check tests are thus recommended during the early phases of ADDW systems validation, when not much performance data is generally available. It is also imperative that the safety of all people involved during the testing procedure (test driver, test conductor, external road users) is guaranteed and they are not exposed to hazardous situations caused by the vehicle being driven by someone distracted.

The advantage of this test procedure is that it can objectively assess the system's sensitivity and specificity and verify how accurate the warnings are, at least when the subject is intentionally distracted during a prescribed, nominal situation. Another advantage is that these tests can be conducted in stationary settings, driving simulators or closed test tracks. This way, the safety of test drivers and other road users is not exceedingly compromised since they wouldn't be engaging in distracted driving in real traffic settings on public roads.

Two main disadvantages were mentioned by stakeholders regarding spot-check tests. First, the variety of investigated noise factors (e.g. drivers' variability, different seating positions) would not be broad enough to validate systems for a representative part of the population. Second, whilst the distraction monitoring system could be objectively assessed, the effectiveness of the HMI is difficult to be evaluated in these conditions, as drivers are instructed to actively engage in distracting situations and this needs to be factored into the transferability of test results to natural conditions. These disadvantages could be compensated by the manufacturers providing comprehensive evidence that they have conducted extensive testing for verifying their systems' performance for a variety of conditions, distraction situations, seating positions and drivers' characteristics. Two methods that could be used to provide such evidence are described in the following: naturalistic tests and repeated tests using a range of subjects.

Naturalistic tests

Many stakeholders suggest naturalistic driving studies for assessing the accuracy of distraction detection and the effectiveness of warnings' emissions. The primary strength of naturalistic studies is that test drivers experience the ADDW system in more natural settings for extended periods. Being involved in longer driving situations similar to day-to-day driving, drivers are allowed to get distracted as a natural result of their spontaneous disengagement from the driving task, which poses a stark advantage over methodical test procedures that, in essence, end up modifying the driver's behaviour and thus poorly reflects the actual effectiveness of the warnings, as drivers are not always conscious of their distracted state. In this context, using a reference system or the manual evaluation employing cross-reference analysis of video recordings can help to counteract the discrepancy between objective and subjective assessments. This, in turn, greatly increases the effort and expenditure of such tests, making them difficult to be applied for a larger number or wide variety of test drivers. Moreover, naturalistic driving studies incur more elaborate ethical and safety issues in relation to the participations of voluntary test drivers, as the to-be-verified systems are intended to warn them about their unsafe behaviour on open, public roads shared with other vehicles.

Repeated tests using a range of subjects

A further variant stakeholders propose to measure the effectiveness of their ADDW systems is through repeated tests routines using subjects of a range of demographics and physical appearances, both robots and humans. Repeated tests with a range of subjects was indeed used by most sources analysed in the literature review for Tasks 1 and 2.

These tests can be done in driving simulators, test tracks and also stationary settings. One stakeholder stated that they employ acting agencies to cover a large variety of demographics, as well as human annotators to validate images to improve algorithms. In this context, stakeholders suggested that systematic and statistical evaluations can also be conducted to prove functionality over a wide variance of people.

(b) General requirements for testing ADDW system performance

Testing requirements

Validation testing shall take place using human participants. The validation testing can be carried out in real-world road environment (naturalistic studies), a simulator, or in a stationary vehicle. If validation testing is performed in a simulator, the manufacturer shall document its limitations regarding real-world open road testing.

Environmental conditions

The system shall be tested in day and night conditions.

Measuring distraction

The participant's level of distraction shall be measured using eye gaze and head position. The manufacturer may use alternative measurement(s) to validate the ADDW system, such as blink rate, eyelid state, hand pose, and object identification.

(c) Challenges for testing system performance

After describing possible test procedures for validating the ADDW systems' performance, the stakeholders expressed that the following issues that they have faced and still expect to confront in the near future are key challenges to be dealt with when testing their systems' performance:

- The definition of the Areas of Interest (AoI)

- The optimum position of the camera
- Robustness against interpersonal and external factors
- Accessibility to testing equipment and facilities

The definition of the Areas of Interest

With regards to the Areas of Interest (AoI), stakeholders suggested it is important to define specific AoI in order to establish test criteria. This definition does not need to correspond with the AoI used when developing a system.

Due to the variation in interior design and geometries between vehicles categories, stakeholders identified that there may be differences in the definition of distracted AOI based on the positional relationship between the camera and the driver. For example, a passenger car compared to a truck may have different AoI in relation to distracted behaviour and non-driving related tasks due to the different cabin interior and geometries. Consideration should be given to ensuring that distracted AoI are suitable for all M and N category vehicles, either by modifying the AoI for each category as required or by already defining initially the AoI for each category individually.

The optimum position of the camera

Another factor stakeholders reported is a challenge to the testing of the system is the optimum position of the camera. Stakeholders reported that the detection of the driver's eye gaze is made more challenging because of the differences in interiors between vehicle categories, arguing that standardised camera number and position to be adopted in test cases may not align with the feasibility of all vehicle categories.

Robustness against interpersonal and external factors

Another challenge identified by stakeholders when testing their ADDW system performance is the robustness against interpersonal and external factors. These have been clustered into accessories worn by the driver, the physical appearance of the driver, and external factors such as bright lights reflecting into the camera.

With reference to the accessories worn by the drivers, multiple stakeholders identified that infrared-blocking sunglasses may make it difficult to test the system as the eye gaze will be undetectable by the system. However, in this instance, head position/tracking can be used as a secondary metric, simply speaking a back-up option, if the driver's eye gaze is not accessible by the system.

Furthermore, a number of stakeholders emphasised that in order to be robust against interpersonal factors, the system needs to be tested based on a range of physical appearances and accessories, including height, eye shape, skin colour, hats, face masks, glasses and facial hair.

Lastly, one stakeholder also identified that external factors might affect the system's performance, such as the weather and lighting conditions (e.g. bright sunlight into the camera or vehicle driving on a street with many trees, causing constant and rapid changes between sunlight and shade conditions). One stakeholder highlighted that convertible vehicles are challenging categories to have the ADDW system implemented in the correct position because when the roof is down, more sunlight enters the vehicle's interior and may be more likely to shine into a camera.

Accessibility to testing equipment and facilities

Possible ways of examining the effectiveness of ADDW systems is through simulation or closed test track studies, as some situations would not be safe to be carried out on the road in real life, such as purposefully acting distracted (i.e. repeated glances at non-driving related zones) to measure the true positive rate of the system.

5.3.4. Review of complementary literature towards deriving test procedures for verifying performance of ADDW systems

(a) Performance measures for detecting driver distraction

As pointed out in Section 3.3.3, one of the main aims during user experience testing is to minimise the number of false positives, often associated with annoyance from the drivers. Fawcett (2006) proposes a “confusion matrix” for defining common performance metrics representing a relationship between a hypothesised class and the actual true class.

Table 16 : Confusion matrix adapted from (Fawcett, 2006)

Hypothesised output / True result	Positive	Negative	True totals
Yes	True positives (TP)	False negative (FN)	Total true positives (P = TP + FN)
No	False positive (FP)	True negative (TN)	Total true negatives (N = FP + TN)

In the context of ADDW systems, the following variables are to be considered:

(1) Hypothesised output: Detection of a distraction event by the system

- Positive output: System classifies the driver as distracted
- Negative output: System classifies the driver as not distracted

(2) True result: Actual occurrence of driver distraction

- Yes output: Driver is distracted
- Negative output: Driver is not distracted

Based on these variables, Fawcett (2006) also defines equations of several common metrics that can be calculated from the confusion matrix and enable researchers to objectively assess the performance of systems designed to output data evaluation for a certain period of time:

False positive rate:
(also called *false alarm rate*)

$$fpr = \frac{FP}{N} \quad \text{(Equation 1)}$$

True positive rate:
(also called *sensitivity*)

$$tpr = \frac{TP}{P} \quad \text{(Equation 2)}$$

True negative rate:
(also called *specificity*)

$$tnr = \frac{TN}{N} = (1 - fpr) \quad \text{(Equation 3)}$$

Precision:

$$precision = \frac{TP}{TP + FP} \quad \text{(Equation 4)}$$

Accuracy:

$$accuracy = \frac{TP + TN}{P + N} \quad \text{(Equation 5)}$$

Ultimately, despite having described potential performance measures for objectively evaluating ADDW systems, neither the research nor the stakeholder consultations could provide conclusive evidence regarding appropriate ranges for the acceptance criteria necessary to assess these performance metrics.

(b) Literature on testing procedures for evaluating driver distraction

As pointed out in Section 2.6, while there is documentation of ADDW systems being assessed under both real-time and simulated environments, there is little systematic research conducted to determine validity and reliability of these systems. Also, since there are no regulated distraction monitoring systems presenting a structured procedure for validating distraction monitoring systems, the work under Task 3 turned to the latest proposals made by Euro NCAP for assessing driver status monitoring systems, which will be implemented in 2023. The following three documents were considered:

- Assessment Protocol: Safety Assist – Safe Driving (Euro NCAP, 2022a)
- Technical Bulletin: Driver Status Monitoring Dossier Guidance (Euro NCAP, 2022b)
- Technical Bulletin: Driver Status Monitoring Spot Testing Guidance (Euro NCAP, 2022c)

Euro NCAP specifies two basic components for the assessment of Driver State Monitoring System (DMS). Firstly, a dossier is required from the OEM containing a detailed technical assessment of its system. Secondly, Euro NCAP test labs will conduct spot tests to validate the information from the dossier.

The first aspect to be contained in the dossier covers the general operational conditions and the sensing capabilities with regard to the variety of driver and operational conditions. The general conditions to be met include the system’s required activation status at the start of every journey (ON), restrictions for system deactivation by the driver as well as speed thresholds and time periods beyond that the system is required to be operational. Additionally, the effect of driver and environment related noise variables on the system need to be covered. Regarding the driver population, specified distributions of age, sex, stature, skin complexion and eye lid aperture must be demonstrated not to lead to a strong deviation of the system’s performance. The same is true for occlusions of facial features by lighting, eyewear and facial hair. Additional variables which may result in degradations include hand placement on the steering wheel and specific reasons for facial occlusions. The OEM must demonstrate for each case whether the performance is degraded and, if that is the case, that the driver is informed of this degradation within ten seconds using visual and/or audible information. The impact of driver behaviour like eating, talking etc. on performance also needs to be documented by the OEM, though there are no performance requirements in this regard.

The second part to be covered by the dossier are the system capabilities regarding the detection of the driver state with respect to distraction, fatigue and unresponsiveness. For the case of ADDW systems, only distraction and unresponsiveness are considered, as fatigue is covered under the DDAW Regulation (EU) 2021/1341 (European Union, 2021) For distraction, three types are defined: long distraction, short multiple distractions and phone usage. For each of these, the system performance in multiple combinations of various distraction scenarios, body movement types (head movement, eye movement, body lean) and gaze location must be demonstrated. Driver unresponsiveness is defined by either the lack of response to an inattention warning within a 3 s window, a turn away of the gaze from the forward road view for at least 6 s or eye closure for the same amount of time.

These detection requirements are complemented by requirements regarding the vehicle response. For each of the listed categories of driver inattention, time and velocity thresholds and further criteria are specified that, when met, should trigger audible, visual and/or haptic warnings. Respective conditions for active interventions are also specified. The required interventions include low-level brake actuations as well as the automatic adjustment of the Front Collision Warning (FCW) and Lane Departure Warning (LDW) systems to the respective highest sensitivity. In case of an unresponsive driver, the vehicle should initiate a minimum risk manoeuvre.

The spot tests by Euro NCAP test labs are to be conducted according to a detailed guideline. It defines the measuring setup including recording frequency (25 Hz), the list of variables to be measured and the measuring equipment. The latter must facilitate the recording of VUT speed to 0.1 km/h precision, driver gaze location and the issued in-vehicle warnings. Further descriptions cover the allowed weather conditions: no precipitation, visibility levels above 1 km and wind speed below 10 m/s. The test track needs to provide a uniform, solid-paved road surface with conformant lane markings.

For the actual test procedure described in the guideline, the preparatory steps before the testing include:

- A sensor calibration drive to ensure full functionality of FCW and LDW systems (if requested by the OEM).
- Seat and control adjustment to a comfortable and safe position for the driver.
- An initial drive with full attentiveness for at least one minute to allow regular system initiation. If that information is provided, the driver should verify the detected attentiveness status.
- Verification that the system state is ON at the start of every journey and that the steps for deactivation by the driver conforms to the specified restrictions.

General provisions for the execution of all tests are:

- Speed ranges from 20 km/h to 80 km/h.
- Transmission set to D, or selection of a gear resulting in at least 1500 RPM at the test speed in case of manual transmission.
- Use of speed limiter or cruise control is permitted, use of ACC is not.

Finally the complete set of test scenarios is specified. They are grouped by the driver states to be detected by the system (distraction, fatigue, unresponsiveness), their subtypes (e.g. phone use) and actions of the test driver such as a change of body posture including hand position, the target location of the gaze, eye closure or phone use. In addition, the vehicle responses (FCW and LDW) described above are covered with additional sets of tests for each driver state.

As spot testing by its definition does not cover all variations, the test lab will select the subset of test to be conducted from the complete set described above, though only those declared as supported in the OEM dossier are considered. The method of selection is prescribed in the guideline and includes random choice of gaze location and accessories.

5.4. Discussion

Upon evaluating the evidence gathered in Section 5.3, three questions can be considered:

1. What are the general requirements that can be established for ADDW systems?
2. What test procedures can be recommended for verifying the performance and validating ADDW systems?
3. How these recommendations fit in the current and future state of the technology?

These questions are discussed in the following sub-Sections.

5.4.1. General requirements on the test procedures

Since ADDW systems shall be regulated under the framework of the General Safety Regulation (GSR) (EU) 2019/2144, all the following requirements from the preamble section of the GSR are applicable to the specification of requirements and the development of test procedures for ADDW systems. In particular, the following items from the “whereas” session of the GSR were considered relevant for the work in Task 3:

- “(4) Type-approval provisions should ensure that motor vehicle performance levels are assessed in a repeatable and reproducible manner. […]”
- “(9), Safety features and warnings used in assisting driving should be easily perceivable by every driver, including the elderly and persons with disabilities.”
- “(10) [...] advanced driver distraction warning [...] systems should function without the use of any kind of biometric information of drivers or passengers, including facial recognition. Therefore, harmonised rules and test procedures for the type-approval of vehicles as regards those systems and for the type-approval of those systems as separate technical units should be established at Union level. The technological progress of those systems should be taken into account in every evaluation of the existing legislation, in order to be future-proof, whilst strictly adhering to the principles of privacy and data protection, and to reduce or eliminate accidents and injuries in road transport. It is also necessary to ensure that those systems can be used safely throughout the life cycle of the vehicle.”
- “(14) Any processing of personal data, such as information about the driver processed in event data recorders or information about the driver’s drowsiness and attention or the driver’s distraction, should be carried out in accordance with Union data protection law, in particular Regulation (EU) 2016/679 of the European Parliament and of the Council. […]”

Moreover, the technical requirements, performance parameters, and suggestions for test procedures laid out in Section 5.3 are foundational for drafting the proposal for the contents of the ADDW regulation.

5.4.2. Recommendations on test procedures for verifying the performance of ADDW systems

(a) Performance measures for evaluating ADDW systems

The performance of an ADDW system can be measured by evaluating how well its goals are achieved. From the definition of ADDW systems by the General Safety Regulation (EU) 2019/2144, two components with individual goals are identified. The driver distraction monitoring technology, for detecting driver distraction, and the HMI, for emitting the distraction warnings. Therefore, the overall performance of ADDW systems depends on the performance of these two individual components. In the following, suggestions on how to evaluate the performance of these two system components are made, but as pointed out in Section 5.3.4(a), no suggestion about ranges for acceptance criteria can be made at this moment.

Fawcett’s confusion matrix from Section 5.3.4.(a) can be adapted for ADDW systems as presented in Table 17.

Table 17 : Primary confusion matrix for ADDW systems

Driver is \ ADDW system output	Driver distracted	Driver not distracted
Distracted	True positives (TP)	False negative (FN)
Not distracted	False positive (FP)	True negative (TN)

Table 17 provides definitions that can be adopted for objectively evaluating the performance of the distraction monitoring component of ADDW systems' by calculating detection rates and the respective metrics indicated by Equations 1 to 5, as defined in Section 5.3.4.(a):

- False positive rate or false alarm rate
- True positive rate or sensitivity
- True negative rate or specificity
- Precision
- Accuracy

These metrics are to be calculated for a certain time duration, e.g. per hour. However, establishing the amount of time appropriate for measuring the performance with ADDW systems still depends on suppliers and manufacturers gaining more experience, either by conducting repeated experiments, preferably with a wide enough variety of test subjects, or systematically collecting feedback on the market from drivers' that purchase vehicles with ADDW systems installed. Other specific parameters for evaluating objective performance of ADDW systems are related to the HMI component and are found in Section 5.3.2.(b):

- ADDW system's effectiveness:
    - Warnings' activation rate, e.g. per hour
    - Warnings' detection rate
    - Rate of driver's compliance with the distraction warnings
    - Time eyes-off-road (TEOR)
    - Time from fully attentive to warning emission
- ADDW system's efficiency:
    - Alert impairment
    - Intelligibility or understandability
    - Driver's reaction time

As Fawcett points out, "as with any evaluation metric, using them wisely requires knowing their characteristics and limitations" (Fawcett, 2006, p. 873). While these characteristics and limitations certainly affect the objective performance of the distraction monitoring component of the ADDW system, they also significantly affect the user's perception and acceptance of the system. Thus the performance of ADDW systems ends up being intrinsically dependent on the driver's subjective experience with the HMI component. Assuming that the distraction monitoring component is reliable and robust and that its output indeed corresponds to the actual state of the driver, the performance of the ADDW system will also depend on whether the driver is subjectively conscious of their distraction. Therefore, considering all the information collected after the literature review in Tasks 1 and 2, as well as the inputs from the stakeholder engagements, the following relationships, listed in Table 18, can be derived.

Table 18: Driver experience-related confusion matrix for ADDW systems

Driver thinks / Driver actually is (which ideally matches the output of a reliable ADDW system)	is distracted	is not distracted
Distracted	Good experience	Bad experience
Not distracted	Reduced trust	Good experience

When there is a match between the driver's own perception of their distracted state and the emission of the warning, the result is a good experience with the system. Good experience is achieved as a result of the driver receiving a distraction warning and agreeing they were distracted or not receiving a distraction warning when not being distracted.

However, if the driver realises they were distracted but notices that they haven't received any distraction warning, they might perceive the system as not robust or reliable enough, which can potentially reduce their trust in the system's performance.

A bad experience with the ADDW system happens when the driver receives a warning but thinks they were not distracted. This could happen because the driver was unaware of their distraction or their mental model of the system's functionality was flawed. Particularly the latter can occur if the areas of interest within the driver's cabin are assigned different time thresholds for detecting distraction. In either case, this bad experience can lead to annoyance and affect the system's acceptance.

Nevertheless, in case the driver receives a warning when they think they were not distracted but actually were (assuming that the distraction detection component of the ADDW system is robust and reliable), the safety benefit of the ADDW system prevails since the driver was indeed distracted and should have indeed been warned, arguably for the sake of higher safety. This would entail, however, that system would need to explain to the driver, after the fact, that they were actually distracted. The only piece of research discovered under Tasks 1 and 2 that indicated any approach to instruct the driver on their distracted behaviour post-drive was an experiment conducted by Roberts, Ghazizadeh, & Lee (2012), described in Section 4.4.3. By showing the drivers an analysis of their driving performance, after the drive, in terms of a graphical display of their distraction levels during the drive, as well as videos of themselves during moments of distraction, the authors aimed to encourage drivers to pay more attention to the driving task in the future.

Specific parameters for evaluating subjective performance after the driver's experience with ADDW systems can also be extracted from Table 13:

- Perceived usefulness
- Perceived ease of use
- Acceptance towards the system or intention to use the system
- Annoyance with the system (alternatively, unobtrusiveness)
- Comprehension of the system functioning
- User's compliance with the distraction warnings (executing the system's required response to be not considered distracted any more)

(b) Test procedures

As pointed out in Section 5.3.4(a), there has been no conclusive evidence from the literature nor consensus or experience enough with the system by manufacturers to suggest ranges for acceptance criteria by the moment this Final Report is delivered. This limitation hinders the definition of test procedures for validating ADDW systems and should be taken into account when proposing the contents for the regulatory text. However, even though target values cannot be defined at the moment, performance parameters for objective and subjective evaluation of ADDW systems have been proposed in Section 5.4.2.(a).

For type-approval, manufacturers should provide evidence, e.g. by means of a dossier or collection of technical documentation, that their ADDW systems are reliable and robust enough to be released in the market. Evidence shall disclose user studies or extensive testing with a wide enough variety of conditions, distraction situations, seating positions and drivers' characteristics, describing how the system can monitor driver distraction and emit the corresponding warnings robustly enough for a representative part of the driving population in Europe. For this, manufacturers may use, extend or adapt the list of objective and subjective metrics proposed in Section 5.4.2.(a).

Taking into account the relative immaturity of existing technologies and the manufacturers' limited market experience with ADDW systems, where applicable, manufacturers should attach to the provided evidence a description of the system's limitations. These can be, but are not limited to, driver-, vehicle- or environment-related noise factors, which may cause the system to have its performance degraded. Within the described limitations of the system, manufacturers should demonstrate how the system is able to still reliably monitor driver distraction and emit the corresponding warnings. This reliability should also be verifiable for a representative part of the European population.

During the stakeholder engagements and discussions with the European Commission's MVWG-DBAS, it has been granted that type approval authorities, or technical services on their behalf, cannot conduct tests for validating ADDW systems for a wide variety of the population, amongst other aspects, due to limited resources. However, beyond examining the technical documentation provided by manufacturers reporting on the performance of their ADDW systems, they should be able to evaluate ADDW systems during nominal situations, in which noise factors are not present or have been at least listed as already mastered.

By means of spot-check testing procedures, type approval authorities and technical services can assess the effectiveness and efficiency of ADDW systems, thus attesting the systems' basic functionality and compliance with the technical specifications for detecting distraction and warning drivers during specific conditions. Gaze locations within the cabin considered relevant for triggering distraction warnings could be listed independently from specific distraction situations, thus allowing test procedures to be repeatable and reproducible. Nevertheless, manufacturers are encouraged to appoint distraction situations that could trigger distraction warnings on the specified gaze locations, as well as noise factors that their systems have already overcome.

Beyond the scope of test procedures to be mandated by the ADDW Regulation, market surveillance is a useful tool to test outside of regulated test procedures for the type-approval. It aims to ensure that products on the market are conform to the applicable laws and regulations and comply with existing EU health and safety requirements (European Commission, 2022).

5.5. Summary and conclusions

The purpose of Task 3 was to consolidate the results from Task 1 and 2 and propose appropriate technical specifications and requirements that could be taken into consideration for the regulatory text of ADDW systems. Moreover, Task 3 also aimed to review Tasks 1 and 2 with a focus on how ADDW systems are currently being tested. This way, identified consensuses could be further recommended and existing challenges could be, at least in part, tackled by complementary literature and stakeholders' inputs. The advantages and disadvantages of test procedures were balanced and an approach combining spot-check testing with user studies is recommended, considering the current state of the technology.

The results from Task 3 are summarised in the form of a draft for the contents of the ADDW regulation under the framework of the General Safety Regulation (European Union, 2019). This draft text is presented in the Appendix B, which has been reviewed and refined with inputs from discussions with the European Commissions' MVWG, as well as with their subgroup DBAS, up to the third meeting of the subgroup on 29 November 2022. After receiving the proposed draft, the European Commission will continue to refine and update the regulatory text.

6. Final remarks

6.1. Recommendations in light of current and future state of distraction monitoring technology

When establishing requirements and test methodologies for ADDW system validation, careful consideration must be taken. During the consultations activities and participations in the discussions within the European Commission's MVWG-DBAS, some stakeholders were in favour of the 2-second distraction threshold suggested by evidence collected from the literature. Others pointed out that the experience of manufacturers with the technology on the market is still limited and that there is still concern with high rates of false-positive. These stakeholders were in favour of longer thresholds for distraction, claiming to still face challenges on assessing system performance for a wide variety of traffic conditions, distraction situations, seating positions, and drivers' characteristics.

Also, a consensus on the appropriate metrics to consistently measure the performance and ultimately the effectiveness and efficiency of ADDW systems still needs to be found. Considering the results obtained under this project, the metrics suggested for evaluating the performance of ADDW systems, presented in Section 5.4.2(a), could provide guidance for manufacturers to evaluate their system and also for future ADDW regulation to formally require. However, further research should be pursued, by academics, suppliers, and manufacturers, in order to arrive at appropriate acceptance criteria that could be used to validate ADDW systems in the future.

Another significant aspect regarding in-vehicle technology and driver distraction is the increasing presence of ADAS that take over parts of the driving task. With more automation, levels of driver distraction will likely increase. However, once the vehicle is capable of taking over the driving task without needing the driver to monitor the traffic situation, new distraction monitoring paradigms and warning strategies will need to be investigated.

6.2. Recommendations for next steps

Considering the results under this project and the challenges identified, the following topics are also worth further investigation:

- Establishment of requirements for intermittent distraction
- How to reach or what would be the benefits of lower, shorter, and stricter thresholds
- Definition of more refined areas of interest, with their correlation with driving or environment situations
- Establishment of appropriate acceptance criteria and testing procedures for ADDW system validation, in order to ensure that system performance is robust and reliable for a representative part of the driving population in Europe
- Further stakeholder engagements to assess the evolution of ADDW technology

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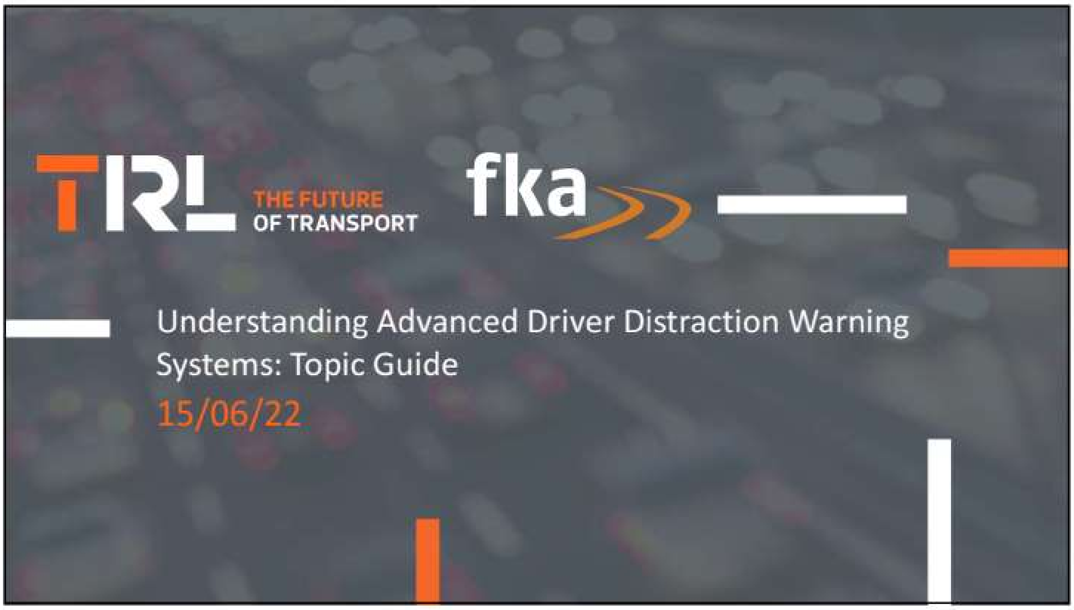
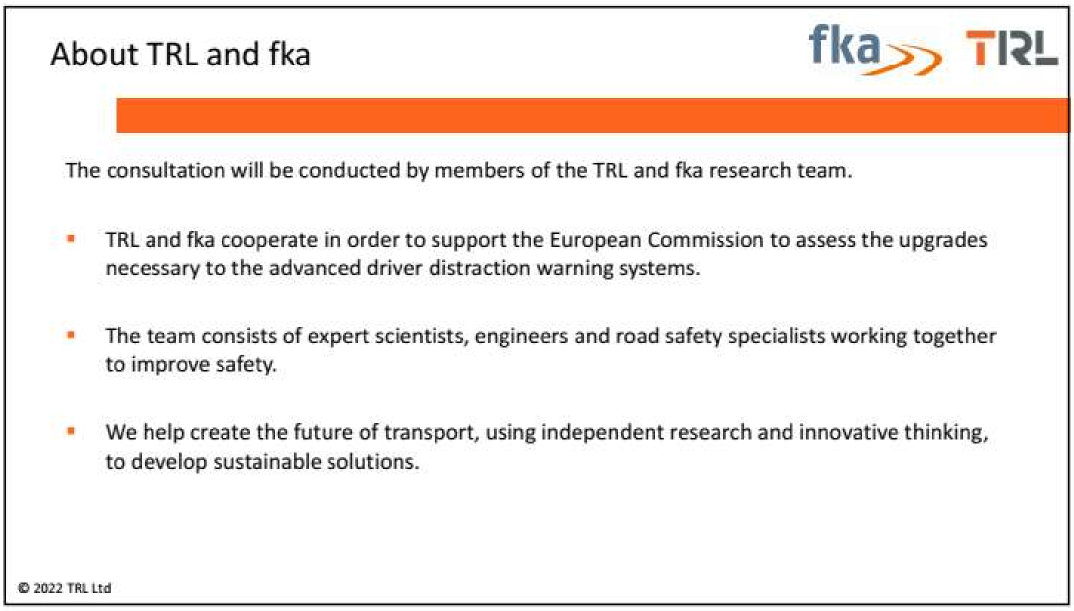
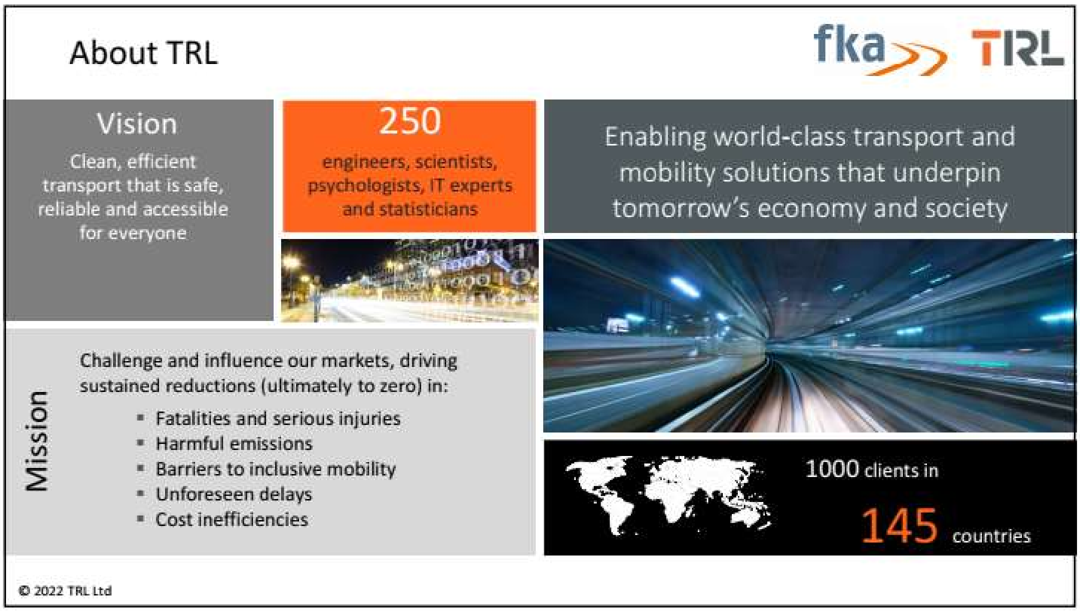
Appendix A: Stakeholder consultation topic guide



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250
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References
Automotive customers from Europe, USA und Asia
OEM and suppliers
Public funded research
Projects structure
55 % Advanced engineering
20 % Serial vehicle development
25 % Future development and others
Developing tomorrow's mobility
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Project overview

- The European Commission estimates that 10-30% of crashes in Europe are caused by road user distraction
  - NHTSA estimates that driver distraction may contribute to 16% of all fatal collisions, 21% of all injurious collisions and 22% of all collision in the US
- To prevent visual distraction-related crashes, Regulation (EU) 2019/2144 aims to mandate the implementation of Advanced Drivers Distraction Warning (ADDW) systems from 2024
  - Vehicle categories M1, M2, M3, N1, N2 and N3
- This project focuses on establishing performance requirements, testing/validation methods and threshold levels that can be applied in legislation on ADDW

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ADDW system

- The scope of ADDW systems is to help the driver to continue to pay attention to the traffic situation and to warn the driver when he or she is distracted. This includes, in particular, the reduction of visual distraction, which is considered the most dangerous when driving.
- ADDW systems shall be designed in such a way that those systems do not continuously record nor retain any data other than what is necessary in relation to the purposes for which they were collected or otherwise processed within the closed-loop system.

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Glossary

Definitions

- **ADDW**: Acronym for "**A**dvanced **D**river **D**istraction **W**arning"
- **Driver distraction:** The diversion of attention from activities critical for safe driving to a competing activity.
- **Visual distraction:** Driver takes their eyes off the road to engage in a secondary activity not related to the driving task.
- **HMI:** Acronym for "**H**uman-**M**achine **I**nteraction", intended as the exchange of information between a user (human) and an interactive system (machine) via the user interface. The user interface comprises all interactive system's components that provide information and controls for the user to accomplish specific tasks with the interactive system. [DIN EN ISO 9241-210:2020]
- **Personal data** means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person [GDPR 2016/679].
- **Biometric data** means personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics of a natural person, which allow or confirm the unique identification of that natural person, such as facial images or dactyloscopic data [GDPR 2016/679].

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Key questions

Background

- What vehicle category is the system designed for?
- Is your system affected by the category of vehicle in which it's installed?
  - What are the challenges for system performance in different vehicle categories?
  - What are the challenges for testing system performance in different vehicle categories?
- What specific situations is your system designed to prevent by informing the driver of their distraction? (not watching the road, watching the phone too much, in the city, on the highway, …)

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Key questions

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Understanding your system – how do you measure distraction?

- What human behaviours does your system measure (e.g. attention, micro sleeps, driving behaviour)?
- How does your system determine the state of the driver? (specific questions on next slide)
  - Does your system monitor gaze direction and/or any physiological indicators? If so, how does it do this?
  - How many states of the driver do you consider?
  - For what environmental conditions does your system work / not work?
  - If your system is camera-based, how does it deal with glances into places other than the road, but that are still relevant for driving, when categorizing distraction? (e.g. mirrors, instruments, pedestrians/cyclists)
  - What are your views on a distraction indicator?
  - Are there any constraints on users (e.g. eye shape, skin colour, seating position, spectacles, sunglasses, face masks…)

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Key questions

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Understanding your system – how do you measure distraction?

- How early-on does the system detect inattention / visual distraction?
  - What is the time threshold for a distraction warning? How quickly do drivers regain a) attention and b) good driving following the warning? This includes the integration with other vehicle technology and scientific research.
- Does your system store any personal / biometric data of the user?
  (as defined in the glossary on slide 7)
  - If so, please describe which kind of personal / biometric data are stored.
  - Would your system not function without the user's consent to use and/or store such data?
- Does your system also measure attention to the driving task?

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Key questions

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Assessing your system's effectiveness

- How would you go about assessing the effectiveness of your system or a similar system?
- What tests have been conducted to determine the sensitivity (true positive rate) and specificity (true negative rate) of the system?
- How does your system deal with false-positives due to individual variability?
- Whilst developing your system, did you experience any issues? Specifically, what limitations or technical feasibility issues did you encounter?
- What subjective and/or physiological metrics do you exploit when evaluating your system?

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Key questions

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Assessing your system's effectiveness

- How do you evaluate the user experience?
  - How should the regulation balance warnings with the acceptance of the system, so that the user/driver keeps the system switched on?
- What would be your view on having a user experience evaluation strategy standardized by the regulation?

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Key questions

Assessing the effectiveness of your system's HMI

- What is your recommendation on HMI to
  - a) be understandable to the driver – so all drivers have a common understanding of the messages from the ADDW system?
  - b) ensure acceptance – to maximize the time of the system being active / switched on?
  - c) not cause distraction?

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Key questions

Interacting with your system

- How does your system alert the driver that they are distracted? What type of warning(s) do you use (visual/audio/haptic/other)?
- When do the warning(s) disappear? What action does the driver need to take in order to be not considered as distracted anymore?
- Studies have shown that a warning escalation strategy benefits the driver's experience with the system. Do you recommend an escalation strategy for the warning(s) on your system?
  - If yes, please describe how you intensify the warning(s) and/or what other warning type(s) do you add. What would be the appropriate thresholds for the escalation in your system and how would you implement the warnings?
  - If not, why not?
  - What would be your general comments about the feasibility of an escalation strategy – from a human factors point of view as well as from the technological side?

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Key questions

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Interacting with your system (2)

- How do you think an adaptive strategy to the emission of warnings would affect the effectiveness of an ADDW system? (e.g. dependent on road/scenario/environment or vehicle speed)
- The European Statement of Principles (ESoP) establishes principles for designing information & communication systems with which the driver interacts. While some of these principles can be helpful for designing HMI for ADAS, they don't provide clear guidance for the design of warning systems that demand a reaction from the driver (e.g. FCW).
  - What do you think about bringing those principles into this ADDW regulation in question?
  - If we don't implement the principles within the ESoP, what would you recommend instead?
- What is your view on the system being customizable, i.e. include functionality for its settings to be modified? (e.g. warning volume or style)
- What would you recommend to ensure that an ADDW system works with drivers with a wide range of disabilities and impairments, as well as with vehicle adaptations?

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Key questions

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Closing remarks

- Would you add any further comment about what you think are the most critical aspects of this ADDW regulation?

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Appendix B: Proposed items for ADDW type approval regulation

This Appendix contains a draft proposal for the contents of the ADDW regulation. It is based on Task 3 of this project (see Section 5), which proposes requirements and tests for ADDW systems based on information from the literature reviews and stakeholder consultations in Tasks 1 and 2 of this project (Sections 2 to 4). The draft regulation in the Appendix was further updated according to the discussions in the European Commissions' Motor Vehicle Working Group sub-group on Driver's Behaviour Assessment Systems, up to the 3rd meeting of the sub-group on 29 November 2022.

Annex I to the draft proposal contains the main technical requirements and is in three parts:

1. Technical requirements for the advanced driver distraction warning (ADDW) systems
2. Test procedures for spot-check testing of advanced driver distraction warning (ADDW) systems by type approval authorities and technical services
3. Procedures for assessment of technical documentation by the manufacturer to be provided to the approval authorities and technical services

Items in square brackets represent values or text that is still under discussion within the sub-group. Items in curly brackets represent sections that will be completed by the Commission when the regulation is finalised. In some cases, we have suggested text based on other recent regulations and taking into account discussions in the sub-group.

{Preamble}

{Whereas:

(1) Article 6 of Regulation (EU) 2019/2144 requires motor vehicles of categories M and N to be equipped with certain advanced vehicle systems, including advanced driver distraction warning ('ADDW)' systems. It lays down in its Annex II basic requirements for the type-approval of motor vehicles with regard to the advanced driver distraction warning.

(2) Detailed rules are necessary concerning the specific test procedures and technical requirements for the type-approval of motor vehicles with regard to advanced driver distraction warning systems.

(3) A certain amount of involvement in secondary tasks, such as changing radio station or setting the air conditioning, is expected and accepted within road traffic regulations. Some may even be necessary for safety, e.g. setting the air conditioning to clear a fogging windscreen while driving. However, distraction from the driving task is recognised as a significant contributor to the number of serious and fatal road traffic injuries in Europe. A review for the European Commission estimated that driver distraction is likely to be a factor in 10% to 30% of all road collisions in Europe each year.

(4) In accordance with Article 3, point (6), of Regulation (EU) 2019/2144, the ADDW system is a system that helps the driver to continue to pay attention to the traffic situation and that warns the driver when they are distracted. Taking into account the wide variety of drivers' characteristics, the variability of seating positions, and the relative market immaturity of the existing technologies, the performance requirements for ADDW should be set at a level that is realistic and attainable. At the same time, those requirements should be technology-neutral, in order to foster development of

new technologies. Therefore, the currently proposed regulation shall focus on warning drivers in cases of sustained visual distraction. Nevertheless, the technological progress of ADDW systems, including intermittent distraction and the assessment of types of driver distraction other than visual (e.g. cognitive distraction), should be further pursued by manufacturers and taken into account for future evaluations of the regulation, in accordance with Article 14 of Regulation (EU) 2019/2144.

(5) Similarly, the Regulation should set reasonable expectations for the range of driver characteristics and seating positions for which ADDW systems should be effective. Manufacturers should provide evidence that their ADDW system is effective across the defined range of driver characteristics and seating positions.

(6) The table in Annex II to Regulation (EU) 2019/2144 containing the list of requirements referred to in Article 4(5) and Article 6(3) of that Regulation does not contain any reference to regulatory acts as regards advanced driver distraction warning systems. It is therefore necessary to introduce a reference to this Regulation in that Annex.

(7) Regulation (EU) 2019/2144 should therefore be amended accordingly.

(8) [As Regulation (EU) 2019/2144 is to apply from 6 July 2022, this Regulation should apply from the same date][2].

(9) The provisions of this Regulation are closely linked as they deal with rules concerning the specific test procedures and technical requirements for the type-approval of motor vehicles with regard to their advanced driver distraction warning systems. As a result of the rules laid down in this Regulation, it is necessary to add a reference to this Regulation in Annex II to Regulation (EU) 2019/2144. It is therefore appropriate to lay down those provisions in a single Delegated Regulation.}

{HAS ADOPTED THIS REGULATION}

{Article 1

Scope

This Regulation applies to motor vehicles of categories M and N, as defined in points (a) and (b) of Article 4(1) of Regulation (EU) 2018/858 of the European Parliament and of the Council (2).

Article 2

Technical requirements for the advanced driver distraction warning system

Technical requirements for the approval of motor vehicles with regard to the advanced driver distraction warning systems are laid down in Part 1 of Annex I.

Article 3

Procedure for spot-check testing of the advanced driver distraction warning system

Test procedure for spot-check testing of advanced driver distraction warning systems by type-approval authorities or technical services on their behalf is laid down in Part 2 of Annex I.

Article 4

[2] From 2021/1341. Will need to be updated, e.g. date of application of the regulation.

Procedure for assessment of technical documentation providing evidence on the performance of the advanced driver distraction warning system

Test procedures for assessment of technical documentation presented by the manufacturer providing evidence on the performance of the advanced driver distraction warning system are laid down in Part 3 of Annex I.

Article 5

Amendment to Regulation (EU) 2019/2144

Annex II to Regulation (EU) 2019/2144 of the European Parliament and of the Council is amended in accordance with Annex II to this Regulation.

Article 6

Entry into force and application

This Regulation shall enter into force on the twentieth day following that of its publication in the Official Journal of the European Union.

It shall apply from 7 July 2024.}

ANNEX I

PART 1

Technical requirements for the advanced driver distraction warning (ADDW) systems

1. Definitions

For the purposes of this Annex, the following definitions apply:

1.1. 'Advanced Driver Distraction Warning (ADDW)' means a system that helps the driver to continue to pay attention to the driving situation[3] and that warns the driver when he or she is distracted.

1.2. 'Visual distraction' means the driver takes their eyes off the road to engage in a secondary activity that shifts their attention away from the driving situation.

1.3. ‘Long visual distraction’ means a single, uninterrupted long-duration gaze by the driver away from the driving situation. Uninterrupted entails that the distraction monitoring system is robust against blinks and measurement dropouts.

1.4. ‘Distraction duration’ means, in case of long visual distraction, the interval in which a buffer/counter starts counting as soon as the driver is looking away from the driving situation [or attentive area] and only stops counting when the driver is looking back

[3] ‘Driving situation’ is the terminology used in the updated European Statement of Principles (EUR-Lex - 32008H0653 - EN)

towards to the driving situation [or attentive area] for an amount of time long enough to be considered not distracted anymore.

1.5. ‘Noise factors’ means elements that can affect the performance of the ADDW system, including, but not limited to, attributes, actions or events related to the driver, to the vehicle, or to the environment.

1.6. ‘Non-nominal situation’ means a situation where the ADDW system is affected by noise factors.

2. General technical requirements

2.1. An advanced driver distraction warning system shall determine when the driver’s visual attention is not directed towards the driving situation and alert the driver through the vehicle human machine interface (HMI).

2.2. The HMI should ensure that it is clear to the driver that the warning has been issued because they appear to be distracted from the driving task.

2.3. The ADDW system shall be designed to avoid or minimise system error (false positive) rate under real driving conditions.

2.4. Privacy and data protection

2.4.1. The ADDW system shall function in normal operation mode without the use of biometric information, including facial recognition, of any vehicle occupant. This requirement does not forbid the use of cameras, it forbids the identification of the person.

2.4.2. The ADDW system shall be designed in such a way that it shall only continuously record and retain data necessary for the system to function and operate within a closed-loop system.

2.4.3. Any processing of personal data shall be carried out in accordance with Union data protection law.

3. Specific technical requirements

3.1. Operational conditions for the ADDW system

3.1.1. The ADDW system shall be automatically activated above the speed of [20[4]] km/h while the vehicle is moving forward.[5]

3.1.2. It shall be possible for the driver to manually deactivate the ADDW system.

[4] Speeds above 20 km/h are associated with a rapidly increasing risk of death for a pedestrian struck by a vehicle. At 30 km/h, 5% are killed; at 50 km/h, 40% are killed; at 60 km/h, 80% are killed (Literature Review on Vehicle Travel Speeds and Pedestrian Injuries (nhtsa.gov)). An activation speed at 20 km/h therefore aligns with rapidly increasing importance of attention to the driving situation to risk for vulnerable road users.

[5] The emission of warnings by the ADDW system can be automatically deactivated when/while the vehicle has the reverse gear engaged.

3.1.3. The ADDW system shall be automatically deactivated in the situations pre-defined by the manufacturer, specifically in situations when another system takes over the [sustained] dynamic driving task, as defined in Commission Implementing Regulation (EU) 2022/1426, and is supported with an appropriate driver monitoring system[6]. The ADDW system shall be automatically reactivated as soon as the conditions that led to its automatic deactivation are no longer present.

3.1.4. The ADDW system shall keep working even under conditions in which distraction cannot be detected, but the warnings can be deactivated. The driver should be informed in a non-distracting manner that the distraction warnings are not being emitted during these bad conditions. The distraction warning emission should be automatically reactivated as soon as the conditions that led to the warnings deactivation are no longer present.

3.1.5. The emission of distraction warning of the ADDW system can be individually deactivated under conditions in which other driving assistance system are warning for an imminent danger or a critical situation, but it is not a condition for deactivation of the ADDW system. The distraction warning emission should be automatically reactivated as soon as the conditions that led to its deactivation are no longer present.

3.1.6. The ADDW system, including HMI warnings, shall be automatically and fully reinstated to normal operation mode upon each activation of the vehicle master control switch. Other automatic reinstatement conditions can be introduced and added by the vehicle manufacturer.

3.2. Environmental conditions

3.2.1. The ADDW system shall operate effectively during the day and night.

3.3. Monitoring driver distraction

3.3.1. The areas of interest, in which the driver’s gaze is to be monitored by the ADDW system, are differentiated between "distracted area" and "attentive area".

3.3.2. Based on the defined areas of interest to be monitored, two use cases for the monitoring of distraction and, when applicable, emission of distraction warnings, are defined in 3.3.2.1 and 3.3.2.2.

3.3.2.1. For the use case 1, the “distracted area” is bounded by the following zones :

(a) A plane, 30° downward from the driver’s eye point, defined as:

- For M2, M3, N2 and N3 category vehicles not based on an M1 platform, eye point E2 as defined in the draft UN

[6] A driver monitoring system is required for ALKS in UN Regulation No.157 and is expected to be required for other automated driving functions that involve handback of control to a human driver. Regulation (EU) 2022/1426 applies to fully automated vehicles and therefore does not require a driver monitoring system.

Regulation 1xx on Direct Vision (ECE_TRANS_WP.29_2022_140E.pdf).

- For M1 and N1 category vehicles, and for M2 and N2 category vehicles based on an M1 platform, the eye point shall be the centre of the eyellipse defined in ISO 4513 (2003) Road vehicle — Visibility, method for establishment of eyellipses for driver's eye location.
- The lateral extent of the "distracted area" is defined by the intersection of this plane and the interior side of the vehicle, projected horizontally rearward along the interior side of the vehicle.
- All interior locations below these boundaries are considered to be within the distracted area.

(b) A vertical plane passing through the driver's eye point and perpendicular to the longitudinal axis of the vehicle as defined by Appendix 2 to Annex 1 of the Consolidated Resolution on the Construction of Vehicles (R.E.3).

(c) The roof of the vehicle is excluded from the distracted zone. The edges of the distracted zone are considered a "grey zone" which uncertainty is +/- [2]° as seen from the eye point of the driver.

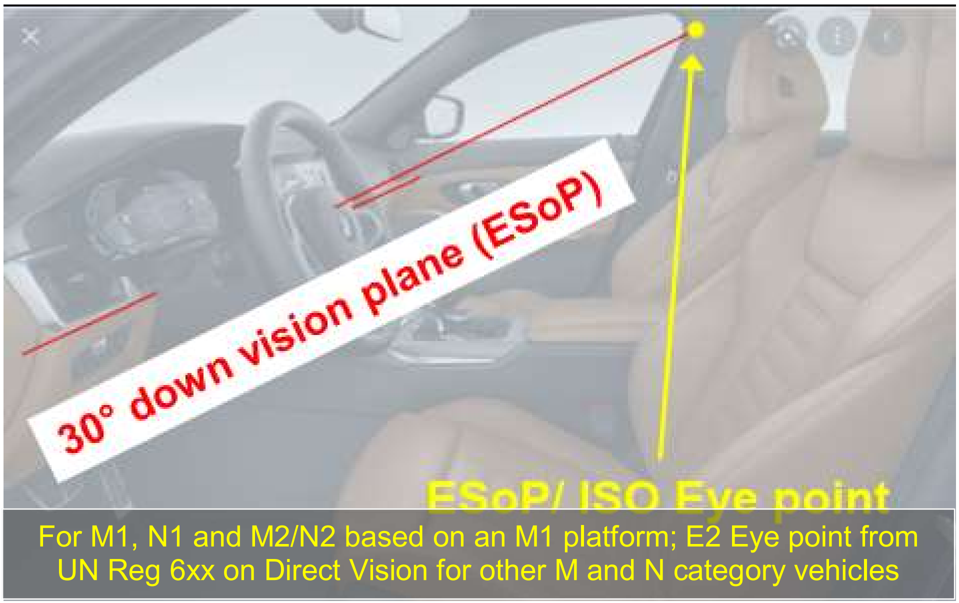

Figure 1: Illustration of 30° downward vision plane for an M1-category vehicle (based on a figure provided by ACEA)

3.3.2.2. For the use case 2, the "attentive area" is defined as the overlap of the following zones :

(a) The area of the windscreen;

(b) any front compartment window visible by the driver, which stops at the orthogonal projection of back of the driver-seat position with the left-front passenger side and of the right-front passenger side (whichever fits best for the cabin considered);

3.3.2.3. The roof of the vehicle is excluded from the “attentive area".

3.3.2.4. The edges of the attentive zone are considered a “grey zone” which uncertainty is +/- [2]° as seen from the eye point of the driver.

3.3.3. Warning triggers of the use cases covered by the ADDW system

3.3.3.1. For the use case 1, a warning shall be provided to the driver as soon as both of the following conditions are verified:

(a) vehicle’s speed at [50] km/h or above;

(b) the gaze of the driver in the distracted area lasts for a maximum time threshold of [3.5] seconds in the nominal situation. Non-nominal situations specified in [OEM documentation defined in Part 3], can extend the maximum nominal situation’s time threshold by an additional [1.5] seconds.

3.3.3.2. For the use case 2, a warning shall be provided to the driver as soon as both of the following conditions are verified:

(a) vehicle’s speed at [20] km/h or above;

(b) the gaze leaves the attentive area for a maximum time threshold of [6] seconds in the nominal situation. Non-nominal situations specified in [OEM documentation paragraph], can extend the maximum nominal situation’s time threshold by an additional [1.5] seconds.

3.3.3.3. The warning of use case 2 can be identical to the warning of use case 1, and shall not be triggered if the warning of use case 1 is on-going.

3.3.3.4. The vehicle manufacturer can choose to set a lower minimum speed requirement in 3.3.3.1. and 3.3.3.2

3.4. Human Machine Interface requirements

3.4.1. Warning nature

3.4.1.1. A visual warning shall be used by the ADDW to inform the driver and an acoustic and/or a haptic warning shall be used by the ADDW system to alert the driver as soon as possible after occurrence of the trigger condition defined in point 3.3.3 cease to be verified.

3.4.1.2. If the driver fails to comply to a distraction warning emission, the system may cascade and intensify the warning until the trigger conditions defined in point 3.3.3. cease to be verified[7].

3.4.2. Visual warning

3.4.2.1. The visual warning shall be located so as to be readily visible and recognisable in daylight and at night-time by the driver and distinguishable from other alerts.

3.4.2.2. The visual warning shall be a steady or flashing indication (e.g. tell-tale, pop-up message, etc.).

3.4.2.3. Any new symbols developed for the purpose of ADDW visual warning are recommended to be designed according to the design principles laid out in ISO 2575:2021.[8].

3.4.2.4. The contrast of the symbol with the background in sun light, twilight and night conditions are recommended to be in accordance with ISO 15008:2017.

3.4.2.5. The following visual alert and background colour combinations should not be used: red/green; yellow/blue; yellow/red; red/violet.

3.4.3. Acoustic warning

3.4.3.1. The acoustic warning shall be easily recognised by the driver.

3.4.3.2. A majority of the acoustic warning shall fall within the frequency spectrum of 200-8000 Hz and amplitude range of 50-90 dB.

3.4.3.3. If speech alerts are utilised, the vocabulary used shall be consistent with any text used as part of the visual alert.

3.4.3.4. The audible portion of the alert shall last for at least the duration that allows the driver to understand it.

3.4.4. Haptic warning

3.4.4.1. The haptic warning shall be noticeable by the driver and be provided directly or indirectly through any interface expected to attract the attention of the driver back to the driving task.

3.4.4.2. Vibration frequencies of 100 Hz to 300 Hz should be used[9].

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[7] Suggestion to make it clear that the manufacturer may choose to escalate the warning.

[8] ISO 2575 :2021 does not have an attention or distraction warning symbol - the paragraph is simply to note that the symbol should be in a similar style and not conflict with those already defined, to minimise the risk that the driver misinterprets the symbol.

[9] ISO/TR 16352:2005, p70. Note that the standard gives a justification for the recommended range as being comfortable of vehicle occupants and unlikely to be obscured by vibration of the vehicle induced by the road surface.

3.5. ADDW failure warning

3.5.1. A constant visual failure warning signal (e.g. warning reflecting the relevant Diagnostic Trouble Codes (DTC) for the system, tell-tale, pop-up message, etc.) shall be provided when there is a failure detected in the ADDW system as a result of which the ADDW system does not meet the requirements of this Annex.

3.5.1.1. Temporary visual failure warning signal can be used as complimentary information to the constant optical failure warning signal.

3.5.2. There shall not be an appreciable time interval between each ADDW self-check, and subsequently there shall not be a delay in displaying the failure warning signal, in the case of an electrically detectable failure.

3.5.3. The system shall recognise a non-temporary sensor obscuration event and the failure warning signal as laid down in point 3.5.1. shall be displayed. A sensor obscuration event covers at minimum the event when no light is measured by the sensor when the ADDW is activated.

3.5.4. Upon detection of a temporary non-electrical failure condition (e.g. temporary obscuration such as caused by sun glare), the failure warning signal as laid down in point 3.5.1.1. may be displayed.

3.5.5. Failures that activate the warning signal mentioned in point 3.5.1., but which are not detected under static conditions, shall be retained upon detection and continue to be displayed from start-up of the vehicle after each activation of the vehicle master control switch, for as long as the failure or defect persists.

3.6. Provisions for periodic roadworthiness tests

3.6.1. For the purpose of periodic roadworthiness tests of vehicles, it shall be possible to verify the following features of the ADDW system:

3.6.1.1. Its correct operational status, by visible observation of the failure warning signal status following the activation of the vehicle master control switch and any bulb check. Where the failure warning signal is displayed in a common space (the area on which two or more information functions/symbols may be displayed, but not simultaneously), it must be checked first that the common space is functional prior to the failure warning signal status check;

3.6.1.2. Its correct functionality and the software integrity, by the use of an electronic vehicle interface, such as the one laid down in point I.(14) of Annex III of Directive 2014/45/EU of the European Parliament and of the Council (1), where the technical characteristics of the vehicle allow for it and the necessary data is made available. Manufacturers shall ensure to make available the technical information for the use of the electronic vehicle interface in accordance with Article 6 of Commission Implementing Regulation (EU) 2019/621 (2).

3.6.2. At the time of type-approval, the means to protect against simple unauthorised modification of the operation of the failure warning signal chosen by the manufacturer shall be confidentially outlined in the assessment of the technical documentation under Part 3. Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status of the ADDW system is available.

PART 2

Test procedures for spot-check testing of advanced driver distraction warning (ADDW) systems by type approval authorities and technical services

1. General requirements for spot-check testing

1.1. Spot-check testing shall be conducted under conditions to ensure that the ADDW system is operational and able to display all the warnings. The conditions can be simulated to facilitate the testing.

1.2. Testing apparatus

1.2.1. Vehicle considered for the type approval.

1.2.2. Equipment that can determine the speed of the test vehicle (real or simulated) to [±0.1] km/h to verify the fulfilment of the requirement of activation speed defined under point 3.1.7. within the Part 1 of this Annex.

1.2.3. Use a minimum of 2 supplementary cameras that are located such as to provide an overview of the test conditions defined in point TBD.

1.2.4. [Other devices necessary for measuring.]

1.3. Testing sample

1.3.1. Testing shall take place with at least [one] nominal test driver in the driver's seat.

1.3.2. The test driver[s] shall present the following attributes:

1.3.2.1. Stature that meets either:

(a) AF25 to AM75; or

(b) Position that allows the driver's eyes, with their normal seat adjustment for driving, to be at the eye point defined in 3.3.1.1. ±100 mm longitudinally and ±50 mm vertically[10].

1.3.2.2. No glasses or head accessory (e.g. hat, mask).

1.3.2.3. No facial hair other than eyebrows.

1.3.2.4. The vehicle manufacturer can choose to forgo or extend the list of attributes listed in 1.3.2.1, 1.3.2.2, and 1.3.2.3 for the test driver[s].

1.4. Gaze fixation points

[10] This ensures that the driver can control the vehicle properly in case testing is performed on a test track.

1.4.1. The appropriate location of the fixation points to be tested shall be proposed by the manufacturer according to the [geometrical]/[design] constraints of the vehicle cabin considered for the type approval.

1.4.2. The selection of the fixation points to be tested needs to ensure repeatability and reproducibility (between Manufacturers, Suppliers, Testing Services and in-service monitoring test laboratories).

1.4.3. Spot-check testing shall include at least [1] fixation point located in all of the following regions:

1.4.3.1. Driver's left knee

1.4.3.2. Driver's right knee

1.4.3.3. Driver's lap[11]

1.4.3.4. Passenger's footwell

1.4.3.5. [Passenger's seat surface]

1.4.3.6. Glove box

1.4.3.7. Air vents to the immediate left side of the driver[12]

1.4.3.8. Air vents to the immediate right side of the driver

1.4.3.9. Instrument cluster [no HUD, no display crossing the base of the windscreen]

1.4.3.10. Steering wheel, when equipped with buttons for interacting with the infotainment or driver assistance systems

1.4.3.11. Gear shifter, when present

1.4.3.12. Heating, ventilation and air conditioning (HVAC) controls, when present

1.4.3.13. Infotainment display, when present

1.4.3.14. Centre console (forward zone near dashboard panel, when not covered by any other fixation point described above)

1.4.3.15. Driver's side door area located outside the attentive and outside the distracted areas.

1.4.3.16. Passenger's side door area located outside the attentive and outside the distracted areas.

1.5. Testing velocities

[11] In Euro NCAP, associated frequently with phone use.

[12] Common mounting position for aftermarket phone mounts.

1.5.1. All gaze fixation points shall be tested, at least, once at [20] km/h and once at [50] km/h[13].

1.6. Environmental conditions

1.6.1. Testing should be carried out once in day conditions and once in night conditions, specified, as follows, according to the chosen testing environment:

1.6.1.1. In case of testing executed on a test track road environment:

(a) Day: testing shall start after sunrise and before sunset;

(b) Night: testing shall start after sunset and before sunrise.

1.6.1.2. In case of testing executed on a simulated road environment:

(a) Day: conditions diffuse with ambient light (ISO 15008: 2017);

(b) Night: condition of low ambient illumination under which the adaptation level of the driver is mainly influenced by the portion of the road ahead covered by the vehicle's own headlights and surrounding street lights, and display and instrument brightness (ISO 15008: 2017).

1.7. Definition of temporal thresholds for warnings:

1.7.1. Primary threshold for emitting distraction warning:
According to the definition of long-distraction, warnings should be triggered according to the requirements specified for both use cases 1 and 2 in Part 1 of this Annex, considering the gaze fixation points defined in point 1.5.3. to be the monitoring parameters.

1.7.2. Further temporal thresholds:
In case the ADDW system under testing employs a repetition or escalation strategy when the driver fails to comply with the primary distraction warning, all gaze fixation points defined in point 1.5.3 shall also be tested the verification of the requirements regarding such additional distraction warnings.

2. Procedure for spot-check testing

2.1. [In case spot-check testing is performed with more than one test driver, the same procedure is to be followed by all test drivers.]

2.2. The test driver under testing shall be instructed on the functionality of the ADDW system, according to the information provided by the manufacturer in the documentation package supplied to the type approval authorities and technical services in accordance with Part 3.

[13] Note that it is not expected that a warning would be generated at each test location. The pass/fail is to confirm whether the absence of a warning is normal (pass) or not (fail).

2.3. If the ADDW system should be calibrated for a period of time after its initialisation, calibration procedures shall take place during baseline driving situation, with no parallel distracting activities.

2.4. Testing of gaze fixation points

2.4.1. Testing procedure of detecting occurrences of long visual distraction shall begin when both conditions are met:

(a) The vehicle registers the velocity to be tested, according to point 1.6.

(b) the ADDW system assesses the driver as not distracted for at least [60] seconds.

2.4.2. The sequence in which the fixation points are tested can be decided by the authority responsible for the type approval.

2.4.3. All fixation points described under point 1.5.3 shall be tested.

2.4.4. The test driver should maintain a relatively stable body posture when measurements are being made.

2.4.5. Measurements of each individual gaze fixation point shall be obtained as follows:

2.4.5.1. The start of each measurement is triggered as soon as the test driver is assessed by the system as not distracted for at least [15 seconds][14].

The vehicle manufacturer can provide information via the documentation to define the key behaviour/activities which will not be recognised as distracted actions for the purpose of this test.

2.4.5.2. The test driver is instructed to shift their gaze to one of the fixation points.

2.4.5.3. The test driver maintains their gaze focused on the fixation point until a warning is emitted.

2.4.5.4. After the measurement of each individual fixation point, it is required that the driver is assessed by the system as not distracted for at least [15 seconds] before moving on to the next fixation point.

3. Test results

3.1. Measurements shall be treated as false negative (FAIL) results upon occurrence of at least one of the following:

3.1.1. The test driver had their gaze focused on a fixation point located inside the distracted zone defined under point 3.3.2.1. within the Part 1 of this Annex

[14] To ensure that the warning triggers for both use cases 1 and 2 have been exceeded.

and a distraction warning is not emitted within 4 seconds (which includes 0.5 second for an uncertainty buffer).

3.1.2. The test driver had their gaze focused on a fixation point located outside the attentive zone defined under point 3.3.2.2. within the Part 1 of this Annex and a distraction warning is not emitted within 6.5 seconds (which includes 0.5 second for an uncertainty buffer)

4. Acceptance criteria

4.1. The goal of the spot-check testing is the verification of the fulfilment of all technical requirements for ADDW systems.

Fail-criterion:
The ADDW system is considered to have failed the spot-check testing when amongst all gaze fixation points defined in point 1.5.3., tested according to the procedure described in point 2, one or more result in a false negative event [for all test drivers].

Pass-criterion:
When the fail criterion is not met.

PART 3[15]

Procedures for assessment of technical documentation by the manufacturer to be provided to the approval authorities and technical services

1. Documentation package

1.1. The manufacturer shall provide the approval authority and technical service a documentation package containing evidence of the performance of the ADDW system.

1.1.1. The documentation package shall cover the description of the system functionality, in accordance with point 1.2., as well as the validation process of the system, in accordance with point 1.3.

1.1.2. Taking into account the relative immaturity of existing technologies and the manufacturers' limited market experience with ADDW systems, where applicable, the manufacturer shall provide a description of the limitations of the system. These limitations can be, but are not limited to, driver-, vehicle- or environment-related noise factors, which may cause the system to have its performance degraded.

1.1.3. Within the described limitations of the system, the manufacturer shall provide information on assessments of the performance of the ADDW system based on repeated tests [with a broad enough range of participants], describing how the system is able to monitor driver distraction and emit the corresponding warnings.

1.1.4. The documentation package shall be provided to the type approval authority and technical service prior to the execution of the spot-check testing prescribed in point 2 of Part 2 of this Annex.

1.2. ADDW system functionality

1.2.1. The documentation package detailing how the ADDW system functions shall include:

(a) an explanation of the system's activation, reactivation and deactivation functions, including the associated vehicle speed ranges;

(b) a list of all the system inputs containing all the metrics adopted for measuring driver distraction;

(c) a description of how the metrics function and monitor driving behaviour, including, if applicable, the relationship between primary and secondary/fall-back metrics;

(d) a description of the triggers in driving behaviour being monitored by the system;

(e) a description (textual description, illustration, technical drawing or any other sufficient means) of the area within the vehicle cabin that the

[15] Note that Part 3 uses the definition of areas from Commission v2.0 of the draft regulation (Circabc (europa.eu))

system considers to be areas 1, 2, and 3, as defined in point 3.3.2. of Part 1, for assessing driver distraction;

(f) the zone(s) delimiting the placement of each of the gaze fixation points for spot-check testing within the vehicle cabin, as defined in point 1.4.3 of Part 2;

(g) a document detailing the components of the system's HMI as well as their intended functionality. This includes:

(g.1) evidence of compliance with the ADDW HMI requirements (point 3.4. of Part 1), and justifications if the manufacturer chooses not to follow the recommendations listed in points 3.4.2.3., 3.4.2.4., 3.4.2.5., 3.4.3.2, and 3.4.4.2. of Part 1.

(g.2) if adopted, a description of the strategy for repetition, cascading or escalation of the warning emission for the cases in which the driver fails to comply with the emitted distraction warnings.

(h) a list with the description of the system limitations, accompanied by evidence on how the system's performance is affected within those limitations. For example evidence could include how occurrences outside the range of the system limitations are handled, e.g. the driver is informed that the system is not operational or that an intervention procedure by other assistance systems of the vehicle will take place.

1.2.2. The list of system inputs shall only be provided to the approval authority or the technical service for the purpose of verifying the ADDW system for the type approval.

1.2.3. [The list of any secondary metrics will not be passed on from the technical service to the approval authority.]

1.3. ADDW system validation

1.3.1. The documentation package detailing how the ADDW system has been validated within the range of the limitations listed in point 1.2.1. subpoint (h) shall include:

(a) evidence about the system's performance collected in repeated tests conducted with human drivers, including the information on the number and demographics of test participants assessed, comprising:

(a.1) inclusionary and exclusionary criteria that were used when selecting participants, ensuring that the system has been deemed effective, within its limitation ranges, for a representative part of the driving population in Europe;

(a.2) a statement on the adequacy of the participants in respect of the targeted demography for the vehicle (for example, participants with a valid license to drive the vehicle on which the ADDW system is installed)

(b) a description of the test conditions assessed, including information on test repeatability and reproducibility;

(c) [evidence that the system works effectively in weather and lighting[16] conditions not limiting the system's operation;]

(d) a description of the full test methodology used to assess the effectiveness of the system and the rationale behind the selection of the methodology. The description of the full test methodology shall include:

(d.1) information on how the measured data were analysed and collated to assess the effectiveness of the ADDW system;

(d.2) evidence that the distraction threshold used in the validation testing is equivalent to the warning triggers defined in point 3.3.2. of Part 1 of this Annex;

(d.3) evidence that the ADDW system distraction warnings are effectively emitted once the distraction thresholds are met;

(d.4) [if assessed, information on how test drivers' compliance with the distraction warnings was evaluated to verify the effectiveness of the warnings in reducing or mitigating driver distraction.]

(e) a description of the analysis technique used both to determine the range of the system limitations defined by the manufacturer and to demonstrate the system's effectiveness within that range. Examples of such techniques can be:

(e.1) samples of training data evidencing how [a varied range of] noise factors influence/degrade the system's performance in monitoring driver distraction efficiently and effectively (e.g. accuracy, repeatability, false-positive rates) and how the system handles such disturbances;

(e.2) usability metrics (e.g., usability, efficiency, efficacy, learnability, false-positive rates) extracted from evaluations of the system with [a wide enough/comprehensive range of] test drivers, and the reasoning behind the adopted acceptability ranges.

(f) an analysis and description of the results.

(f.1) The manufacturer shall provide all statistical relevant data related to the validation tests, allowing the test authority to assess the tests' quality.

1.3.2. If validation testing was performed in a driving simulator, the manufacturer shall document its limitations with regard to real-world open-road testing for the purpose of testing the ADDW system. Such documentation shall include:

(a) a comparison of primary input data used for the ADDW system from the simulator and primary input data from the vehicle in real conditions; and

(b) an analysis of the validity of the simulated validation's results.

1.3.3. [If the validation was performed as part of research to establish compliance with the technical requirements or to improve the system's performance for type approval, the documentation shall contain information on the parameters, including acceptance ranges, used by the manufacturers to

[16] An example of varying lighting conditions would be the vehicle driving on a street with constant change between shade and sun (e.g. sequence of trees or buildings).

assure the type approval authorities that the ADDW system performs as intended under the regulation.]

2. Assessment by the technical service of the ADDW system documentation package and test report

2.1. The technical service shall analyse the body of evidence provided by the manufacturer in accordance with the documentation package detailed in point 1 and thus ensure that the ADDW system installed in the vehicle candidate for type-approval:

(a) fulfils the technical criteria laid out in Part 1 of this Annex; and

(b) has passed the spot-check testing laid out in Part 2 of this Annex.

ANNEX II

Amendment to Regulation (EU) 2019/2144

{To be updated by the Commission as necessary.}

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