Report on Advanced Driver Distraction Warning systems

1. Introduction

The work in this report was carried out to prepare and support the development of technical annexes for Advanced Driver Distraction Warning (ADDW) systems for vehicle categories M_1, M_2, M_3, N_1, N_2 and N_3. ADDW is defined as a system capable of recognising the driver's level of visual attention to the traffic situation and warning the driver when distracted. This work falls within DDR (Driver Distraction and Drowsiness Recognition) safety measure forming part of the European General Safety Regulation.

The European Commission estimates between 10% and 30% of crashes in Europe are caused by road user distraction and 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 (European Commission, 2019;NHTSA, 2009). These figures are likely to be underestimates given the difficulty in determining contributory factors after a crash has occurred (Kinnear and Stevens, 2015).

Driver distraction is the diversion of attention from activities critical for safe driving to a competing activity. The competing activity comes in a variety of forms and can originate from sources both inside and outside the vehicle. Research into the effects of driver distraction using naturalistic driving data found that drivers engaged in secondary tasks about 23.5% of their driving time, which significantly increases their collision risk (Klauer *et al.*, 2010). Thus, reducing distraction to improve driver's attention to activities required for safe driving is expected to reduce the collision risk.

There are four types of distraction, where often drivers experience more than one type of distraction at the same time:

- Visual distraction: Driver takes their eyes off the road to engage in a secondary activity not related to the driving task.
- Auditory distraction: Noise diverts drivers' attention from activities needed for safe driving.
- Manual distraction: Driver takes one or both hands off the vehicle controls to attend to an activity not required for safe driving.
- Cognitive distraction: Driver's mind is engaged with other tasks not required for safe driving.

Driving is primarily a visual task, thus it is not surprising that visual distraction is often referred to as being especially dangerous for safe driving performance – large and frequent lane deviations, abrupt steering movements, slow reaction time to vehicle braking events and safety critical events, failure to detect hazards etc. (Klauer *et al.*, 2006). This was corroborated by the European Commission (2015): "Activities that cause visual distraction (e.g. looking away from the road during texting) appear to be the most dangerous, as estimated by odds ratios". Therefore, to prevent visual distraction-related crashes, Regulation (EU) 2019/2144 mandates the implementation of Advanced Driver Distraction Warning (ADDW) systems on M_1, M_2, M_3, N_1, N_2 and N_3 vehicles from July 2022 (new types) and July 2024 (all new vehicles). Specifically, the system must assess the driver's visual attentive state by detecting and monitoring the driver's gaze direction and be capable of determining when the driver is visually distracted. This aim of this report is to develop a preliminary 'table of contents' for the future ADDW technical annexes.

2. METHOD

During the development of the potential list of items that will be regulated in relation to the implementation and performance of automotive ADDW systems within Europe, TRL undertook the following tasks:

1. A review of the indicators and metrics of visual distraction, and a rapid review of visual distraction thresholds
2. A review of current national and international standards
3. Expert stakeholder engagement

These tasks were undertaken to gather information on the current state of the art within the literature and automotive market. The aim was to identify facets of ADDW systems that should be regulated in a technology-agnostic manner and to highlight the elements requiring further research. For more details on the methodology, please refer to Annex 2.

3. RESULTS

This section of the report summarises the findings from the literature reviews and stakeholder engagements. The full results are detailed in Annex 3 of this report.

3.1. Literature review

3.1.1. Indicators and metrics of visual distraction

The most accurate way to monitor the driver visual attentive state is by directly tracking the eyes. However, there are situations where the eyes cannot be tracked due to eye occlusion. This can be overcome by indirectly tracking the eyes by monitoring coarse visual behaviour metrics (i.e. head movement or facial orientation). However, this provides a rough estimate of eye gaze and can provide an incorrect interpretation of eye gaze direction. A solution to these technological limitations is to use both types of metrics to determine the driver's eye gaze direction. For example, eye movement can be the primary metric and when the eyes are not visible, coarse visual behaviour metrics can be used to estimate the drivers gaze direction (Kim and Shin, 2014).

3.1.2. Visual distraction thresholds

It appears that glances away from the road exceeding two seconds significantly increases crash risk (Klauer *et al.*, 2010). With regards to an established Glance Duration[1] threshold, two recommendations were found: 1.6 seconds and 2 seconds, where the two-second duration is the most widely recognised glance duration threshold (European Commission, 2015;Klauer *et al.*, 2006;Klauer *et al.*, 2010). It should be noted that both of these values are based on a driver interacting with an in-vehicle device or mobile phone, which usually results in a driver's eyes gazing downwards and not having the road in their peripheral vision (i.e. no visual awareness of the road – please refer to Section 2.4.1.1 for more details). The review also revealed that drivers commonly glance frequently between the driving task and a distracting task. For this type of distraction behaviour, the following measurements were identified: Percentage Road Centre (PRC)[2],

[1] Glance Duration: time from the moment at which the direction of gaze moves towards a target to the moment it moves away from it (ISO 15007-1:2014)

[2] PRC: percentage of time within 1 minute that the gaze falls within a road centre area of 8° radius from road centre

Total Eyes-Off Road (TEOR)[3], Total Glance Duration[4] and Glance Frequency[5]. One threshold was identified for TEOR from one source: TEOR glance duration greater than two seconds in a six-second window (Klauer *et al.*, 2006). For Total Glance Duration, two contradictory thresholds were identified: a distracting task should be completed within 15 seconds (Klauer *et al.*, 2010) and 20 seconds (AAM, 2006) of total glance duration. Further research to validate the TEOR threshold and to establish thresholds for the other measurements identified as being sensitive to detecting visual distraction should be conducted. As this was a rapid literature review, it is recommended that an in-depth analysis of distraction thresholds should be conducted in the next phase of this research project.

3.1.3. Current standards and test procedures

One test procedure assessing the effectiveness of distraction monitoring systems was found in the literature. This procedure was developed by NHTSA, where full details of the assessment procedure and development thereof can be found in the following reports:

1. Distraction Detection and Mitigation Through Driver Feedback (Lee *et al.*, 2013)
2. Distraction Detection and Mitigation Through Driver Feedback: Appendices (Lee *et al.*, 2013b)

A summary of the assessment procedure can be found in Annex 3.1.3.

3.2. Stakeholder engagement

To gather information on current ADDW systems, TRL engaged with 14 stakeholders, including seven OEMs, six Tier 1 suppliers and Euro NCAP. Of these, seven had developed ADDW systems to date, where all Tier 1 suppliers have an ADDW system on the market, one OEM has a system on the market, three OEMs have a system in-development and three OEMs do not have a system on the market or in development.

The main findings from the engagements was that the technology to monitor the driver’s eyes, head and/or facial feature(s) exists (Tier 1 supplier). However, the integration of this technology with other components (i.e. hardware and software) to create a reliable and robust ADDW system has been highlighted as a challenge by OEMs, resulting in many ADDW systems still being in development (i.e. undesirable amount of false-positive and false-negative alerts by the system).

The key findings regarding the function, validation, effectiveness and HMI of ADDW systems are detailed in Annex 3.2.

4. DISCUSSION

4.1. Readiness of ADDW systems

The technology to monitor a driver’s eyes, face and/or head whilst driving exists. This technology, which is normally in the form of a driver-facing camera embedded in the steering wheel or instrument cluster, has the ability to determine or estimate the driver’s gaze direction by tracking one or more facial features (including the head), and thus is

[3] TEOR glance duration: the summation of all glance durations to areas of interest other than the road scene ahead during a condition, task, subtask or sub-subtask (ISO 15007-1:2014)

[4] Total glance duration: summation of all glance durations to an area of interest (or set of related Areas of Interest) during a condition, task, subtask or sub-subtask (ISO 15007-1:2014)

[5] Glance Frequency: number of glances to a target within a pre-defined time period, or during a predefined task, where each glance is separated by at least one glance to a different target

able to determine or estimate whether the driver is looking forward at the road ahead or has their attention diverted somewhere else.

This technology is one component of an ADDW system, where manufacturers are responsible for taking this piece of technology and creating an ADDW system with it (i.e. integrating it into the vehicle, developing algorithms to detect distraction and non-distraction events, optimising the interaction with the vehicle and driver, interacting with the driver when needed etc). From the stakeholder engagement it became clear that many manufacturers are still developing their ADDW systems, where several do not yet have a system in development. The manufacturers that are still developing their ADDW systems have encountered several challenges which have extended their development period. The two main issues, which need to be overcome in order for the systems to be deemed effective and implemented into vehicles, are the reliability and robustness of the systems. This was corroborated by Euro NCAP who stated that manufacturers need more time to become familiar with the technology before it can be regulated.

With regards to reliability of the system, manufacturers expressed that their systems are displaying an undesirable number of:

- False positive alerts, which negatively impacts customer experience and trust in the system (i.e. will ignore or turn it off), as well as potentially causing distraction instead of preventing it; and
- False negative alerts which defeats the purpose of the system and negatively effects driver’s trust in the system (i.e. not alerting a driver when they are distracted).

The false positive and false negative alerts are mainly attributed to manufacturers’ lack of experience with ADDW systems, and as such 1) are still learning how best to integrate the technology with other components needed for an ADDW system, 2) are still developing and refining their algorithms to accurately detect and alert a distracted driver and 3) are still optimising the interaction between the system and driver, as well as with the vehicle. This is explained further in Section 2.4.1.1. With regards to robustness of the system, the technology is subject to several limitations which occasionally prevent the system from operating effectively. These limitations, which are dependent on the system and visual distraction indicator being monitored, prevent the driver’s gaze from being continuously monitored, and hence negatively impact the detection of a visual distraction event. These limitations are discussed further in Section 2.4.1.2.

4.1.1. Lack of experience

From our engagements, we noted discrepancies between Tier 1 suppliers and manufacturers (OEMs) with regards to ADDW system readiness. This may be because there is a difference between the technology being able to monitor the driver visual attentive state and determining/estimating where the driver is gazing, which Tier 1 suppliers are responsible for and have claimed to have achieved, and an ADDW system being able to determine and alert the driver when they are visually distracted, which manufacturers are responsible for and are still attempting to achieve (i.e. the system is configurable). The most common factors related to false positive and false negative alerts are highlighted below.

4.1.1.1. Understanding the complex nature of eye glance behaviour whilst driving

One of the main challenges causing false positive and false negative alerts surrounds the difficulty in determining whether or not someone is visually distracted. The reason for this is the complex nature of eye glance behaviour whilst driving. A driver is not simply visually distracted when their eyes are removed from the forward roadway. They may have removed their eyes to perform an activity related to the driving task such as checking mirrors and blind spots, reading road signs, scanning the windscreen and gazing out of side windows to assess the environment or traffic situation, looking at the instrument cluster or centre console etc. As a driver needs to gaze at several targets inside and outside of the vehicle to perform the driving task safely, the system needs to establish exactly where the driver is gazing and determine whether the gaze is related to the driving task or not, which is extremely challenging. It should be noted, that depending on the situation, gazing at a target relevant for driving for an extended period of time (e.g. looking in the passenger-side wing mirror ten seconds), especially when the vehicle is in motion, may still be considered dangerous, emphasizing the need for established and appropriate distraction thresholds (i.e. glance duration threshold > 2 seconds)

Some systems have attempted to do this by defining multiple AoI such as the mirrors, instrument cluster and Forward FoV etc. and have coded these AoI as relevant for driving, meaning that when a driver gazes at one of these areas, the system will not deem the driver as being visually distracted. However, even with these areas defined, issues are still arising. For example, if monitoring a coarse visual behaviour metric, the system may not accurately estimate the gaze direction of the driver, resulting in a false positive or false negative warning. This can be overcome by monitoring the eyes; however, there are several technological limitations affecting the continuous detection of the eyes (Section 2.4.1.2). Until these limitations are overcome, can this indicator be continuously monitored to determine, at all times, whether the driver is visually distracted or not.

A few systems have incorporated secondary metrics such as indicators, ADAS and the external environment etc. into their algorithm to understand the driver's intentions, and hence assist in determining whether a gaze is related to the driving task or not. For example, a driver gazing frequently or for a long duration towards the offside window may be interpreted as a distraction event (e.g. engaging with a passenger). However, the driver may also be assessing the traffic situation when stopped at a junction waiting to turn onto a busy perpendicular road (i.e. waiting for a gap). In this situation, information about the turn signals and vehicle speed will assist the system in determining the driver's intentions and infer that the driver is not distracted. This method is a recent development and manufacturers require more time to refine and validate the method, where some manufacturers are not yet at this stage of development.

4.1.1.2. Understanding the breadth and limitation of human vision

Another factor influencing the number of false positive alerts, which stakeholders are still trying to understand and incorporate into their systems, is the breadth and limitations of human vision. Human vision is divided into three ranges: foveal range, extrafoveal range and peripheral vision range. Vision is most detailed in the foveal range, which extends approximately one eccentricity angle[6] for the line of sight (Ludin and Zaimovic, 2015). The following range, known as the extrafoveal range, extends up to about 30 degrees eccentricity angle, whereas the last range, the peripheral visual range, extends from 30 degrees eccentricity angle up to 100°-110° horizontally (away from the nose towards the ear), 60° up and 70°-75° down (Ludin and Zaimovic, 2015) Figure 3. For both eyes, the combined visual field is 130°-135° vertically and 200°-220° horizontally (Ludin and Zaimovic, 2015).

[6] Degrees of visual angle from the centre of the eye

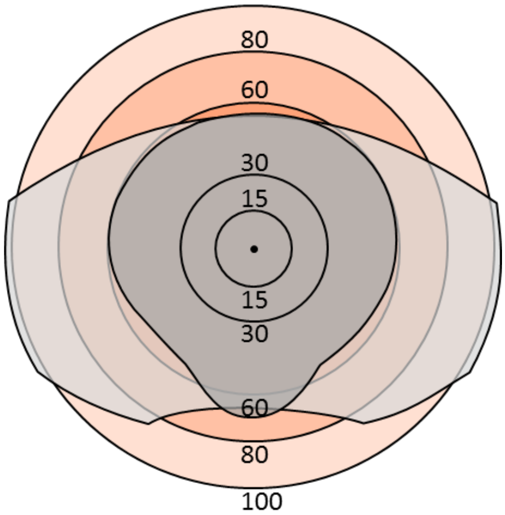

Figure 3. The normal FoV in degrees of visual angle. The light grey areas are visible to only one eye (the right light grey area to the right eye and vice versa) while the dark grey area marks the binocular FoV (adapted from Lundin and Zaimovic, 2015)

The main factor impacting the reliability of the systems is the breadth of driver's peripheral vision, particularly horizontal peripheral vision. This is due to the fact that a driver is able to monitor the periphery of their visual field even when focusing their primary attention on its centre. For example, a driver may gaze outside of the Forward FoV (e.g. centre/nearside windscreen) and still have a visual awareness of the road ahead and traffic environment. In this situation, the driver will be deemed distracted and will be alerted to revert their attention back to activities relevant for driving. However, a driver may not agree with this alert, especially if driving on an empty straight motorway in daylight, resulting in potential driver annoyance and distrust in the system leading to the driver turning the system off. To overcome this, some stakeholders suggested that the sensitivity and distraction thresholds of the system should be dependent on eccentricity angle from the target to the Forward FoV (i.e. the system would be more sensitive and thresholds lower when the driver has no visual awareness of the road – outside the combined visual field: 130°-135° vertically and 200°-220° horizontally).

Whether these approaches are appropriate with regards to safety is unknown and should be investigated further in the next phase of the research project:

1. How far from the forward FoV can a driver accurately monitor their horizontal and vertical peripheral vision with regards to road safety and does road type or traffic flow influence this?
2. Should distraction thresholds or sensitivity of a system depend on the eccentricity angle from the target to the Forward FoV?

Whether the findings concur with the stakeholder's feedback or not, requirements should be established around these factors to ensure road safety.

4.1.1.3. Visual behaviours indicative of distraction and technological limitations

One thing noted from the stakeholder engagements was the fact that the majority of systems were only using long glance duration at a target not relevant for driving as a trigger behaviour. However, distraction whilst driving is more complex than this. Indeed, a visually distracted driver may remove their eyes from the driving task to engage in a secondary activity for a long duration, but more frequently, a driver will divide their attention between the two activities by frequently shifting their gaze between the driving task and secondary task. The latter behaviour, which is a strong indication of visual distraction, is more challenging to monitor, because glance direction needs to be precisely monitored and the driver's behaviour (i.e. intentions) or context needs to be understood (e.g. short glances between the mirror and road whilst trying to get from one lane to another on a busy motorway versus short glances between a mobile device and road over the same period of time). In the current state, these systems are not yet capable of doing this reliably. However, the technology, as well as familiarity, is advancing rapidly and it is expected that in time, these issues will be overcome, and this visual distraction trigger behaviour can be monitored.

4.1.1.4. Distraction thresholds

Another factor highlighted by stakeholders as negatively impacting the reliability and robustness of ADDW systems was the difficulty in establishing appropriate distraction thresholds. The manufacturers stated that there is insufficient guidance in the literature on distraction thresholds for in-vehicle distraction monitoring systems. This was corroborated by the rapid literature review of distraction thresholds, which revealed limited guidance on distraction thresholds for Type 2, which is defined as frequently shifting gaze between the driving task and distracting task. For Type 1, defined as a single long glance to a target not relevant for driving, the most widely recognised guidance in the literature was that a single glance should not exceed a two-second duration. This guidance was based on instances when a driver engages with an in-vehicle device or mobile phone. In these situations, the driver is visually, cognitively and manually distracted (potentially auditory as well), where their eyes are generally gazing downwards with no visual awareness of the road (i.e. upward peripheral vision is the most limiting at 60°). The problem arises in situations where the driver has visual awareness of the road and is only experiencing one form of distraction (i.e. visual distraction only). In these instances, a driver may not agree with a visual distraction alert being presented and perceive it as a false-positive alert resulting in negative customer experience and increased likelihood of the system being turned off. Thus, either 1) manufacturers need more time to understand the nature of distraction and to establish appropriate thresholds, which can be used for the future development of ADDW systems or 2) more research or an in-depth review of literature on distraction thresholds for in-vehicle distraction driver monitoring systems needs to be conducted to establish the distraction thresholds for the regulation, which manufacturers need to comply with.

4.1.2. Limitations of the technology

ADDW technology relies on the detection and recognition of the eyes, head and/or facial features to monitor the driver's visual attentive state. Depending on the system, if one or more of these indicators are occluded, the system is unable to operate effectively. This is especially the case for systems monitoring only one visual distraction indicator (e.g. the eyes only). The following factors were identified in the literature review and from the stakeholder engagements as potentially occluding the eyes, head or facial features:

- Eye obstruction: glasses (incl. sunlight reflection on glasses), sunglasses, eye make-up, eye shape, eye squinting and large head rotation
- Facial obstruction (excluding eyes): facial hair, masks, hand over mouth - yawning, long hair and hair covering the driver's face
- Head obstruction: hair style (i.e. long hair) and headwear (i.e. hats, caps and scarfs etc.)
- General obstruction: varying real-world illumination conditions and direct sunlight

These limitations are dependent on the system, for example, most stakeholders mentioned several limitations, whereas a few expressed zero limitations. Moreover, the limitations were inconsistent between systems due to 1) the technology being different and 2) monitoring different visual distraction indicators. Some systems monitoring more than one indicator of visual distraction claimed to have overcome these limitations. This was generally done by fusing eye and head movement data[7]. For example, the system will primarily monitor the eyes to determine the driver's gaze direction and if the eyes become occluded, the system starts monitoring head movement to estimate the driver's gaze until the eyes are no longer occluded.

Even with this limitation highlighted above, it should be noted, that it is better to have a system monitoring a driver's gaze most or some of the time (alerting them that they are distracted), versus not being able to monitor or detect it at all, so long as it does not cause distraction and negatively impact the driver's trust in the system (i.e. turning it off).

4.1.3. Summary

The technology to monitor the driver's visual attentive state exists. Manufacturers are responsible for taking this technology, which tracks the driver eyes, head and/or face by a driver-facing camera and creating a reliable and robust ADDW system with it. Currently, manufacturers are still developing their ADDW systems and have encountered several challenges which have extended their development period. In order to develop a technology neutral regulation, sufficient information on the functions, operations and validation testing of different systems needs to be gathered and understood. This can only be done once systems are further along in the development period or on the market. It is envisaged that over time and with technological advancements the issues highlighted above are expected to be overcome – something that also needs to be understood to develop a technology neutral regulation. This was corroborated by Euro NCAP who stated that OEMs need more time, potentially two more years, to become familiar with these systems before they can become regulated.

4.2. Developing type-approval tests and regulatory requirements

Due to the readiness state of ADDW systems, it is not possible to develop a draft technical annex for ADDW type-approval. Nevertheless, from the engagements and literature review, items that should be considered for the future ADDW regulation were identified. These items, which relate to the system function, validation testing and HMI, are discussed below, where the elements requiring further research and consideration are highlighted.

4.2.1. ADDW system function

4.2.1.1. Tool

An ADDW system must be capable of recognising the driver's level of visual attention to the traffic situation. In order to do this, the drivers visual attentive state needs to be continuously monitored. All stakeholders did this by continuously monitoring the driver using a driver-facing camera, commonly embedded into the instrument cluster or steering wheel. No other tools were identified in this study, including the discussions surrounding the future of ADDW systems. However, over time another tool or physiological indicator may be developed or identified, and should be accommodated by the regulation. The key is to ensure that the system is monitoring the driver directly, instead of the vehicle, to determine whether the driver is visually distracted. Therefore, a requirement needs to be established around this stating that the tool being used needs to continuously and directly monitor the driver to determine their visual attentive state

[7] Fusion: fuses gaze direction and head direction to evaluate direction situations where the driver's eyes are not visible

i.e. driver-facing camera. If another tool is used, the manufacturers need to supply evidence of the effectiveness of the tool in monitoring the driver's visual attentive state.

4.2.1.2. Indicators of visual distraction

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 (i.e. indirectly assessing gaze direction by tracking the movement of the head or facial feature(s)). There is a strong correlation between head and eye movement; however, during driving, eye movement may not be accompanied by head movement, and vice versa, resulting in the estimate being incorrect, leading to the misinterpretation of the driver's visual attentive state. An incorrect interpretation could lead to 1) false positive alerts likely resulting in driver annoyance, driver distrust (i.e. turn off the system) and/or driver distraction and 2) false-negative alerts resulting in the driver not being warned when they are visually distracted, which negates the purpose of the system and could lead to an undesirable event, which could have been avoided, as well as negatively impacting driver trust of the system.

The following indicators were identified in the stakeholder engagements: eye movement, head movement and facial feature(s) movement. Systems used either one or more indicators to assess the driver's visual state (i.e. gaze direction). The systems that did not monitor eye movement stated it was due to the technical limitation of eye tracking technology not always being able to track the eye (i.e. eye occlusion). Similar limitations were mentioned for systems monitoring coarse visual behaviour indicators (i.e. head or face occlusion). There was no consistency amongst stakeholders regarding the limitations of the systems. Some systems monitoring the same visual distraction indicator mentioned limitations which other systems have already overcome, and vice versa. For example, one stakeholder will state glasses are a limitation occasionally occluding the eyes whereas make-up does not, and another will state that eye make-up is a limitation occasionally occluding the eyes whereas glasses do not.

Some systems are overcoming these challenges by monitoring more than one visual distraction indicator (i.e. fusing eye gaze and head gaze direction data). These systems primarily monitor eye movement to determine eye gaze direction and when the eyes are occluded, the system will use head movement to estimate eye gaze direction. This system works well for scenarios where the eyes are occluded for a brief period, like when a driver performs a large head rotation (e.g. blind spot check). The concern with this type of system is about continuous eye occlusion (e.g. IR sunglasses). In this scenario, eye gaze direction will be estimated from head movement for the period that the eyes are occluded which could be the length of the driving task (e.g. several hours). This estimate could be incorrect, potentially alerting the driver they are distracted when they are not, or not alerting the driver when they are distracted, both of which need to be avoided.

As coarse visual behaviour indicators are unreliable at accurately estimating the driver's gaze direction and eye gaze technology is subject to several limitations preventing the continuous detection of the eyes, TRL suggests a requirement should be established stating that the system should primarily infer eye gaze direction from directly monitoring eye movement and that coarse visual behaviour indicators can be used as secondary indicators for when the eyes are occluded. It is recommended that manufacturers provide evidence or information on how the system accounts for instances where eye occlusion occurs, as well as for head or facial feature(s) occlusion if being monitored by the system. This will ensure systems are robust and reliable.

4.2.1.3. Trigger behaviours, measurements and thresholds

When a driver is visually distracted and engaged in a secondary task, they tend to either glance away from the road for an extended period (Type 1) or, most commonly, shift their gaze between the two tasks frequently until the secondary task is completed (Type 2). From the stakeholder engagements, all systems monitored the first type of visual distraction behaviour, whereas a few also monitored the latter type of visual distraction behaviour. The reason some systems were not monitoring the latter was due to technological limitations (i.e. the system needs to accurately and reliably detect eye gaze direction) and/or the system still being in development, meaning the manufacturer has not yet explored the option (i.e. can only do this once other issues are resolved and when further along in the development lifecycle). If the technological limitations can be overcome, a requirement should be established stating that the system shall be able to detect the two visual distraction behaviours highlighted above (i.e. trigger behaviours). Moreover, the assessment procedure should be designed in such a way that both types are tested. If these technological limitations cannot be overcome (i.e. systems cannot reliably detect the second type of visual distraction behaviour), the regulation cannot require manufacturers to monitor that type of behaviour. This can be determined by conducting further research and by reengaging stakeholders once they have progressed further in the development of their system or when more systems are on the market. It should be noted that Type 1 can be mandated prior to Type 2, whereas Type 2 can be mandated once the technology is capable of monitoring this type of distraction behaviour reliably and effectively.

Thresholds need to be established for each trigger behaviour being monitored by the system. The most recognised threshold for Type 1 is that a driver should not glance away from the road for more than two seconds. It should be noted that a 1.6 second threshold has also been suggested by some authors. There was no consistency in the threshold used by stakeholders for single glance duration. This was mainly due to the fact that the two second (and 1.6 second) threshold is related to how long a driver can look away from the road when interacting with an in-vehicle HMI or device (e.g. mobile phone). Stakeholders suggested that this threshold is not appropriate for certain driving situations due to the breadth of human's peripheral vision (i.e. a driver may be visually aware of the road when the driver is gazing out of the windscreen away from the Forward FoV) and results in an undesirable number of false positive alerts. Thus, it was suggested that the sensitivity of the threshold is dependent on the driver's visual awareness of the road (i.e. sensitivity and threshold dependent on the eccentricity angle from the target to the centre of the road). Moreover, stakeholders suggested that the sensitivity of the threshold is also dependent on the driving context (i.e. time of day, road type, traffic, drowsiness level etc.). Whether these approaches are appropriate or safe needs to be determined in order to establish this threshold for ADDW systems.

Measurements identified to measure Type 2 visual distraction behaviour included: TEOR, PRC, Total Glance Duration and Glancy Frequency. One threshold was identified for TEOR from one source: TEOR glance duration greater than two seconds in a six-second window (Klauer *et al.*, 2006). For total glance duration, different guidance was provided by the SAE and AAM: a distracting task should be completed within 15 and 20 seconds of total glance duration respectively. If this behaviour were to be one of the trigger behaviours required to be monitored by the system, 1) the most sensitive measurement(s) to monitor this type of behaviour should be determined and 2) thresholds for these measurements need to be established, as well as validated. If more than one measurement is identified, it is recommended that the regulation states these with their corresponding thresholds, and then requires a system to measure at least one of the measurements. The same applies for Type 1 distraction behaviour.

4.2.1.4. Areas of interest

All systems had a minimum of two AoI defined. This was either classified as Forward FoV and Distracted FoV, or as FoV relevant for driving and FoV not relevant for driving. The FoV relevant for driving generally consisted of multiple AoI such as mirrors, instrument cluster and Forward FoV etc. Some systems also specified other areas within the vehicle such as side windows and windscreen, where secondary inputs such as indicators were used to assess whether the AoI was relevant for driving in real-time. Stakeholders stated that specifying multiple AoI and making use of secondary inputs made their systems more robust and reliable. For the majority of systems, the size of the Forward FoV was dependent on vehicle speed, where the Forward FoV was smaller at higher speeds than at lower speeds. Some stakeholders stated that one of the reasons for this was due to the driver attention zone being wider in urban driving environment compared to motorway driving environments. This means that some systems would allow more head movement in urban environments (i.e. wider Forward FoV), but shorter time duration before the warning, whereas, in a motorway environment, the system would allow less head movement (i.e. narrower FoV), but a longer time before a warning would be considered.

A requirement should be established around the minimum number of AoIs that need to be defined, along with a definition of these AoIs. This could simply require manufacturers at minimum to define the Forward FoV and Distracted FoV (anywhere outside the Forward FoV), as this will ensure that systems are monitoring when the driver takes their eyes off the road, which is the simplest means of monitoring visual distraction. To ensure consistency amongst systems, it is recommended that the size of the Forward FoV is specified and that this is done for different speed ranges if deemed acceptable. To establish these, further research (including a standards review) and stakeholder engagements are needed to 1) determine the appropriate Forward FoV size and 2) to understand the relationship between driving speed and Forward FoV.

4.2.1.5. Secondary metrics

Some stakeholders suggested incorporating secondary metrics into their algorithm to make their systems more robust and reliable. These metrics assist the system in determining 1) whether an AoI is relevant for driving in real-time, 2) the intentions of the driver and 3) the sensitivity or distraction thresholds in real-time. These metrics can be broadly categorised into two groups: vehicle control metrics (e.g. indicators, wipers, ADAS etc.) and external environmental metrics (e.g. weather, time of day, presence of other vehicles or objects). It is recommended that a requirement is placed around the inclusion of secondary metrics, allowing them to be incorporated into algorithms, so long as evidence is provided that the metric is aiding the effectiveness of the system in detecting visual distraction.

4.2.1.6. Other potential requirements

Due to the small number of systems on the market, there were certain aspects of ADDW systems which TRL was unable to gather information on and for which requirements need to be established. In order to establish these requirements, manufacturers with systems on the market should be reengaged on the following ADDW system functions:

- Activation speed: the minimum requirements around the system activation speed needs to be established
- Time-to-activation: the minimum time-to-activation for ADDW systems needs to be established
- Road type: the road types on which the system shall effectively work need to be established (i.e. urban, rural and motorway). Ideally, the system shall be active on all road types; however, it was pointed out in the engagements that systems are not as robust on urban roads compared to rural roads and motorways due to

a driver's attention zone being wider in urban environment – resulting in more gaze shifts (linked to Forward FoV size potentially being dependent on vehicle speed, See Section 2.4.2.1: Area of Interest). More information is needed to clarify this, especially as this may be overcome with the advancements in and experience with ADDW technology.

- Weather: the system shall work effectively in all weather conditions.
- Activation, recycling and deactivation: requirements need to be established around 1) when the system shall be active, 2) whether the system shall restart or continue monitoring each time the vehicle is started and 3) whether the driver shall be able to deactivate the system.

4.2.2. ADDW assessment procedure

All systems which had undergone validation testing used human participants, where each participant was required to either perform a number of distracting tasks or certain movements or behaviours indicative of distracted driving (i.e. eyes off the forward road for more than two seconds). The system's effectiveness was determined by the amount of correct or incorrect visual distraction alerts: high true positive and high true negative rate, and low false negative and low false positive rate (i.e. sensitivity and specificity rating). There was no consistency amongst stakeholders on the true positive and true negative rate that needs to be achieved by a system to be deemed effective at monitoring visual distraction.

All systems were validated on real roads, where a few systems were tested in a simulator or in a static environment prior to the on-road trials. There was no consistency in the sample size or demographic of participants used to validate the systems. Moreover, there was no consistency in the number and type of conditions assessed. The conditions identified in the stakeholder engagements can be broadly categorised into two groups: environmental factors (e.g. time of day, weather, lighting etc.) and facial obstruction factors (e.g. facial hair, mask, make-up, glasses, headwear, hair length and style etc.).

From the review of national and international standards, only one test procedure, developed by NHTSA, was identified for testing the effectiveness of in-vehicle distraction monitoring systems. In contrast to the stakeholders, this assessment procedure is required to be conducted in a driving simulator. The assessment procedure involves the participants performing distracting tasks, as well as normal driving (not distracted), in a simulated motorway, urban and rural environment. Depending on the environment, several driving scenarios were assessed such as merging onto a motorway, driving on a rural road at night-time and navigating a green light on an urban road. Similar to the stakeholders, the effectiveness of the system was based on the true positive, true negative, false positive and false negative rates. To ensure participants were distracted by the distracting task, NHTSA developed an incentive system[8] which encouraged participants to fully engage in the secondary activity, and hence, allowing themselves to be distracted.

Recommendations for the ADDW assessment procedure:

An ADDW system must be capable of recognising the driver's level of visual attention to the traffic situation. This is done by directly monitoring and assessing the visual state of the driver whilst driving. Therefore, to validate an ADDW system in detecting the driver's eyes, head and/or facial features, human participants are required. Moreover, similarly to NHTSA, to ensure the system can determine whether a driver is visually distracted or

[8] Participants are informed that their performance on the distracting tasks will be assessed, where the experimenter informs the driver of their cumulative score throughout the experiment, presenting them with a total score out of 100 at the end of the experiment.

not, the participants should perform drives with distracting tasks and drives with no distracting tasks (i.e. normal driving conditions). The distracting tasks should be designed in such a way that all trigger behaviours, and corresponding thresholds, specified in the regulations are assessed. For example: Type 1 is defined as glancing away from the road for an extended period of time. If the threshold for this was to be set at 2 seconds, for example, a distraction task should be designed in such a way that a driver will need to remove their eyes off the road for more than two seconds to complete the task.

Similar to NHTSA, it is advised that the effectiveness of ADDW systems is tested and validated in a controlled and safe environment. The reason for this is that 1) driver distraction is strongly linked to accident risk and 2) manufacturers have expressed that systems are not yet sufficiently robust or reliable resulting in an undesirable number of false positive and false negative alerts, which, if tested on the road, could potentially result in an undesirable event. Thus, a requirement should be established stating that the assessment procedure shall be conducted in a driving simulator. The driving simulator needs to reflect and represent real world driving conditions; thus, it is important to ensure there are minimum requirements established around the simulator specifications (e.g. high-fidelity, motion specifications, yet-to-be-determined screen resolution, number of projector screens etc.).

Ideally, the system should work effectively on all road types (i.e. urban, rural and motorway). If this were the case, the assessment procedure should include this, where minimum requirements surrounding the three environments should be specified (i.e. traffic flow, number of lanes, curvature of the road, road layout, other road users, road infrastructure etc.). This ensure that the assessment procedure reflects, so far as possible, real world driving conditions (i.e. results need to be transferable) and it ensures the development of a standardised robust assessment procedure, which can be applied universally. If minimum requirements are not established for the environments, a manufacturer, for example, can test the system on a three-lane empty and straight motorway, which is not a true reflection of a motorway driving environment. ADDW systems should also work effectively in the day and at night, so these conditions should also be assessed in the assessment procedure. It is also recommended that an incentive system, similar to NHTSA's, is developed to encourage drivers to fully engage in the distracting task.

It is recommended that eye movement (eye tracking), driving performance and vehicle control data, independent of the system, are collected during the testing. This data will assist in the interpretation of the system's data, and hence, validation of the system. For example, a driver may receive a visual distraction alert during a baseline drive, and eye tracking data can determine whether the driver was actually distracted. In contrast, if a driver does not receive a visual distraction alert during a distracting task, the eye tracking data can be used to determine whether the participant exceeded the threshold or not.

A literature review conducted by NHTSA (Lee *et al.*, 2013b) lists a number of metrics that are promising for detecting visual distraction and may be able to be used to validate ADDW systems. Only the metrics which had a large effect size are detailed below (Lee *et al.*, 2013b). For the full list, please refer to Table 1 in 'Distraction Detection and Mitigation Through Driver Feedback: Appendices (Lee *et al.*, 2013b).

- Vehicle control metrics: Steering Entropy, Steering Wheel Reversal Rate, Brake Reaction Time and Throttle Hold.
- Driving performance metrics: Standard Deviation (SD) of Lane Position and SD of Speed
- Eye tracking metrics: Mean/SD Glance Frequency, Mean/SD Percentage Glance Duration Off Road > 2 seconds, Percentage of Gaze on Road Centre, Mean/SD Percentage of Gaze Off the Road and Blink Rate

In order to establish which metrics should be used to validate ADDW systems, a review of literature needs to be conducted detailing the potential metrics sensitive to visual distraction. During the development of the ADDW assessment procedure, data should be collected for each of these metrics for each distraction tasks developed. The metrics which reveal sensitivity to the distraction tasks (i.e. significant difference between the distraction and non-distraction conditions) should be the ones used to validate ADDW systems. It should be noted that the metrics may be dependent on the distraction task. Therefore, if the assessment procedure includes several distracting tasks, different metrics could be required to be measured for different distraction tasks. If none of the metrics are sensitive to one or more of the distraction tasks, a new distraction task examining the same type of visual distraction behaviour needs to be developed.

Evidence suggests that eye gaze direction inferred from coarse visual behaviour metrics can be misinterpreted. If the regulation allows a system to monitor these behaviour metrics, the assessment procedure should assess the accuracy of the system in determining or predicting eye gaze direction. A similar approach can be taken to that of NHTSA, which presented one of the distracting tasks between 15 and 30 degrees of the driver’s vertical and horizontal viewing positions. According to NHTSA, in this position, it is expected that some participants will only move their eyes to perform the task, whereas others may move both their eyes and head (Lee *et al.*, 2013b).

From the stakeholder engagements and literature review, it became apparent that ADDW systems are subject to several limitations. These limitations result in the system not being able to continuously monitor the driver’s visual state due to eye, head and/or facial feature(s) occlusion. Ideally, depending on the visual distraction indicators specified in the regulation and being used by a system, these limiting factors should be assessed in the assessment procedure. This may only be done for factors which impact a large portion of the European driving population. For example: if the eyes are monitored, the assessment procedure should assess the effect of glasses on distraction detection. Alternatively, the regulation could state the conditions where the system should be able to operate effectively (i.e. in varying real-world illumination conditions, in all weather conditions, direct sunlight, when drivers are wearing glasses, sunglasses or headwear, or has facial hair etc.) and request manufacturers to provide evidence that their system is able to operate effectively under these conditions. It is recommended that manufacturers should only be requested to supply evidence on the factors limiting the detection of the visual distraction indicator being monitored by their system.

To ensure the results from validation testing are accurate, a sufficient number of participants need to be tested, where the participant should reflect, so far as possible, the European driving population (e.g. include males and females of varying ages etc.). Thus, it is recommended that requirements are established around the sample size and demographics (i.e. gender, age and ethnicity etc.). The sample size can be determined by a statistician using a sample size calculation software after the assessment procedure is developed.

This study identified system effectiveness to be generally determined by a system’s true positive, true negative, false positive and false negative rates. It is recommended that ADDW system effectiveness is determined by the same or similar approach. This is especially due to the fact that stakeholders have highlighted their concerns with the high false positive and false negative rates of their systems. To ensure adequate effectiveness and standardisation amongst ADDW systems, it is recommended that an acceptance criterion, similar to Driver Drowsiness and Attention Warning (DDAW) acceptance criterion (Section 1.3.2 and 1.4.3), is developed, which ADDW systems need to achieve in order to be deemed effective. For example:

- Step 1: Establish ADDW sensitivity and specificity thresholds
- Step 2: Calculate the sensitivity and specificity of the system for each participant

- Step 3: If [95%] of the sample size has sensitivity and specificity values equal to or greater than the thresholds, the system shall be deemed effective OR if the average sensitivity or specificity of sample is equal to or greater than the threshold with minimal variance between participants, the ADDW system shall be deemed effective.

The assessment procedure developed to assess the effectiveness of ADDW systems can only be established once the system requirements are established. This is due to the assessment procedure being dependent on the following factors:

- The visual distraction indicators which can be monitored by ADDW systems
- The trigger behaviours specified, and thresholds established
- The road types on which the system shall operate (i.e. urban, rural and motorway), and
- The conditions under which the system shall be able to operate effectively etc.

Only a small number of manufacturers have an ADDW system on the market. As such, limited information was gathered from manufacturers on the system's operations and validation testing. It is advised that after more systems are brought to the market, manufacturers are reengaged about the operations and functions of the system, as well as the validation testing procedures. This will assist in the development of the requirements and procedures, as well as ensuring the assessment procedure is technology-neutral and can be standardised across all ADDW systems. Once the assessment procedure is developed, it should be validated prior to becoming regulated due to the cost of testing, use of human participants and complex nature of distraction (i.e. effectiveness of the assessment procedure).

4.2.3. ADDW system HMI

The minimum performance requirements for the human machine interface (HMI) for ADDW systems need to be established and included in the regulation. The HMI is a vital component of ADDW systems. If the system does not interact with the driver in an appropriate manner or does not inform the driver that they are distracted effectively, the driver may ignore the alert, potentially resulting in collisions. Additionally, if the alert is not designed appropriately, or if the system is not sufficiently robust (high false positive rate), it may cause distraction or driver annoyance.

From the engagements, it was noted that at a minimum, drivers are or will be presented with a visual alert when visually distracted. Being presented with only a visual alert is insufficient, as the driver will likely not see the alert because they are visually engaged in another activity. The alert needs to be able to attract the attention of the driver and encourage them to revert their attention back to the traffic situation. This can be done by using a different human sense, such as an auditory or haptic alert, to attract their attention in conjunction with a visual alert informing them of their state.

Some systems only alerted the driver that they were visually distracted when they were at risk of having an imminent collision. This means that if there were no vehicles or obstacles in close proximity to the vehicle, the driver would be allowed to engage in a secondary activity and take their eyes off the road for an indefinite period of time, which TRL believes is inappropriate. Thus, it should be emphasised in the regulation that the warning type needs to be a visual distraction warning, rather than a collision warning. It is expected that the requirements and assessment procedure established for this regulation would prevent such a system being classed as an ADDW system.

Due to the small number of systems on the market and Tier 1 suppliers not developing the HMIs of ADDW systems, minimal information was gathered on ADDW HMI functions and operations. It is advised that further engagements take place surrounding the HMI of ADDW systems once manufacturers have developed this component of their system.

This will ensure a technology neutral regulation and ensure consistency amongst systems.

The following regulations, along with further stakeholder engagements, should be used to develop the minimum performance requirements for the HMI of ADDW systems:

- NHTSA Human Factors Design Guidance for Driver-Vehicle Interfaces
- ISO 12204: 2012 – Road vehicles – Ergonomic aspects of transport information and control systems – Introduction to integrating safety critical and time critical warning signals
- 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

5. Proposed items for ADDW type approval regulation

This section provides a summary of the draft proposal for the contents of the ADDW regulation under the headings of scope, definitions, system requirements, HMI requirements, data management, verification and tests, and assessment procedure requirements.

5.1. Scope

This regulation applies to the approval of vehicles of Category M_1, M_2, M_3, N_1, N_2 and N_3 with regards to an on-board system

a) Capable of recognising the driver's level of visual attention to the traffic situation, and

b) Warning the driver when distracted.

5.2. Definitions

Once the regulation has been finalised, required definitions for the ADDW regulation need to be established. This can be achieved by collating information from the European Commission, literature, stakeholders and Euro NCAP, or drafted by the consultant finalising the regulation.

Example definitions:

- 'Advanced Driver Distraction Warning' means a system capable to assist the driver in keeping attention to the traffic situation and warning the driver when distracted
- 'Visual distraction' means the driver takes their eyes off the road to engage in a secondary activity not related to the driving task.
- 'Human Machine Interface (HMI)' means the aggregate of means by which drivers interact with their vehicle or any mobile tools. In this case specifically the way by which drivers can interface with the ADDW system.
- 'Visual attentive state' means…

- ‘Eye movement’ means…
- ‘Eye gaze direction’ means…
- ‘Coarse visual behaviour metrics’ means…
- ‘Secondary metrics’ means…
- ‘Vehicle control metrics’ means…
- ‘External environmental metrics’ means…
- ‘Trigger behaviour’ means…
- ‘Glance Duration’ means…
- ‘Glance Frequency’ means…
- etc.

5.3. System requirements

5.3.1. System

The system shall directly and continuously monitor the driver’s visual attentive state to assess their visual attention to the traffic situation (e.g. driver-facing camera).

If a camera-based system is not used, manufacturers shall provide evidence in the documentation package of the effectiveness of the tool in monitoring and assessing the driver’s visual attentive state.

5.3.2. Primary metrics

[The system shall directly monitor eye movement to determine eye gaze direction. Coarse visual behaviour metrics can be used in conjunction with the primary input or as a substitute in instances of eye occlusion (e.g. head or facial feature(s) movement).

If the system does not monitor eye movement as the primary input, the manufacturers shall provide evidence in the documentation package of the system’s primary input in accurately determining eye gaze direction.]

5.3.3. Secondary metrics

Systems are allowed to utilise secondary metrics, such as vehicle control metrics and external environmental metrics, to aid the reliability and robustness of the system.

[These metrics will be disclosed in the documentation package, where the Technical Service will assess whether these metrics aid the system in detecting visually distracted drivers.]

5.3.4. Trigger behaviours

The system shall monitor [Type 1 and Type 2] trigger behaviours.

If an alternative trigger behaviour is monitored by the system, the manufacturer shall provide evidence of the relationship between the trigger behaviour and driver visual distraction behaviour.

[If both types of distraction identified in this study are required to be monitored by a system, the following can be stated:

The system shall monitor the following visual distraction trigger behaviours:

1. Driver’s glance duration to a target in the Distracted AoI exceeds the glance duration threshold

2. Driver frequently glances to a target in the Distracted AoI exceeding the yet-to-be-determined threshold

   More research is needed to establish what the most appropriate measurement(s) are to monitor the latter visual distraction behaviour (e.g. TEOR, PRC and glance frequency etc.)]

If Type 2 cannot be reliably monitored by a sufficient number of ADDW systems by 2024 (expected date for ADDW systems to be mandated), it is recommended that the system shall at a minimum monitor Type 1 as a trigger behaviour, where Type 2 can be a recommendation. If systems are able to monitor Type 2 in the future, the regulation should be updated mandating both types of distraction behaviours as trigger behaviours for ADDW systems. If this were the case, the assessment procedure should initially only test for Type 1 trigger behaviour, and when Type 2 is made mandatory, the assessment procedure should be updated to test for this type of distraction behaviour.

5.3.5. Visual behaviour metrics and thresholds

The system shall monitor a yet-to-be-determined number of visual behaviour metrics (e.g. Glance Duration, Glance Frequency, TEOR and PRC etc.), and alert the driver when the threshold for at least one of them is met.

These metrics and corresponding thresholds can only be determined after the trigger behaviour requirement is established. If both trigger behaviours mentioned above become a requirement for a system, Glance Duration should be recommended for Type 1, where more research needs to be conducted to determine the most sensitive and appropriate measurement(s) for Type 2. To establish the thresholds for these metrics, more research and stakeholder engagements are required.

[Example:

The system shall measure Glance Duration and at least one other visual behaviour metric below and alert the driver when the threshold for at least one of them is met:

- Glance duration: [2 second threshold]
- Glance frequency: yet-to-be determined Glance Frequency threshold
- TEOR: yet-to-be determined TEOR threshold
- PRC: yet-to-be-determined threshold
- etc.]

5.3.6. Area of Interest

The system shall at a minimum have the Forward FoV and Distracted FoV defined. Information including the definitions and descriptions of the AoIs shall be presented in a document for the Technical Service to review.

5.3.7. Forward Field of View

The Forward FoV will have the following yet-to-be-determined dimensions when travelling at yet-to-be-determined vehicle speeds, with the centre of the Forward FOV being in line with the driver’s eyes.

To determine the dimensions for the Forward FoV, it is recommended that 1) a literature search into human vision and driving is conducted, 2) a review of national and international standards relating to human vision and driving is conducted and 3) stakeholders are reengaged about their defined FoV. Moreover, research needs to be conducted to determine whether the size of the Forward FoV should be dependent on vehicle speed or road type.

5.3.8. Activation speed

The system shall activate between a yet-to-be determined speed range.

This requirement is dependent on the road type requirement.

5.3.9. Time-to-activation

The system shall activate and initiate driver monitoring immediately after the ignition is cycled and when the vehicle is travelling between the yet-to-be determined activation speed and yet-to-be-determined road type(s).

5.3.10. Activation, Recycling and Deactivation

<u>Activation</u>

[The system shall automatically activate each time the ignition is cycled.]

<u>Recycling</u>

[The system shall reinitiate driver monitoring each time the ignition is cycled.]

<u>Deactivation</u>

[The driver 'shall or shall not' be able to deactivate the system.

- If deactivated, the system shall reactivate on the following ignition cycle
- The driver shall be able to deactivate or silence the HMI warning alert, which shall reinitiate each time the ignition is cycled.]

5.3.11. Environmental Conditions

<u>Time of day</u>

The system shall work effectively during the day and night. Evidence of this shall be presented to the Technical Service for review.

<u>Weather</u>

The system shall work effectively in all weather conditions. Evidence of this shall be presented to the Technical Service for review.

<u>Road type</u>

At a minimum, the system shall work effectively on yet-to-be-determined road types.

This requirement must establish which road types the system shall work effectively on (e.g. motorways, expressways, rural roads and urban roads etc.). Ideally the system shall work effectively on all road types, excluding gravel roads, however this may not be technically feasible, particularly for urban roads. To establish this requirement, it is recommended that manufacturers are reengaged once their systems are further developed.

5.3.12. Conditions whereby the system shall operate effectively

[The system shall operate effectively under the following conditions:

- When the driver is wearing glasses (potentially also sunglasses)
- In-varying real-world illumination conditions
- In all weather conditions
- On all specified road types
- When the system is exposed to direct sunlight

- Etc.
- If a system is monitoring coarse visual behaviour metrics:
    - When the driver has facial hair occluding their face
    - When the driver is wearing headwear
    - etc.

Evidence shall be provided in the documentation package on the system's ability to operate effectively in these conditions]

For this requirement, it is recommended that eye, head and facial occlusion conditions represent a large portion of the European driving population.

5.4. Human machine interface requirements

Minimum performance requirements for the HMI need to be established. This should include alert type and the way in which the HMI interacts with the driver. Some potential requirements are highlighted below:

- [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 suppress audible warnings, but such action shall not at the same time suppress system functions other than audible warnings
- The alert shall be representative of the level of visual distraction
- The driver shall be able to deactivate the alert]

5.5. Data management

ADDW systems shall be designed in such a way that they shall only continuously record and retain data necessary for the system to function and operate within the closed loop system. Furthermore, this data shall not be accessible or made available to any third parties and shall only be held for the length of time for which it holds direct relevance to assessing the driver's current visual attentive state.

5.6. Verification of tests

The technical service employed to verify the ADDW system on behalf of the European Commission shall verify the information provided in the documentation package by testing a selection of aspects of the declared function of the system. The elements audited will be chosen at the discretion of the technical service. If possible, the minimum number of elements to be audited should be determined and specified in the regulation.

5.7. Assessment procedure requirements

The assessment procedure to assess the effectiveness of ADDW systems can only be established once the system requirements are established. This is due to the assessment procedure being dependent on the following factors:

- The visual distraction indicators which can be monitored by ADDW systems
- The trigger behaviours specified, and thresholds established
- The road type in which the system shall operate (i.e. urban, rural and motorway), and
- The conditions under which the system shall be able to operate effectively etc.

It is imperative that the developed assessment procedure is validated due to the high costs of testing, the use of human participants and the complexity of visual distraction behaviour (i.e. ensuring the assessment procedure is effective).

5.7.1. Sample size and demographics

The sample size can be determined by a statistician using a sample size calculation once the requirements, assessment procedure and acceptance criterion are established.

The sample should be representative of the European driving population consisting of males and females distributed equally across age ranges. The drivers should hold a valid driver licence for the category vehicle being assessed and should have a yet-to-be-determined driving experience level.

5.7.2. Distracting tasks

The distracting tasks should be designed in such a way that all trigger behaviours, and corresponding thresholds, specified in the regulations are assessed. If coarse visual behaviour indicators are allowed to be a primary input for ADDW systems, it is recommended that one of the distraction tasks is positioned between 15 and 30 degrees of the driver's vertical and horizontal viewing positions.

5.7.3. Baseline tasks

The driver shall perform drives reflective of normal driving conditions. These drives should be assessed on all road types. These drives will be used to assess the true negative and false negative rates of the system.

5.7.4. Incentive system

It is recommended that an incentive system is developed that encourages participants to fully engage in the secondary task, allowing themselves to become distracted.

5.7.5. Dependent variables

It is recommended that eye tracking, driving performance and vehicle control data, independent of the ADDW system, are collected during the testing. This will assist in the interpretation of the data and validation of the systems. For example, a driver may receive a visual distraction alert during a baseline drive, and eye tracking data can determine whether the driver was distracted at that point. In contrast, if a driver does not receive a visual distraction alert during a distracting task, the eye tracking data can be used to determine whether the participant exceeded the threshold or not.

Metrics that are promising for detecting visual distraction include:

- Vehicle control metrics: Steering Entropy, Steering Wheel Reversal Rate, Brake Reaction Time and Throttle Hold.
- Driving performance metrics: Standard Deviation (SD) of Lane Position and SD of Speed
- Eye tracking metrics: Mean/SD Glance Frequency, Mean/SD Percentage Glance Duration Off Road > 2 seconds, Percentage of Gaze on Road Centre, Mean/SD Percentage of Gaze Off the Road and Blink Rate

5.7.6. Equipment

The assessment procedure shall be conducted in a high-fidelity motion-based driving simulator. The minimum specification for the simulator should be specified to ensure consistency and standardisation amongst ADDW systems (i.e. screen resolution, motion requirements, number of projector screens etc.). It is recommended that the driving simulator is able to measure vehicle control metrics, driving performance metrics and is either equipped with eye tracking technology or can be easily integrated with it.

5.7.7. Driving routes

Minimum requirements need to be established for the driving routes or drives that need to be performed in the simulator. This includes factors such as the length of the route, traffic flow, road curvature and gradient, daylight conditions, weather conditions, road junctions and layout, number of lanes, road infrastructure (e.g. traffic lights and walkways), other road users (e.g. pedestrians and cyclists) etc. It is imperative that the assessment procedure tests the effectiveness of the system on all road types that the system is required to operate effectively on (i.e. urban, rural and motorways).

5.7.8. Assessment procedure

The assessment procedure to assess the effectiveness of ADDW systems can only be established once 1) the system and remaining assessment procedure requirements are established, 2) stakeholders are reengaged about their validation testing and 3) further research, such as a literature review into validation testing of distraction monitoring systems, is conducted.

Some aspects to consider in the development of the procedure include:

- Prior to testing, the participant should be informed of the study and expectations, and that they are able to withdraw from the study at any point, signing a consent form.
- Participants should be informed to drive as they normally would on the road
- The participant should be made aware of the data being collected from them (i.e. dependent variables and ADDW system) prior to entering the simulator and signing the consent form
- It is recommended that drivers initially perform a familiarisation drive in the simulator to get used to the dynamics of the vehicle and environment. Once the participants feel comfortable and are aware of the expectations and requirements of the study, they can begin the main drives.
- Depending on the experimental design, participants should be explained how to use the equipment for the distraction tasks and what is expected of them prior to the execution of the distraction tasks.
- The order of conditions (i.e. road type and distraction/non-distraction drives) should be randomised amongst participants

5.7.9. Acceptance criterion

An acceptance criterion to determine the effectiveness of ADDW systems needs to be established. This will ensure robustness and consistency amongst systems. It is recommended that this criterion assesses the system's sensitivity and specificity (i.e. system performance), however this is dependent on the experimental design.

[Two potential options:

1. The system shall be deemed effective if [95%] of the sample size achieves sensitivity and specificity values equal to or greater than the ADDW sensitivity and specificity thresholds.
2. The system shall be deemed effective if the average sensitivity and specificity values are equal to or greater than the ADDW sensitivity and specificity thresholds and the variance between the participants is kept to a minimum.]

6. NEXT STEPS

The sections below highlight the topics identified in this study requiring further research or additional stakeholder engagements. This is necessary in order to establish the requirements around each topic.

6.1. Establishing requirements for the Forward FoV

To ensure road safety and consistency amongst systems, the dimensions of the Forward FoV should be specified. To determine the dimensions for the Forward FoV, it is recommended that:

1. A literature search into human vision and driving is conducted,
2. A review of national and international standards relating to human vision and driving is conducted and
3. Stakeholder are reengaged about their defined FoV.

Moreover, for many systems the size of the Forward FoV was dependent on driving speed (or road type). Whether this is appropriate with regards to road safety, as well as the purpose of the system (reducing distraction vs. customer experience), needs to be investigated further, where, regardless of the outcomes, requirements should be established.

6.2. Peripheral vision research questions

According to manufacturers, one of the main factors impacting the reliability of the systems is the breadth of drivers' peripheral vision, particularly horizontal peripheral vision. To overcome this, the sensitivity and distraction thresholds of some systems are dependent on eccentricity angle from the target to the Forward FoV. Whether this is appropriate with regards to safety, as well as the purpose of the system (i.e. distraction vs. customer experience), is unknown and should be investigated further. Regardless of the outcome, requirements should be established to ensure consistency amongst systems, road safety and system effectiveness. Thus, the following research questions should be investigated in the next phase of the project:

1. How far from the forward FoV can a driver accurately monitor their horizontal and vertical peripheral vision with regards to road safety and does road type or traffic flow influence this?
2. Should distraction thresholds or sensitivity of a system depend on the eccentricity angle from the target to the Forward FoV?

6.3. Establishing trigger behaviours

In order to establish the distraction thresholds for ADDW systems, the trigger behaviours of the system need to be specified. Two trigger behaviours were identified in this study: long glance duration to a target not relevant for driving (Type 1) and frequently shifting gaze between the driving task and a target not relevant for driving (Type 2). Type 1 can currently be monitored by systems, and as such, can be made a mandatory requirement for ADDW systems. Further stakeholder engagements are required (once more systems are on the market or are further along in the development) to determine whether Type 2 can also be made a mandatory requirement by 2024. If not, when the ADDW systems are able to monitor Type 2, the regulation should be updated making both trigger behaviours a mandatory requirement for ADDW systems.

6.4. Establishing distraction thresholds

There was insufficient guidance in the literature (rapid literature search) and inconsistencies amongst stakeholders on distraction thresholds for ADDW systems, therefore it is recommended that:

- Manufacturers are reengaged about their distraction thresholds once they have more experience with their ADDW system and the nature of visual distraction
- An in-depth literature review on distraction thresholds for ADDW systems is conducted, which includes validating thresholds identified in this study and establishing thresholds for other measurements identified as being sensitive to detecting visual distraction

The distraction thresholds, and corresponding measurements, can only be established after the trigger behaviour requirement is established.

6.5. Limitations of ADDW technology

The study identified several technological limitations resulting in the system not being able to continuously detect, and hence monitor, the driver's eyes, head or facial features. It is envisaged that manufacturers will be able to overcome these limitations over time. The way in which this is done needs to be understood to write a technology neutral regulation, thus it is recommended that stakeholders are reengaged about this topic.

6.6. Establishing other potential requirements

Due to the majority of the systems being in the development stage, there were certain aspects of ADDW systems which TRL was unable to gather information on. Thus, it is recommended that manufacturers with systems on the market should be reengaged on the following topics:

- Activation speed
- Time-to-activation
- Road type
- Weather conditions

6.7. Dependent variables

It is recommended that eye tracking, driving performance and vehicle control data, independent of the ADDW system, are collected during the testing. This data will be used to validate ADDW systems. The exact metrics to be used was not determined in this research project and should be established in the next phase of the research project. To do this, TRL recommends the following steps:

1. Perform a literature review on the metrics sensitive to visual distraction.
2. Test, in a driving simulator, the visual distraction sensitivity of each of the metrics identified for each of the distracting and non-distracting task developed for the ADDW assessment procedure.
3. The metrics which reveal a significant difference between the distracting and non-distracting conditions should be the ones used to validate ADDW systems.

It should be noted that the metrics may be dependent on the distraction task. Therefore, if the assessment procedure includes several distracting tasks, different metrics could be required to be measured for the different tasks. If none of the metrics are sensitive to one or more of the distracting tasks, a new distraction task examining the same type of visual distraction behaviour needs to be developed.

6.8. Assessment procedure

The assessment procedure to assess the effectiveness of ADDW systems can only be established once:

1. The system and remaining assessment procedure requirements are established,
2. Stakeholders are reengaged about their validation testing (only one manufacturer has a system on-market), and
3. Further research, such as a literature review into validation testing of distraction monitoring systems, is conducted.

6.9. Stakeholder engagements

Only one manufacturer had a system on the market, resulting in TRL obtaining insufficient information on how systems function and operate, as well as how systems will be validated or tested. Thus, it is advised that after more systems are brought to market, manufacturers are reengaged about these topics. This will assist in the development of the requirements and procedures, as well as ensuring that the assessment procedure is technology neutral and can be standardised across all ADDW systems.

7. CONCLUSION

The technology to monitor the driver's visual attentive state (i.e. eyes, head and/or face) exists. However, the integration of this technology with other components to create a reliable and robust ADDW system (i.e. integration with the vehicle and driver, development of algorithms to detect distraction and non-distraction event, interacting with the driver when needed etc.) has been a challenge for many manufacturers resulting in many ADDW systems still being in the development phase. As many systems are still under development, insufficient information was obtained on the function, operation and validation testing of ADDW systems to write a technology neutral regulation. It is expected that over time, the issues preventing these systems from operating effectively will be overcome. Only once this is achieved and more systems are on the market by manufacturers, can ADDW systems become a mandatory requirement for road vehicles. This report highlights these facts, as well as proposing a list of technical items that should be covered with requirements and tests to support the development of the future ADDW technical annex. There were requirements which could not be established in this study. To establish these requirements, TRL recommends conducting further research (i.e. literature, theory and national and international standards review), reengaging manufacturers and engaging other relevant stakeholders or experts. Once these requirements are established and more information is gathered on distraction monitoring validation methods and techniques, the assessment procedure can be developed. It is essential that this procedure is validated prior to the regulation being published due to the cost of testing, use of human participants and complex nature of distraction.

Annex 1 ADDW Topic Guide

Definition: A system capable of monitoring the level of attention of the driver to the traffic situation and warning the driver if needed

Objective: The system must monitor the driver's attentive state and be capable of determining when a driver is exhibiting insufficient attention for the conditions, either due to prolonged inattention (driver drowsiness) or misdirected attention (distraction), and interact with and alert the driver (HMI)

Topics	Notes
<u>What is your system and how does it work?</u> What human behaviours does your system measure i.e. distraction, drowsiness, micro sleeps etc.? What physiological metrics/indicators does your system monitor and how does your system do this? How does your system determine the state of the driver? What thresholds have you utilised and how were these determined? This includes the integration with other vehicle technology and scientific research. How early-on does the system detect inattention? What road type, vehicle type and environment is the system designed for?	
<u>Effectiveness and limitations:</u> 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? Whilst developing your system, did you experience any issues? Specifically, what limitations or technical feasibility issues did you encounter? Did you explore any other human characteristic and physiological metrics? If so, please elaborate why you did not pursue the measure(s) i.e. technical constraints and limitations. How does your system deal with false-positives due to individual variability?	

<u>HMI and alert:</u> Does your system alert the driver that they are drowsy, sleeping or distracted? If so, how is the driver alerted and what action does the driver need to take? Does your system have the capability to inform a ‘base’ when a driver is identified as being inattentive/distracted? Alerts can cause driver distraction and false-positive alerts can lead to driver annoyance. How would you suggest mitigating these effects?	
<u>Future of ADDW technology:</u> Looking to the future, how do you think ADDW technology and systems are going to develop?	

Annex 2 ADDW Methodology

Annex 2.1 Literature review

A literature review was conducted with two objectives:

1. To identify the indicators of visual distraction documented within scientific and academic literature, as well as identifying the metrics to measure and thresholds to use to determine whether a driver is visually distracted. The aim was to understand the nature and manifestation of visual distraction to determine the most reliable means to monitor and measure it.

   Many manufacturers highlighted that establishing appropriate distraction thresholds for their system has been a challenge, where each manufacturer had established different distraction thresholds. Establishing appropriate distraction thresholds for an ADDW system is vitally important with regards to road safety and customer experience. Thus, after the stakeholder engagement, TRL performed a rapid literature search on distraction thresholds with the aim of gaining greater insight, at a high-level, of the guidance that is available in the literature, which will hopefully assist in the establishment of the distraction thresholds for the future ADDW regulation.

2. To identify any current available test procedures in national or international standards that can be used to support the development of the future ADDW regulation. The aim was to identify elements of the standards or procedures which either can be applied to the development of such systems, or to adapt relevant principles for application within a European-centric use case.

The literature search gave priority to recent, high quality (peer-reviewed) research that was considered to be of most direct relevance to the objectives of the current study.

The review used the databases and search terms documented in Table 1 and Table 2.

Table 1. Indicators of visual distraction search terms

Search terms	Databases
("driver" AND "visual" AND "distraction") AND ("measurement*" OR "metric*" OR "indicator*") AND ("monitor*" OR "measure*" OR "detect*")	Google Scholar
	TRID

Table 2. ADDW system assessment procedure search terms

Search terms	Databases
("driver" AND "visual" AND "distraction") AND ("test procedure" OR "assessment procedure" OR "assessment" OR "test")	Google Scholar
	British Standards Institution

Annex 2.2 Expert stakeholder engagement

The stakeholder engagement was carried out to gather information on the types of systems OEMs and Tier 1 suppliers either currently have on the market or in development. The stakeholders were engaged using a standardised series of structured questions to guide discussion and ensure that relevant information was captured from each stakeholder in a consistent manner. The questions covered the readiness, function, design logic, effectiveness and validation testing of their current and/or future ADDW system, as well as questions surrounding the HMI functions of the system (Annex 1). Stakeholders were engaged either face-to-face or via teleconference.

Annex 3 ADDW RESULTS

Annex 3.1 Literature review

Annex 3.1.1 Indicators and metrics of visual distraction

When a driver is visually distracted, they shift their visual attention (i.e. move their eyes) from the tasks relevant for driving to engage or focus on a secondary task or stimulus unrelated to driving. The shift in eye gaze is normally accompanied by head movement. According to Nakashima and Shiori (2014), humans often align their eyes and head when investigating an object in detail as it enhances the accuracy of attentional focus, spatial perception and visual performance. However, there are instances where head movement does not occur with a gaze shift. Nakashima and Shioiri (2014) found numerous studies examining eye-head coupling during saccades[9] and concluded that eye movements made within the limits of eye-in-head range may or may not be associated with head movement. . According to Oommen et al. (2004), the unconscious decision to move the head during a gaze shift is dependent on multiple factors, including the expected duration the gaze will be maintained for and weighing of the costs and benefits of executing head movement.

Eye movement metrics are considered the most sensitive metrics for measuring visual distraction. According to the National Highway Traffic Safety Administration (NHTSA) (Lee *et al.*, 2013a), visual behaviour is indicative of attention selection related to both the driving and distracting task(s) and there is a strong relationship between eye movement and attention. Therefore, NHTSA suggest that eye movement metrics provide a direct indication of the driver visual state (Lee *et al.*, 2013a).

The most commonly used eye glance metrics to determine the visual attentive state of the driver include single glance duration and glance frequency (Lee *et al.*, 2013b;Regan *et al.*, 2009;Seppelt *et al.*, 2017;McGehee, 2014). NHTSA, along with others, states that the most sensitive metrics combine eye glance duration and frequency: Percentage Road Centre (PRC), Total Eyes-Off Road (TEOR) or Total Glance Duration (Lee *et al.*, 2013b;Regan *et al.*, 2009;Seppelt *et al.*, 2017;Klauer *et al.*, 2006). This is due to visual timesharing - the pattern of glancing back and forth between the road and an object - being considered the most direct indicator of visual distraction. Metrics measuring this quantify the amount of time spent looking at the road and object/task of interest, for each glance or period of time.

Glance Frequency and Percentage Single Glance > 2 seconds have also been proven to be highly sensitive in determining whether a driver is visually distracted (Lee *et al.*, 2013a). Another metric to be considered is visual eccentricity – the angle (or distance) away from the road centre. The greater the visual eccentricity, the greater the reduction in visual sensitivity (i.e. the farther away the driver looks from the road, the poorer the information available for event detection or lane keeping etc.) (Lee *et al.*, 2013a). A study conducted by Lamble, Laasko and Summala (1999), found that time to collision reduced from 7.5 seconds to below 4.5 seconds when the eccentricity angle increased from 0° to 90° at a 40 m headway.

In vehicles, eye movement metrics are commonly measured using a high-resolution driver-facing camera integrated with eye tracking technology. Despite rapid technical advancements, this technology is still subject to several limitations and cannot always track eye movement. This is due to the system not being able to continuously detect the eye (i.e. eye occlusion). This can be caused by:

- Sunlight reflections on glasses

[9] Saccade: Brief, fast movement of the eyes that changes the point of fixation (ISO 15007-1:2014)

- The eye blink of the driver
- A large head rotation
- Sunglasses
- Eye make-up
- Direct sunlight
- Hat, caps or scarves
- Varying real world illumination conditions, and
- Certain facial features etc.

(Kircher and Ahlstrom, 2010;Fernández *et al.*, 2016)

Eye movement can also be indirectly assessed by using coarse visual behaviour metrics – head movement and facial feature(s) movement (e.g. mouth or nose) – to predict or estimate eye gaze direction. According to Fernández et al. (2016), many researchers have used head orientation to estimate the drivers gaze direction. A coarse estimate of glance direction is considered sufficient to infer a driver's visual attention and is widely accepted and used as a metric in many vision-based driver monitoring systems (Jha and Busso, 2016;Kim and Shin, 2014). This is mainly due to the fact that 1) real driving behaviour in natural driving results in many drivers moving both their head and eyes when looking at a target and 2) the pupils are not always visible (i.e. eye occlusion) preventing the eyes from being tracked (Fernández *et al.*, 2016;Jha and Busso, 2016;Kim and Shin, 2014).

Similar to eye tracking, systems estimating gaze direction are subject to several limitations. Coarse visual behaviour metrics provide a coarse description of the driver's visual attentive state (Lee, et al., 2013). Evidence suggests that there is a strong correlation between head and eye gaze direction; however, during natural driving, drivers tend to have less head rotation but more gaze searching to maintain safe driving (Xing *et al.*, 2018). Thus, visual behaviour metrics provides a broad estimate of where the driver is looking (i.e. area vs. precise target). Moreover, head orientation can bias the perceived gaze direction towards the head orientation (Otsuka and Clifford, 2018). For example, the head can be directed straight ahead when the eyes are gazing to the right or left. Alternatively, the eye could be fixed straight ahead, but the head can be orientated to the right or left. Drivers also tend to use a time-sharing strategy when engaged in a visual-manual distracting task[10] – gaze is constantly switched between the driving task and distracting task(s) for short intervals of time (Tivesten and Dozza, 2014). When this occurs, the driver often positions the head in the middle of the two gaze targets and only uses the eyes to move between the two targets (Fernández *et al.*, 2016).

In summary, it is clear that the most accurate way to monitor the driver visual attentive state is by directly tracking the eyes. However, there are situations where the eyes cannot be tracked due to eye occlusion. This can be overcome by indirectly tracking the eyes by monitoring head movement or orientation. However, this provides a rough estimate of eye gaze and can sometimes provide an incorrect interpretation of eye gaze direction. A solution to these technological limitations is to use both types of metrics to determine the driver's eye gaze direction. For example, eye movement metrics can be the primary metric and when the eyes are not visible, coarse visual behaviour metrics can be used to estimate the drivers gaze direction (Kim and Shin, 2014).

Currently, there is a lot of research being conducted into 1) the limitations of eye tracking technology within a vehicular environment and 2) minimising the bias of coarse

[10] Meaning the driver looking at a device, manipulating a device-related control with the driver's hand, and watching for visual feedback (i.e. interacting with an in-vehicle infotainment systems)

visual behaviour metrics on perceived gaze. Thus, it is likely that the limitations identified in this review may be overcome in the future, and systems may be able to determine the driver's eye gaze accurately only using eye movement metrics or coarse visual behaviour metrics.

Annex 3.1.2 Visual distraction thresholds

Despite years of research, it is still unknown what a safe (maximum) task time or visual demand is for a distracting task whilst driving. This is due to the many factors influencing the effect of distraction on crash risk:

- Timing: Crash risk increases if the distracting task coincides with an unexpected event
- Intensity: the more resources required to perform the distracting task, the higher the crash risk will be
- Reusability: Tasks which can be dropped and restarted efficiently will have a lower crash risk
- Frequency: Actions repeated more often are more likely to coincide with a critical event
- Duration: the longer the duration of distraction, the more likely it will coincide with a critical event
- Hangover effect: Any lingering cognitive or emotional distraction may influence crash risk

(Kinnear and Stevens, 2015)

Moreover, a driver's visual awareness of the road scene also influences crash risk. For example, a person gazing out the nearside of the windscreen on an open motorway will have a greater awareness of the road scene due to their peripheral vision, and hence lower crash risk, compared to someone gazing at a passenger seated in the passenger seat on a busier motorway. This section of the report will highlight the most common visual distraction guidelines presented in the literature.

In 2006, the Alliance of Automobile Manufacturers (AAM) released "*Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communications systems*" (AAM, 2006). Within this document, there are two guidelines specifically referring to task completion and eye glance duration. These two guidelines are written as follows:

- Single glance durations generally should not exceed 2 seconds
- Task completion should require no more than 20 seconds of total glance time to task display(s) and controls

The Society of Automotive Engineers (SAE) suggests that task completion should not exceed 15 seconds of total glance time (Klauer *et al.*, 2010). According to NHTSA, SAE generally accepts that glances should not exceed 2 seconds, but the organisation has not yet stated an official position to this effect. The 2-second guideline was based on research conducted by Rockwell (Rockwell, 1988), who performed numerous instrumented-vehicle studies over several years analysing the length of eye glances away from the forward road scene. From this data, the distribution of eye glance lengths was calculated. The 85^{th} percentile eye glance length was approximately 1.9 seconds, which was rounded up to two seconds to provide a design criterion in whole numbers.

According to Klauer et al. (Anon., 2006), the risk of a crash or near crash doubles when a driver does not look at the road for 2 seconds or longer. Moreover, the naturalistic 100-car driving study also indicated that eye glance durations greater than 2 seconds significantly increased individual near-crash/crash risk whereas eye glance durations less than 2 seconds did not significantly increase risk relative to normal (Klauer *et al.*, 2006).

The Driver Distraction 2015 report published by the European Commission states the findings highlighted above by Klauer et al. (Anon., 2006), as well as the following findings from Theeuwes (2008) and Horrey & Wickens (2007): glance duration from the traffic to equipment or an object should not exceed 1.6 seconds (cited in European Commission, 2015). Eighty percent of simulator-crashes in the study conducted by Horrey and Wickens (2007) were attributed to glances at objects inside the vehicle that took longer than 1.6 seconds (cited in European Commission, 2015).

Several authors suggest that drivers tend not to look away from the road scene for more than 1.5 seconds (Klauer *et al.*, 2010). Rather, if engaged in a secondary task, drivers tend to look back and forth at the road scene, not looking away from the forward road scene for more than 1.5 seconds at a time until the secondary task is complete (i.e. [11]visual time sharing'). For this reason, NHTSA suggests that TEOR (total eye-off-road) during the completion of a secondary task may be a better limiter i.e. eyes cannot be off the road for more than 15 out of 20 seconds (Klauer *et al.*, 2010). According to Klauer et al. (Anon., 2006), TEOR glance duration greater than two seconds in a six-second window increased crash or near-crash risk twofold, relative to normal driving.

The evidence above is based on the length of time that the driver's eyes are off the road and does not consider that drivers need to glance off the road to various areas in the vehicle to perform tasks related to driving (e.g. glancing at the mirrors, instrument cluster and driver controls such as pedals and steering input). Yuan et al. (2018) therefore suggest that glance location should also be used as an indicator for visual attention, where glance location, for example, can be categorised into three areas: 1) forward road, 2) driving-related areas and 3) other areas.

Yuan et al. (2018) also state that the driving scenario has a significant impact on a driver's visual behaviour and suggest that the driving context and environment (i.e. road type and traffic etc.), should also be considered when establishing distraction thresholds. For example, driving on an urban road requires drivers to update their information about parked cars, intersections, pedestrians, cyclists, traffic lights, and other surrounding traffic, while drivers only need to monitor driving speed, lane position, and surrounding cars on motorways. Thus, glance frequency and duration are dependent on contextual factors, where contextual targets require different amounts of attention (Yuan *et al.*, 2018).

In summary, it appears that glances away from the road exceeding two seconds significantly increases crash risk. With regards to an established glance duration threshold, two recommendations were found: 1.6 seconds and 2 seconds, where the two-second duration is the most widely recognised threshold. It should be noted that both of these values are based on a driver interacting with an in-vehicle device or mobile phone, which usually results in a driver's eyes gazing downwards and not having the road in their peripheral vision (i.e. no visual awareness of the road – please refer to Section 0 and 0 for more details). The review also revealed that drivers commonly glance frequently between the driving task and a distracting task. For this type of distraction behaviour, the following measurements were identified: TEOR, PRC, Total Glance Duration and Glancy Frequency, where one threshold was identified for TEOR from one source: TEOR glance duration greater than two seconds in a six-second window (Klauer *et al.*, 2006) and two contradictory thresholds were identified for Total Glance Duration: a distracting task should be completed within 15 seconds (Klauer *et al.*, 2010) and 20 seconds (AAM, 2006) of total glance duration. Further research to validate the TEOR threshold and to establish thresholds for the other measurements identified as being sensitive to detecting visual distraction should be conducted. As this was a rapid literature review, it is recommended that an in-depth analysis of distraction thresholds should be conducted in the next phase of this research project.

[11] Visual time-sharing metrics mainly quantify the amount of time spent looking on or off the road, for each glance or for a period of time such as a task interval or an artificial time-window

Annex 3.1.3 Current standards and test procedures

One test procedure assessing the effectiveness of distraction monitoring systems was found in the literature. This procedure was developed by NHTSA, and full details of the assessment procedure and development thereof can be found in the following reports:

1. Distraction Detection and Mitigation Through Driver Feedback (Lee *et al.*, 2013)
2. Distraction Detection and Mitigation Through Driver Feedback: Appendices (Lee *et al.*, 2013b)

The assessment procedure developed and validated by NHTSA focuses on assessing the ability of algorithms to detect distraction – assuming the algorithm receives valid sensor data. The assessment procedure requires human participants to drive in a simulator in various driving situations performing secondary tasks indicative of the different types of distraction.

Below is a summary of the assessment procedure; refer to Chapter 4 (Lee *et al.*, 2013a) and Appendix G (Lee *et al.*, 2013b) of the NHTSA reports for more details:

- Participants: 32 participants balanced for gender between the ages of 25 and 50 are required. Participants are required to have experience engaging in distracting activities whilst driving (such as talking on the phone, texting, eating, emailing and changing CDs) and a certain level of driving experience to participate in the study.
- Equipment: The assessment procedure must be conducted in a high-fidelity, motion-based driving simulator equipped with eye tracking hardware.
- Distraction tasks – please refer to the NHTSA report for full details and explanation on the tasks below:
    1. Visual manual task: The Arrow – this task was designed to require visual processing and some manual engagement, with minimal cognitive engagement. For this task, participants are presented a total of five matrices (4 rows of 4 objects) of arrows on a 3-inch LCD touch screen display and are required to touch yes or no on the screen when the target object (arrowing pointing upwards) is presented.

       The task is required to be presented between 15 and 30 degrees of the driver’s vertical and horizontal viewing positions. In this position, it is expected that some participants will only move their eyes to perform the task, whereas others may move both their eyes and head. This ensures that systems monitoring coarse visual behaviour metrics are effective in estimating the gaze direction of the driver.
    2. Reaching task: Bee Catching task – this visual/manual tracking task requires a participant to follow a bee on an LCD screen with their hand in three different locations. Location 1 requires a slight body turn, whereas locations 2 and 3 require movement towards the driver’s nearside and full orientation of vision behind the passenger seat headrest respectively.
    3. Cognitive task: This complex cognitive task involves the participant navigating an interactive voice response [12] menu – making a call to a simulated interactive voice menu to retrieve flight information.
    4. Simple self-paced visual manual task: this task - adjusting settings on a radio - is an on-going simple visual manual distraction task aimed to represent circumstances under which people allow themselves to be distracted.

[12] Interactive voice response is a technology that allows a computer to interact with humans through the use of voice and tone input via a keypad

- Baseline tasks: to assess true negative and false positive alerts, the assessment procedure included conditions which represented normal driving conditions.
- Incentive system: Performance of these tasks is measured by calculation equations located in Appendix G of the NHTSA report, where the scores are verbally relayed to participants. This feedback system is used to encourage participants to engage in the secondary activities, which is essential as the aim of this assessment procedure is to validate and refine distraction detection algorithms.
- Dependent variables: primary dependent variables include lateral and longitudinal control and eye movements. There is a list of other potential dependent variables located in Table G-1 of the appendices of the NHTSA report.
- Participants are required to be tested in a variety of environments covering urban, rural and freeway roads. Multiple scenarios were tested in each environment, where the scenario was dependent on the distraction task being assessed, as well as on the environment. The level of detail for each simulated environment (i.e. number of lanes, road curvature, traffic flow, driving route, road layout etc.) is also specified. Descriptions and full details of the scenarios and environments can be found in Figure 3, 4 and 5, and Table 6 in Chapter 4 of the report and Table G-2 in the appendices of the NHTSA report.
- Effectiveness: the algorithms were assessed on their true positive, true negative, false positive and false negative rates. True positives and false negatives were defined by the presence of a distracting task, while true negatives and false positives were defined in locations where distraction was not present.

Annex 3.2 Expert stakeholder engagement

To gather information on current ADDW systems, TRL engaged with 14 stakeholders, including seven OEMs, six Tier 1 suppliers and Euro NCAP. Of these, seven had developed ADDW systems to date, where all Tier 1 suppliers have an ADDW system on the market, one OEM has a system on the market, three OEMs have a system in-development and three OEMs do not have a system on the market or in development.

The main finding from the engagements was that the technology to monitor the driver’s eyes, head and/or facial feature(s) exists (Tier 1 supplier). However, the integration of this technology with other components (i.e. hardware and software) to create a reliable and robust ADDW system has been highlighted as a challenge by OEMs, resulting in many ADDW systems still being in development (i.e. undesirable amount of false-positive and false-negative alerts by the system).

The key findings regarding the function, validation, effectiveness and HMI of ADDW systems are detailed below.

Annex 3.2.1 ADDW system function

- All systems monitored the driver’s eyes, head and/or facial feature(s) using a driver-facing camera-based system
- All stakeholders had developed a system that was capable of monitoring visual distraction and at least one other human factor (e.g. driver drowsiness, microsleeps, other types of distraction etc.)
- Each system used a minimum of one visual behaviour indicator and one metric to assess the driver’s visual attentive state.
- The visual behaviour indicators used to assess the driver’s visual attentive state included:
    - Eye movement to directly determine eye gaze direction

    - Head movement to indirectly assess eye gaze direction
    - Facial feature(s) movement to indirectly assess eye gaze direction
- Some systems used one metric to determine the visual attentive state of the driver, whilst others used multiple metrics to determine this. The following metrics were identified:
    - Glance duration
    - Glance frequency
    - TEOR
- Some systems incorporated secondary metrics into their algorithm. These can be characterised into two groups: vehicle control metrics (e.g. indicators, wipers, ADAS etc.) and external environmental metrics (e.g. weather, time of day, presence of other vehicles or objects). These stakeholders suggested that the additional metrics were used to make the system more robust.
- All systems had at least two Areas of Interest (AoI) defined. The way in which these were defined varied amongst systems, where two main system types were identified:
    - Simple system[13]: Forward Field of View (FoV) and Distracted FoV (i.e. eyes on the road versus eyes off the road)
    - Complex system: FoV relevant for driving and FoV not relevant for driving, where the FoV relevant and not relevant for the driving task consisted of multiple AoI (e.g. Forward FoV, mirrors, instrument cluster, passenger window, nearside windscreen, centre console etc.). The amount of AoI varied between systems. In some systems, certain AoIs were determined as relevant or not relevant in real-time using information from secondary metrics (e.g. gazing out of the passenger window whilst the indicator is on)
- The Forward FOV size ranged from 15 degrees eccentricity[14] (known as central vision) when gazing straight ahead at the forward road scene to the entire length and breadth of the windscreen. For the majority of systems, the forward field of view size was dependent on vehicle speed, where the size was smaller when travelling at high speeds compared to when travelling at low speeds.
- All systems had at least one trigger behaviour. Three were identified:
    - Driver's glance duration to a target outside of the Forward FoV or FoV relevant for driving exceeds the glance duration threshold of the system
    - Driver's glance frequency to a target outside the Forward FoV or FoV relevant for driving exceeding the glance frequency threshold of the system
    - Driver glances for a period of time and/or frequently to a target outside of the Forward FoV or FoV relevant for driving exceeding the TEOR threshold of the system
- There was no consistency amongst stakeholders on the visual distraction thresholds used. For example, OEMs used different glance duration thresholds to

[13] Classification as either "Simple" or "Complex" within this report is not a reflection of TRL's assessment of the competence and robustness of the ADDW systems. This is a means of segmenting systems based on the number of AoI used to determine the distracted and non-distracted fields of view. It is perfectly feasible for a system classified as simple to measure visual distraction more accurately and robustly than one which falls under the classification of complex, and vice versa

[14] Degrees of visual angle from the centre of the eye

determine whether the driver was distracted or not. For some systems, the thresholds were dependent on the AoI (i.e. definition and location). Tier 1 suppliers provided little information on the thresholds due to the fact that the thresholds are determined by the OEMs (i.e. system is configurable)

- Some stakeholders suggested that visual distraction thresholds or system sensitivity are dependent on the driving context (i.e. vehicle speed, road type and external environment). For example, thresholds would be lower, and sensitivity of the system would be higher if driving (at the speed limit) on a busy motorway or winding rural road at night compared to driving on an open motorway during the day
- Due to the small number of systems on the market by OEMs, the following information could not be obtained:
    - Activation speed – Driving speed at which the system is active
    - Road type – Roads on which the system will be active (i.e. motorway, rural and urban)
    - Activation and deactivation – Conditions when the system will be active and whether the driver is able to deactivate the system

Annex 3.2.2 System validation

- Of the stakeholders engaged, all Tier 1 suppliers and two OEMs had performed some type of validation testing. The remaining OEMs had not performed any validation testing, either because their system was still in-developed or due to the OEM not having a system on the market or in development.
- All stakeholders validated their system with user trials (i.e. human participants). The method or tools used to determine the effectiveness of the system was inconsistent amongst stakeholders. The only common element found amongst stakeholders was the testing of the system on real roads with participants performing a number of distracting tasks or movements indicative of distracted driving behaviour.
- There was no consistency in the number and demographics of the participants used to validate the different systems.
- There was also no consistency in the number of factors assessed. Some systems assessed the effectiveness of the systems for numerous of conditions, where others only did this for a few. The conditions assessed can be mainly categorised into two groups: environmental factors (e.g. time of day, weather, lighting, road type etc.) and occlusion factors (facial hair, mask, make-up, glasses, headwear, hair length and style etc.).
- The majority of systems were deemed effective at detecting visual distraction if the system alerted the driver that they were visually distracted when performing the distracting task or movement (i.e. high true positive rate).
- The majority of systems were deemed reliable and robust if the system did not alert the driver that they are visually distracted when not performing a distracting task or movement (i.e. low false positive rate).

Annex 3.2.3 System effectiveness

- All OEMs reported that their systems displayed an undesirable number of false positive and false negative alerts. Some of the factors contributing to this included:
    - Lack of experience with the technology

- Understanding the eye glance behaviour of a distracted driver
- Uncertainty surrounding visual distraction thresholds
- The challenge in defining or determining whether an AoI is relevant or not relevant for driving, and/or
- Limitations of the system/technology in detecting the eyes, head and/or facial feature(s)

- A few stakeholders reported no system limitations, whereas others reported one or more limitations. There was no consistency amongst the stakeholders regarding the number and type of factors negatively affecting the effectiveness of their system. Some of the factors mentioned included: eye shape, glasses, sunglasses, facial hair, masks, hair length and style, headwear, eye make-up, lighting conditions, time of day and weather conditions.

Annex 3.2.4 Human Machine Interface

There was not a lot of information obtained about the Human Machine Interface (HMI) of ADDW systems due to 1) Tier 1 suppliers not developing these and 2) the number of systems still in development or not yet developed by OEMs.

From the engagements, it can be reported that drivers are or will be presented with at least a visual alert when distracted. Some stakeholders suggested presenting the driver with both a visual and auditory alert. Stakeholders gave different opinions regarding the behaviour of repeated alerts, with some suggesting keeping it the same as the initial alert and others suggesting cascade or escalate the alert.

The majority of systems alert (or will alert) the driver that they are visually distracted when they exceed the visual distraction threshold(s) of the system. For example: when gazing at the area(s) not relevant for driving for a certain duration (glance duration threshold), the system would alert the driver that they are visually distracted. Some systems only alerted the driver if they were at risk of potentially having a collision or in a dangerous situation. This type of alert was a collision warning alert rather than a visual distraction alert. For example, if the driver’s eyes are off the road and there is a vehicle/obstacle in close proximity, the system would warn the driver that they were at imminent risk of having a collision. Thus, if the driver is perceived to be driving appropriately and there are no vehicles/obstacles in close proximity, the driver will not be alerted if their eyes are off the road for a considerable length of time.

Annex 3.2.5 Euro NCAP

Euro NCAP states that the technology for ADDW systems exists and is robust (i.e. Tier 1 suppliers), but that OEMs are still learning these systems and figuring out 1) what to do with the information that the system outputs (i.e. what the information means), 2) how to handle this information, 3) what thresholds to use and 4) what the intervention should be. This is mainly due to the lack of experience with the technology and due to a lot of the elements of these systems being configurable (i.e. set by the OEM). Moreover, Euro NCAP stated that OEMs do not want an aggressive or annoying system, because this would reduce customer experience and may cause distraction instead of preventing it. Instead, they only want to be engaging with the driver when they are at risk of potentially having a collision. Euro NCAP suggests that OEMs need more time, potentially two more years, to become familiar with these systems before they become regulated.

Annex 3.2.6 Future developments of ADDW

As many of these systems are still in-development, all information acquired on the future developments of these systems cannot be reported.