EURO NCAP RESCUE – TERTIARY SAFETY ASSESSMENT

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Paper Number 23-0258

ABSTRACT

The European New Car Assessment Programme (Euro NCAP) has until recently concentrated on passive and active safety assessments. The organisation realised the need to address post-crash (tertiary) safety to improve the outcomes for those involved in vehicle crashes. In 2018 the Rescue working group was created and is supported by Euro NCAP's members, affiliated members and CTIF (International Association of Fire & Rescue Services). Industry also contributes with representatives from both the European Automobile Manufacturers Association (ACEA) and the European Association of Automotive Suppliers (CLEPA).

The first Rescue test and assessment protocol was published in early 2019 and from the start of 2020 the topic of Rescue was included in the overall star rating as part of the adult scoring area. The assessment for Rescue is divided into 3 areas:

1. Rescue – Rescue Sheets for the vehicle.
2. Extrication - Unlocking of automatic door locking, door opening forces & seat belt unbuckling forces.
3. Safety - Advanced eCall and Multi Collision Brake technology.

In June 2020 Euro NCAP launched the "Rescue App" available for Android and iOS users with support from CTIF and the car manufacturers. This free app gives access to ISO 17840 compliant rescue sheets for hundreds of vehicle models and is constantly updated.

Rescue services require detailed but easily understood information regarding the construction of individual vehicles to extricate trapped occupants as quickly and safely (for occupants and rescuers) as possible. This is becoming more important as vehicles become stronger, use different sources of power and are equipped with increasing numbers of safety devices and new features such as electric door handles. For this reason, Euro NCAP has planned further updates of requirements and will add new ones to be implemented in 2023 and 2026, including requirements related to vehicle submergence and battery safety.

INTRODUCTION

The remarkable progress in vehicle safety during recent years has been largely delivered through industry innovation, effective legislation, and consumer demand for safer vehicles. Combined with tangible advancements in road infrastructure and effective policies, to reduce driving under the influence and speeding, the development of a safer vehicle fleet has made Europe's road transport one of the world's safest. The European New Car Assessment Programme, Euro NCAP, provides motoring consumers with an objective and independent assessment of the safety performance of new vehicles on the European market. Thanks to its continuous evolution and promotion of the newest, essential safety technology on offer, its five-star rating has been a driving force behind many vehicle safety improvements, in terms of active (primary) and passive (secondary) safety.

In recent years, Euro NCAP has recognised the need to expand into tertiary safety to improve the outcomes for occupants, post-crash. The first item that was identified as needing immediate improvement was Rescue information for first and second responders, in the form of so-called Rescue Sheets. As cars became better equipped to deal with crashes and mitigate the consequences for occupants, challenges for crash responders to extricate victims from the vehicle have increased. These challenges include obtaining access to the compartment, removing parts of the vehicle to allow safe removal of victims, dealing with potentially deployable safety systems, such as airbags or other pyrotechnic devices as well as managing fire or electrical risks.

To understand what could be done to address these growing challenges, Euro NCAP teamed up with International Association of Fire and Rescue Services, CTIF. This association stimulates the co-operation between the fire departments and other emergency services from all over the world. This organisation was created in 1900 and has 39 members, among them most European countries but also other countries like Japan, South Korea and the United States of America. CTIF has highlighted that Rescue Sheets provided by vehicle manufacturers varied in content and presentation where some may provide all the useful information clearly laid out, but others were missing vital information. More detailed Rescue information was commercially available, but not always affordable by (voluntary) firefighters. Almost all rescue information was only provided in one or two languages, i.e. German and/or English.

Hence, Euro NCAP added Rescue to their rating from 2020 onwards requiring vehicle manufacturers to provide full ISO 17840 compliant rescue sheets, initially in 4 European languages (English, German, Spanish and French). This would ensure that the data presented in these sheets is following the same format for all passenger vehicles and would help the first responders better understand the vital safety information on clearly presented concise rescue sheets. These sheets must contain important vehicle information to be used by first responders such as the presence and location of pyrotechnic safety devices like airbags and seat belt pretensioners, vehicle body materials, high voltage batteries and associated cabling, how to identify vehicle, secure and disable vehicle. It is a requirement for the format of these rescue sheets (sometimes called rescue cards) to follow *ISO standard 17840 Road vehicles — Information for first and second responders — Part 1: Rescue sheet for passenger cars and light commercial vehicles* (and Part 3 from 2023).

As part of a new Rescue assessment Euro NCAP also saw a need to look into the area of extrication, initially addressing the following areas: Post-crash checks of the unlocking of automatic door locking systems, measuring door opening forces and seat belt unbuckling forces. Requirements were put in place, and verified after the Euro NCAP crash tests, ensuring that first responders to the scene can effectively gain access to the vehicle and unbuckle occupants. Finally, the Rescue protocol encourages vehicle manufacturers to equip their vehicles with Advanced eCall and Multi Collision Brake technology (Figure 1).

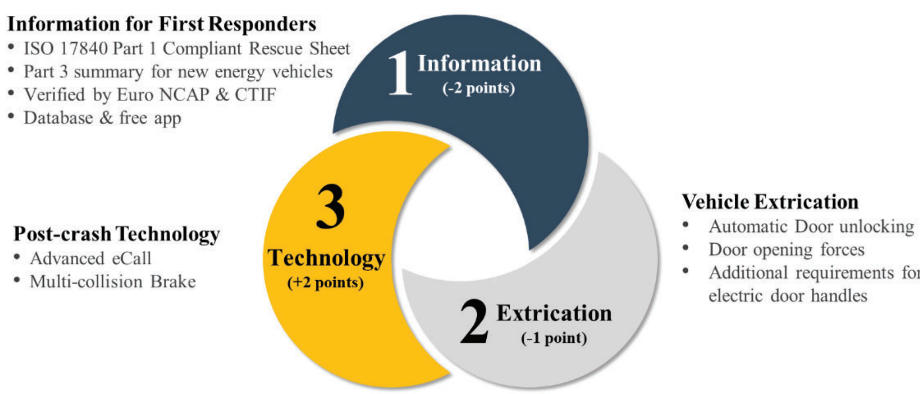

Figure 1: Rescue topics covered by Euro NCAP since 2020 [1].

Euro NCAP rating scheme currently has four areas of assessment: Adult occupant protection, child protection, vulnerable road user protection and safety assist. Rescue and extrication cannot easily be categorised in these boxes, but it was felt to be best placed under the Adult Occupant Protection (AOP) in the scoring scheme, accounting for 2 points out of a total of 38 for this part of the assessment. A pre-requisite for the possibility of scoring these 2 points is that the vehicle manufacturer must supply ISO compliant rescue sheets for the assessed model.

BACKGROUND

What is Tertiary Safety?

Today when talking about vehicle safety it is generally divided into three areas:

1. Primary or Active Safety – This covers technology that helps the driver avoid a crash in the first place such as ESC, AEB, LSS etc.
2. Secondary or Passive Safety – This assumes you are having an accident and includes items to help the occupants during an impact such as a stable vehicle structure, seat belts, airbags and so on.
3. Tertiary or Post-Crash Safety – This covers the stage immediately after an impact looking at ways to improve the outcome for any vehicle occupants and, in the future, Vulnerable Road Users (VRU). Rescuers aim to act as fast as possible upon reaching the accident scene armed with information on the vehicle (Rescue Sheet) and information on the occupants and accident (eCall). Tertiary Safety also includes technology such as MCB (Multi-Collision Braking) which can help a vehicle avoid secondary impacts or at least reduce the impact speed if a second impact cannot be avoided.

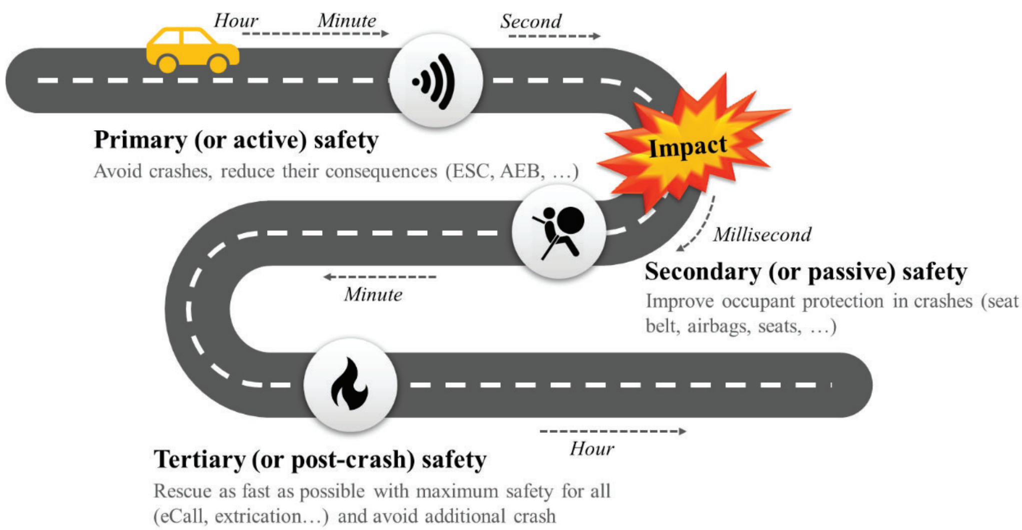

Figure 2: What is Tertiary Safety?

Why improvement is necessary in Tertiary Safety?

Worldwide, first responders face many common challenges when dealing with vehicle accidents:

- Vehicle identification / recognition – Not always easy for the first responder to identify what kind of vehicle or exact model and fuel source they are working on. To have the vehicle's identification information as soon as possible is critical for a successful road rescue operation, e.g. eCall can be a very efficient way to get the information quickly.
- Immobilisation, stabilisation – rescuers need to make the damaged vehicle safe and stable before working on it to not only protect the occupants but also themselves.
- Disable direct hazards, liquids, gases – rescuers should be able to easily disconnect any power source (high voltage) or fuel source (fuel tank, gas tank and so on). Approaching a new electric or hybrid vehicle can be quite different compared to dealing with traditional propulsion technology like gasoline or diesel. The energy stored in any vehicle could pose a risk to both the rescuers and to the public, and this creates a need for first and second responders to quickly find information which can guide them in how to proceed safely.

- Access to the occupants – The vehicle may pose problems for the first responders getting inside such as electric door handles and boot/trunk no longer working.
- Extrication risks posed by pyrotechnic components, inflators, preloaded springs, high strength zones, high voltage, battery pack, gas storage can be found in most passenger vehicles involved in accidents today.
- Fire & water submersion – The vehicle may be on fire when first responders arrive or there could be a risk of a fire starting when they are working on the vehicle. If vehicle enters water or is surrounded by rising flood waters, it is highly desirable for there to be systems that remain operable for some time, such as electric windows, to prevent occupants becoming trapped in the vehicle.

Work of ISO and the need for an ISO Rescue standard

In 2012 national body France made a proposal to develop an ISO standard for the uniform layout/format of rescue sheets for passenger vehicles. The new work item was approved, and the work was allocated to the existing Working Group 7 Traffic accident analysis methodology under ISO/TC22/SC12. PSA (now Stellantis), responsible for the French proposal became project leader. After several meetings and official voting within the ISO member countries ISO 17840:2015 Part 1 was first published in 2015 [2] and updated in 2022. Part 3, that defines the pictograms, was published in 2019 [3] and Part 4, that defines the diamond symbols, was published in 2018. The ISO standard 17840 can be used worldwide by public transport sector, fire and rescue services, automotive and heavy-duty vehicle sector, and consists of:

1. "Symbols" indicating which propulsion energy is used and where tanks, batteries, etc. are located in the vehicle.
2. "Rescue Sheets" (quick info about the construction of the vehicle) used by first and second responders.
3. "Emergency Response Guides" (ERGs) containing in-depth information (with the same headlines as the rescue sheets).

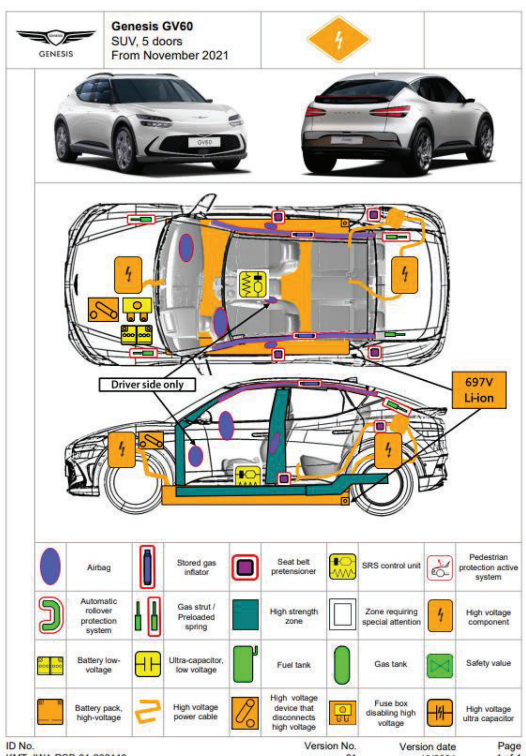

Figure 3. First page of Rescue Sheet for electric vehicle Genesis GV60 in accordance with ISO 17840 Part 1, showing ISO standardised symbols for batteries, airbags etc. Image courtesy of Genesis.

Euro Rescue App

As vehicles have become stronger, more complex and alternatively powered, it has become increasingly crucial that first responders know what they can and can't do at the scene of an accident. Intervention within the golden hour is critical and rescuers need quick and straightforward information regarding the construction of a vehicle to help safely remove persons from the wreck. For this reason, car manufacturers make so-called "Rescue Sheets" and "Emergency Response Guides" available.

Euro NCAP has, together with CTIF centralised the manufacturers' rescue sheets in an app, 'Euro Rescue'. The app can be downloaded freely and is available for Android & iOS. It can be used both online and offline, allowing rescuers to access the information even when there is little or no network coverage at the scene of the crash. The vehicle can be searched for in the app in a variety of different ways: by brand logo, brand name, model name, energy type or by scanning QR code on vehicle if present. For all cars assessed from 2020 onwards, Euro NCAP has verified the content and shared ISO-compliant rescue sheets and emergency response guides for new energy vehicles, via the Euro Rescue app. Euro Rescue was launched in English, French, German and Spanish. From 2023, the app and Rescue Sheets will be available in all European languages. The use of the app is not restricted to Europe: The Australasian New Car Assessment Program, (ANCAP SAFETY), the region's independent vehicle safety authority, also has an app 'ANCAP Rescue' based on Euro Rescue. The app is available for both iOS and Android operating systems and since its launch it has been downloaded over 200,000 times and contains over 1,500 Rescue Sheets. Looking at country ranking where it is most popular for downloading for the Android version the top countries are 1. Italy, 2. France, 3. Germany, 4. Spain, 5. UK and for iOS downloads 1. Germany, 2. UK, 3. France, 4. Italy, 5. US.

Feedback from CTIF from its rescuers using the app has been very positive so far: "The CTIF/Euro NCAP partnership started in 2018 has allowed, during the first 2020 roadmap, to highlight the need for rescue services to have a unique and freely accessible database of standardised rescue sheets. By releasing the Euro Rescue application in June 2020, Euro NCAP is actively contributing to the operational efficiency of rescue services in road accidents. With more than 200,000 downloads to this day, Euro Rescue shows the interest it generates among European rescue services but also worldwide. The integration of rescue sheets for trucks and buses as well as the identification of rescue sheets by the registration number are the next steps expected by CTIF, in order to make this application universal".

TEST & ASSESSMENT PROTOCOL *(current v1.2 until end of December 2022)*

The protocol [1] consists of the three areas of assessment: Rescue, Extrication and Post-crash Safety. Within these areas the following items are examined:

Rescue information - Information for First Responders:

<u>ISO 17840 Part 1 Compliant Rescue Sheet</u>

This Rescue Sheet is an operational Summary sheet for a vehicle produced for rescue services containing relevant information on vehicle hazards such as electrical systems, pyrotechnic devices, material location and properties (high strength steel etc), fuel storage location and properties etc. The Rescue Sheet is the main document that first and second responders use at the scene of an accident. The Euro NCAP vehicle inspectors will check the rescue sheets supplied by the vehicle manufacturer for ISO compliance. Availability and ISO compliance is a pre-requisite for scoring points for the Rescue assessment.

<u>Part 3 summary for new energy vehicles (ERG – Emergency Response Guide)</u>

The ERG is a template for more in-depth emergency response information to be used in combination with the Rescue Sheet for non-conventional engine vehicles. It is generally used by first and second responders as a source of information for training on non-conventional engine vehicles. (From 2023 onwards ERGs will be required for all vehicles assessed by Euro NCAP).

Euro NCAP stipulates [4] that The Rescue Sheet(s) must meet ISO 17840 Part 1 format (layout, order of information and pictograms) [2] and must include an Emergency Response Guide (ERG) following ISO 17840 Part 3 [3] and not exceed 4 pages (see example Figure 4).

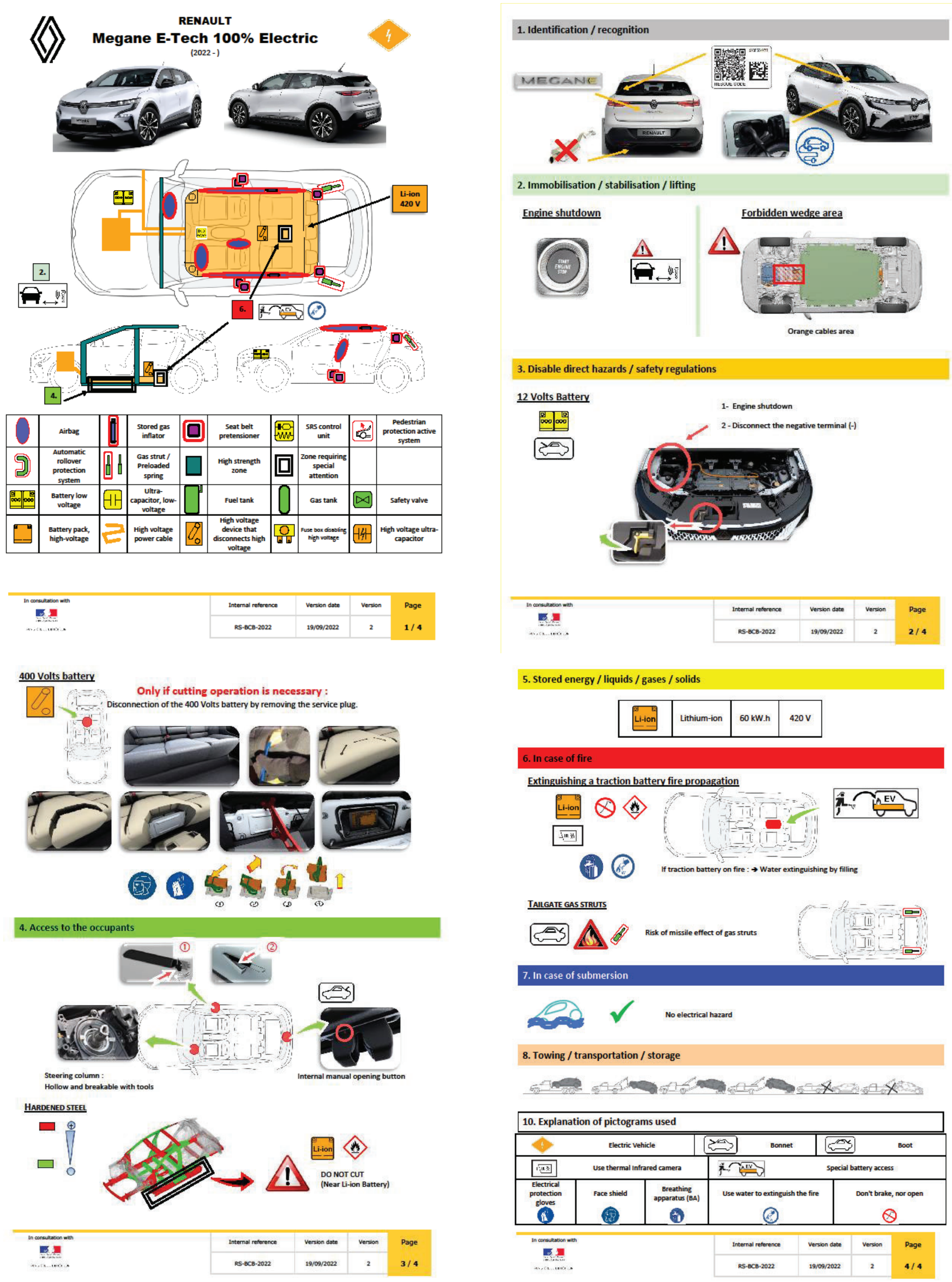

Figure 4. Rescue Sheet for electric vehicle Renault Megane E-Tech in accordance with ISO 17840 Part 1, including ERG information. Image courtesy of Renault.

Extrication - Tools to help intervention:

Automatic Door Locking (ADL)

As part of the extrication assessment Euro NCAP laboratories check the post-test status of a vehicle equipped with automatic door locking (which should automatically unlock post-impact).

Door Opening Forces
The door opening forces will be measured post-impact to ensure that in the real world first responders can access occupants quickly without having to use tools to open the doors.

Electric door handles and retracting door handles
Laboratories will check that electric door handles still function post-impact and will also look at door handles that sit flush with the vehicle body to ensure that these also function without any tools being needed or special operations required to use them after a crash (Figure 5).

Seat belt buckle unlatching
No extrication assessment would be complete without also dealing with the belted occupants and ensuring that the seat belt itself can be unlatched as normal to allow extrication of the occupant, also to ensure the occupant can free themselves from the belt and exit the vehicle when possible.

Figure 5. Example of recent door handle designs. Euro NCAP's assessment of post-crash safety includes a check that electric door handles still function post-impact.

Safety / Post-crash Technology - Technology supporting post-crash rescue:

Advanced eCall
eCall: This is a system fitted to a vehicle that sends an automatic message to an emergency call centre in case of a crash of the vehicle. eCall technology capable of sending advanced content, beyond what is legally specified (ECE 144), is referred to as eCall+ or Advanced eCall. Euro NCAP awards points to those vehicle manufacturers that go beyond this and includes extra data such as number of occupants, type of impact, vehicle orientation etc. (and in 2024 the severity of the impact using the Delta V of the vehicle).

Table 1. List of Advanced eCall parameters.

Parameter	**Mandated in eCall (ECE 144)**
Vehicle ID (VIN)	●
Propulsion type (energy storage)	●
Timestamp	●
Vehicle location	●
Vehicle direction	●
Number of occupants	○
Type of impact (front, side, rear)	○
Vehicle orientation (on wheels, on roof)	○
Crash severity/degree of potential injuries	○
Detection (water, smoke, ...)	○

Post-crash braking technology

Multi Collision Brake (MCB): This is a system fitted to a vehicle that applies the brakes to prevent or mitigate a subsequent impact when a vehicle has been involved in a collision of sufficient severity. In response to a primary collision with or without airbag deployment, information is sent to the braking system to decelerate the vehicle with the intention to bring the vehicle to a standstill. It must not be possible to deactivate the MCB by the driver. After a crash and the vehicle coming to a standstill it is allowed for the MCB to release the brakes in order to help first responders move the vehicle. The test procedure for the Multi Collision Brake technology consists of two parts: Part A) a destruction-free demonstration of braking caused by the MCB trigger signal and Part B) documentation showing that the MCB trigger signal is sent during a Frontal crash test.

UPDATES TO THE RESCUE PROTOCOL 2023

The 2020 protocol will be expanded in 2023 to include the following new items [5]:

New requirements on manufacturers to provide Rescue sheets to be in all EU languages (following technical bulletin 002) and for all models on sale (since 2020). Euro NCAP does not test every model available from a vehicle manufacturer and therefore with this new requirement it is anticipated that the availability of Rescue Sheets for an entire OEM's range will soon become the norm and also be more relevant for all EU first responders, being available in all EU languages rather than just 4 as was previously required by Euro NCAP. This is a pre-requisite for scoring points for Rescue in 2023.

Provide rescue information in the expanded ISO format (technical bulletin 030).
Euro NCAP will closely follow the work of ISO, and as standard 17840 is updated and improved Euro NCAP will also align its rescue sheet requirements with these ISO updates.

Provide Emergency Response Guide (ERG) to be available for all power sources, not just electric vehicles.
One unique ERG that covers all the cars from the same brand is accepted. It is possible for the OEM to produce just one ERG covering all models for a brand or one ERG for each model range, that is at the discretion of the OEM. In chapter 0 of the ERG the scope of the document should be mentioned – it should be clear which car models/energy types the ERG applies to. A penalty (-1 point) will be applied, where the ISO compliant ERG is not available for the tested vehicle.

EV and hybrid vehicle compliance with ECE regulations regarding electrical vehicle safety
With the increasing number of EVs on Europe's roads an additional post-crash check has been added to the Rescue assessment from 2023 onwards. After the official Euro NCAP crash tests a compliance check will be made to assess if the post-crash requirements from ECE R94, ECE R95, ECE R135 and ECE R137 for EVs and Hybrids have been met. A maximum -1 point penalty will be applied if the vehicle is not compliant.

Use of correct labels on vehicle, marking potential hazards and making it easier to identify relevant hazard as well as select the right equipment to disable car energy (electricity, CNG, H_2, etc). The making safe/disabling of on-board energy in vehicles (high-voltage electricity, pressurised or liquified gas etc) is a major challenge for the safe execution of emergency operations. As part of good practice, many vehicle manufacturers have taken the initiative to position stickers on vehicles, specifying for some, the type of energy on board, and for others the location and/or action to be carried out (e-plug handling, service plug handling, valve handling, isolation loop section etc), see Figure 6. In response to the increasing number of manufacturers' differing instructions on energy neutralisation and the absence of harmonisation of procedures, there is a need for OEMs to produce common markings and in turn aid rescuers attending the vehicle. A maximum -1 point penalty will be applied if hazards are not correctly marked on the vehicle.

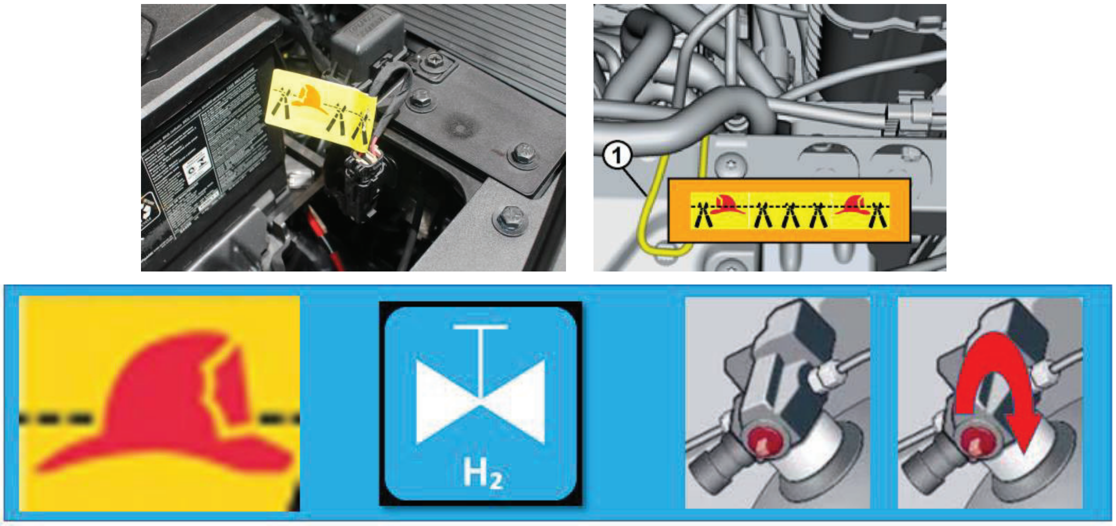

Figure 6. Examples of labels on vehicles showing rescuers where to cut / disable the vehicle.

Vehicle Submergence – windows and doors should still function as normal.
Vehicle submergence (vehicle entering a body of water or being surrounded by rising flood water for example) is thankfully a relatively rare occurrence on Europe's roads. However, when it does occur the outcome for the occupants is usually very serious. Therefore, Euro NCAP has introduced some simple requirements to ensure side windows can still be operated and side doors can still be opened during a submergence type incident to enable the occupants to help themselves and exit the vehicle in the early stages of submergence. The Euro NCAP test laboratory will perform the door check and the vehicle manufacturer shall provide a dossier covering the window opening/operation checks.

Advanced eCall and Third-Party Service eCall (TPS): new elements added such as hazard detection, multi-language communication etc.
Digital information sent out at the time of the crash could help Rescue Teams to be prepared for the intervention at the moment they receive the call. Information like the number of occupants, the direction of impact, severity of the impact could help rescuers to estimate the equipment necessary for their intervention. The early identification of the crashed vehicle through the e-Call makes it possible to establish a link with its Rescue Sheet and ERG which contains the essential information necessary for first responders. In order to score points TPS should be fitted as standard in all countries where the Euro NCAP star rating is applicable. If it is not allowed due to governmental laws / regulations to use the TPS eCall in a specific country, then only the legislative eCall needs to be applied.

Accuracy of Event Data Recorder (EDR) will be checked after the crash tests. Clear guidelines to be followed regarding eCall delta-V and location of impact following ASN1 format described in Euro NCAP *Technical Bulletin 040 eCall Additional Data Concept Triggering Incident v1.0.* (from 2024) [6]. An Event Data Recorder or EDR is a function or device installed in a vehicle that records technical vehicle and occupant information for a brief period of time before, during and after a collision, for the purpose of monitoring and assessing vehicle safety system performance. Euro NCAP wants to ensure that if a vehicle is sending EDR data that this data is actually accurate and providing useful information to the rescue services in order that they can send the relevant rescue teams and equipment. The data sent through the eCall system (Delta Vx in the frontal impacts, monitoring only for Vy in lateral impacts) must be within a tolerance of +/- 10km/h from the reference data measured by the test laboratory.

Overview of Updated 2023 Rating and Scoring

The 2023 overall rating spreadsheet extract in Figure 7 below shows that Rescue remains part of AOP area. From 2023 the points assigned to Rescue increase from 2 to 4 points.

	AOP (total 40 pts)	COP (total 49 pts)	VRU (total 63 pts)	SA (total 18 pts)
	Front MPDB (8)	Dynamic front (16)	Adult head form (6)	Occupant State (3)
	Front FW (8)	Dynamic side (8)	Child head form (6)	SAS (3)
	Side AMDB (6)	CRS installation (12)	Cyclist head form (6)	AEB/AES C2C Head-on (1)
	Side pole (6)	Vehicle based (13)	Leg form(s) (18)	LSS C2C (3)
	Far side (4)		*LSS PTW (3)	AEB/AES C2C Crossing (4)
	Whiplash F/R (4)		*AEB PTW (6)	AEB/AES C2C Rear (4)
	Rescue (4)		*AEB/AES Pe (7)	
			*AEB Reverse Pe (2)	
			*AEB/AES Cy (9)	
★★★★★	≥32 pts (80%)	≥39.2 pts (80%)	≥44.1 (70%)	≥12.6 pts (70%)
★★★★	≥24 pts (60%)	≥23.4 pts (60%)	≥31.5 (50%)	≥9 pts (50%)

Figure 7. Rating scheme for 2023, including the 4 points score for Rescue under AOP.

The breakdown of the points scoring in 2023 and 2024 is as follows: if for the tested vehicle, ISO compliant Rescue Sheet and ERG are available and meeting the requirements of Chapter 4 of the protocol, a maximum of 4 points can be scored:

- **1 point** if the vehicle is equipped with Advanced eCall (based on 112 eCall) in accordance with the requirements in Chapter 6 of the protocol:

  2023:
  Potential number of occupants 0.50 points
  Recent locations N1 & N2 0.50 points
  Direction of impact & Delta V 0.00 points

  2024:
  Potential number of occupants 0.33 points
  Recent locations N1 & N2 0.33 points
  Direction of impact & Delta V 0.33 points

- **1 point** maximum for Third Party Service eCall (TPS eCall) in accordance with the requirements in Chapter 6 of the protocol:
  Multi-language communication 0.5 points
  Hazard detection 0.5 points
  Transfer of paired mobile number 0.5 points
  Transfer of vehicle type 0.5 points
  Additional functions (subject to acceptance by Euro NCAP and CTIF) 0.5 points

- **1 point** Vehicle Submergence countermeasures in accordance with the requirements in Chapter 8 of the protocol
  Door opening with vehicle 12V disabled 0.5 points
  Window opening functionality 0.5 points

- **1 point** can be scored when the vehicle is equipped with Multi-Collision Brake technology in accordance with the requirements in Chapter 7 of the protocol. If these technologies are optional equipment they must meet the Vehicle Selection, Specification, Testing and Retesting (VSSTR) protocol fitment requirements to be awarded.

FUTURE WORK 2026 AND BEYOND

In November 2022, Euro NCAP published its strategic goals for the period up to 2030 [7]. The current rating scheme will be replaced in 2026 with a system identifying four phases of a vehicle accident: safe driving, crash avoidance, crash protection and post-crash safety. The final phase covers the tertiary safety assessment, which is now more logically placed in the rating scheme.

The starting point of the next development of the Rescue protocol is the situation in 2023 (up to and including 2025): the Euro Rescue app (Euro NCAP, 2022) offers post-crash rescue information in all European languages, greatly improving accessibility and ease-of-use for first responders across Europe, verifies easy extrication and has put incentives in place for post-crash technology.

Euro NCAP will closely follow the development of ISO 17840 and, where necessary, complement the standard. This is particularly true for (Lithium-Ion) battery electric, fuel-cell, and hydrogen cars, which pose specific safety risks to first responders, such as thermal runaway, battery reignition and stranded energy.

From CTIF real world experience disabling energy procedures are very different from one car manufacturer to another (different devices to use, different locations, with alternative option or not). Euro NCAP would like to make it easier for the first responders and the actions needed to disable energy within a vehicle.

It will also support the rollout of extended eCall functionalities, smarter blue light dispatching, and en-route support built on communication services. This includes intelligent eCall or dCall services, a system for dispatching doctors, based on calculations of probability of risk to driver and passengers. This calculation can be done either by the vehicle, which can then send the probability of injury with the e-Call message, or the PSAP can derive the injury probability, or urgency, from vehicle delta-v using a centralised and standardised method (such as the algorithm and parameters under review in ISO TC22/SC36/WG7) relevant to the European market.

Other supported advanced eCall services may include the inclusion of VRU accidents, such as pedestrians and bicycle, and automatic notification of thermal incidents, with or without the occurrence of a crash.

Looking to the future, it is possible that internal sensors could transfer live the images and vital life signs of injured persons, such as heart rate, breathing etc., taken from in-cabin sensors, allowing for instance an assessment of driver consciousness.

CONCLUSIONS

As first NCAP in the world, Euro NCAP has started to promote post-crash safety as part of its consumer protection programme. Building on the ISO work and experience of the vehicle industry and firefighters' community, Euro NCAP developed the first assessment protocol which came into force in 2020. To support first responders, it also launched the Euro Rescue application providing basic Rescue information for the European market. Since the introduction, further improvements have been made to the protocol and these will be applied from 2023. Euro NCAP's roadmap 2030 is paving the way for future work of Rescue, Extrication and Safety Group, in particular by focusing on accidents with vulnerable road users, on vehicles using new energy type and on improvement of digital information given by e-Call and in-vehicle sensors. Euro NCAP will continue to work with CTIF in parallel to promote best practice intervention procedures for first responders in Europe and all over the world, understanding that the most efficient organisation of rescue intervention is done at national and regional level.

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7. Euro NCAP Vision 2030, A Safer Future for Mobility, November 2022.

ACKNOWLEDGEMENTS

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Appendix I

Rescue 2023 topics from vehicle rating spreadsheet

Rescue, Extrication & Safety

RESCUE	AVAILABILITY	COMPLIANCE
ISO Compliant Rescue sheet		
Availble for Model tested - All EAA languages	PASS	PASS
Available for all other cars from OEM (launched 2020 onwards)	PASS	PASS
Emergency Response Guide for tested variant	PASS	
RESCUE ASSESSMENT	**0.000**	

EXTRICATION	MPDB		FW		AE-MDB		POLE	
	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side
Automatic Door Locking (if applicable)								
Front								
Rear								
Automatic door locking assessment	**0.000**							
	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side
Door opening forces - N								
Front								
Rear								
Door opening force assessment	**0.000**							
	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side
Retracting door handles (if applicable)								
Front								
Rear								
Retracting door handles assessment	**0.000**							
	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side	Driver side	Passenger side
Seatbelt buckle unlatching - N								
Front								
Rear								
Seatbelt buckle unlatching assessment	**0.000**							
Compliance with ECE regulations re EV safety	PASS							
Identification of Direct Hazard Disabling Equipment	PASS							
EXTRICATION ASSESSMENT	**0.000**							

POST-CRASH TECHNOLOGY		
Advanced eCall		
Potential # of occupants	PASS	**0.33**
Recent vehicle locations N1 & N2	PASS	**0.33**
Direction of impact & Delta V	PASS	**0.33**
Advanced eCall assessment	**1.00**	
Third Party Service eCall		
Multi-language communication	PASS	**0.50**
Hazard detection	PASS	**0.50**
Transfer of paired mobile number	FAIL	**0.00**
Transfer of vehicle type	FAIL	**0.00**
Any new function	FAIL	**0.00**
Third party eCall assessment	**1.00**	
Vehicle Submergence		
Door opening check	PASS	**0.50**
Window opening check	PASS	**0.50**
Vehicle submergence assessment	**1.00**	
Multi Collision Brake		
Name	MCB	**1.000**
Description in manual	PASS	
Deceleration during activation	PASS	
Brake light activation	PASS	
Multi-collision brake assessment	**1.00**	
POST-CRASH TECHNOLOGY ASSESSMENT	**4.000**	

SUMMARY	
Rescue	**0.000**
Extrication	**0.000**
Post-crash technology	**4.000**
TOTAL RESCUE, EXTRICATION & SAFETY	**4.000**

DEVELOPMENT OF A DIRECT DRIVER STATUS MONITORING ASSESSMENT SCHEME

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Paper Number 23-0289

ABSTRACT

Analysis of naturalistic driving behaviour shows that engaging in visually demanding tasks and driving while drowsy results in higher near crash/crash risk. In addition, increasingly busy global traffic environments, the trend of vehicles being marketed on their connectivity and ever growing screens loaded with potentially distracting features, it becomes necessary for technology to encourage safe and attentive driving.

Indirect monitoring systems have featured in vehicles for many years, identifying decaying control accuracy and advising the driver to take a break. A new development is direct driver status monitoring, typically using infrared camera technology to directly observe the driver's facial orientation, glance behaviour and eyelid aperture, enabling real time assessment of attentiveness.

The aim of this research was to develop a test and assessment protocol grounded in real world data to guide the development and evaluate, in an objective and repeatable format, the performance of systems targeted at addressing the most common attributes of the inattentive driver problem to the benefit of road safety.

A test and assessment scheme were developed that was proven to successfully enable the differentiation of pioneer direct driver status monitoring systems for inattention in the form of distraction, fatigue and unresponsive driver. This has been adopted by Euro NCAP to guide the development of new systems entering the market. providing consumers with independent information supporting them making safer vehicle choices.

Parameters for warning and intervention strategies were carefully considered to balance the desire for effectiveness in test scenarios with driver acceptance to achieve real world effectiveness. The testing requirements for driver status monitoring systems were novel in that the test driver is necessarily the test subject triggering the system. Therefore, research testing was conducted to refine the driver glance behaviours, necessary measures and associated instrumentation to deliver repeatable testing.

This initial iteration of the scheme was guided by nascent market technology enabling direct monitoring of the drivers face and eyes, and to a certain extent, seating posture. Future technical innovations will see the monitoring scope increase from that of the driver's face to the cabin of the vehicle, and it is recommended that a future generation of the scheme take full advantage of the opportunities of understanding not only the driver attentiveness, but their seating position and posture, hand position and occupancy etc. as well as the presence and attributes other passengers in the vehicle.

INTRODUCTION

Analysis of driver attentiveness in naturalistic driving studies [1] shows that engaging in visually demanding tasks (even for two second glances) and driving while drowsy result in higher near crash/crash risk [2]. The National Highway Traffic Safety Administration (NHTSA) term distracted driving as 'risky driving' and cite it as 'dangerous', claiming 3,142 lives in the United States in 2020 [3].

Allied to this, there is the continuing global megatrend towards urbanisation and an increasingly busy global traffic environment [4]. In the developed world there is a diverse mix of traffic participants including a growing proportion of Vulnerable Road Users (VRUs) in line with the sustainable transport agenda. Considering the vehicles themselves, there is the trend towards cars being marketed on their connectivity and screen-based user interfaces are being employed not only for infotainment, but also for everyday controls, necessitating driver direct attention to manipulate because of their absent tactility. Some even enable internet browsing whilst the vehicle is in motion! Acknowledging these factors competing for driver attention, in parallel with the proliferation of mobile device use whilst driving, it has become necessary for technology to encourage safe and attentive driving to maintain and improve road traffic safety.

Figure 1 illustrates how inattentiveness to driving can be split into two headline categories: distraction and impairment. In the context of driving, both distraction and impairment affect the driver’s ability to perceive the surrounding vehicle, road and traffic environment. Impairment also challenges driver’s ability interpret and respond appropriately because cognitive processes and actuation capabilities are also affected, whereas a previously distracted driver has the ability to quickly redevelop situational awareness and maintains the interpretation and actuation capabilities. Therefore, specific strategies were developed to support drivers exhibiting distraction and impairment behaviours.

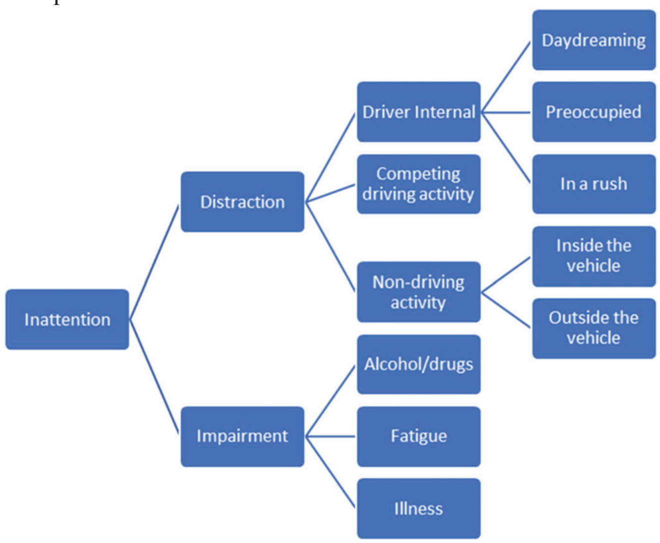

Figure 1 – Categorisation of driver inattentiveness

Indirect driver attentiveness monitoring systems have featured in vehicles for many years, typically observing journey duration, driver inputs or vehicle control (e.g., lane positioning consistency) to identify decaying control accuracy, subsequently advising the driver to take a break. The advantage of indirect monitoring is it can be readily implemented using existing modern vehicle hardware, requiring the engineering of an appropriate interface. It can be effective at discerning the characteristics of impaired driving by observing poor dynamic control e.g., in the case of substance abuse, and as they develop over time e.g., in the case of fatigue. However, its ability to detect distraction or illness is limited because these inattentions present momentarily rather than exhibit over an observable history.

Figure 2 – A typical indirect driver status monitoring output (Ŝkoda)

A new development is direct driver status monitoring, driven not only by the potential safety benefit of addressing inattentive driving, but also the need for observing the driver status to safely implement automated driving. Such systems typically use infrared camera technology, mounted immediately in front of the driver in the instrument panel or offset to one side in the central infotainment stack, to directly observe the driver’s facial orientation, glance behaviour and eyelid aperture opening. The benefit of direct monitoring over indirect is the ability to determine real time attentiveness, and therefore support addressing the momentary distracted driver and illness related safety issues. However, its effectiveness relies on the ability to accurately detect and classify the driver status acknowledging their personal characteristics e.g., facial and eye shape, skin tone etc., occlusions e.g., facial hair, makeup, head and face wear etc. and under the wide range of conditions in which vehicles are used e.g., lighting and temperature etc.

Figure 3 – An example of a direct driver status monitoring system (Valeo)

AIM

The aim of this research was to develop a test and assessment protocol grounded in real world data to guide the development and evaluate, in an objective and repeatable format, the performance of systems targeted at addressing the most common attributes of the inattentive driver problem to the benefit of road safety. It will provide the consumer with information describing the system capability, performance and limitations in use, and help them understand the system and how to use it effectively and responsibly.

SCOPE

An analysis of Britain's official Road Accident Statistics (STATS19) for 2018 identified that for factors relevant to driver status monitoring (highlighted rows in table 1), inattention was identified as a contributory factor in 14 per cent of all road traffic collisions, rising to 26 per cent of fatal collisions. Approximately half were alcohol or illicit/medicinal drugs related across all severities, with the remainder distributed across sudden illness, fatigue and distraction.

Table 1: STATS19 2018 data for impairment or distraction contributory factors

	Fatal accidents		Serious accidents		Slight accidents		All accidents	
Contributory factor reported in accident	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Impairment or distraction	**390**	**26.8**	**3,089**	**16.6**	**9,137**	**14.1**	**12,616**	**14.8**
Driver/Rider impaired by alcohol	117	8.0	1,186	6.4	3,048	4.7	4,351	5.1
Driver/Rider impaired by drugs (illicit or medicinal)	80	5.5	404	2.2	837	1.3	1,321	1.6
Fatigue	62	4.3	339	1.8	1,127	1.7	1,528	1.8
Uncorrected, defective eyesight	3	0.2	53	0.3	140	0.2	196	0.2
Driver/Rider illness or disability, mental or physical	110	8.0	584	3.1	1,395	2.2	2,089	2.5
Not displaying lights at night or in poor visibility	4	0.3	87	0.5	201	0.3	292	0.3
Rider wearing dark clothing	6	0.4	88	0.5	314	0.5	408	0.5
Driver using mobile phone	25	1.7	92	0.5	306	0.5	423	0.5
Distraction in vehicle	68	4.7	540	2.9	2,039	3.1	2,647	3.1
Distraction outside vehicle	17	1.2	236	1.3	984	1.5	1,237	1.5

It is anticipated that the data related to impairment by alcohol and drugs are representative because presence can be confirmed by laboratory testing if suspected as a contributory factory. However, those pertaining to fatigue and distraction, and in some cases illness, are anticipated to be underestimation because physical they are transient states: tests to confirm do not exist, and identification as a contributory factor is reliant upon witness evidence or confession by the culprit if they are able to do so, potentially incriminating themself in the process.

The accident data indicates for an assessment of systems addressing inattentive driving to have effective real world performance it must cover both distraction and impairment, with impairment including alcohol and drug driving, fatigue and illness.

Identification of alcohol or drug impaired driving by a driver status monitoring system during a journey poses the question regarding reliability of detection and what action the vehicle should take given that it is illegal to be in control of a motor vehicle whilst impaired to a greater or lesser extent. In this initial step, it was decided that because the behaviours and driving performance exhibited by the driver under the influence of alcohol or drugs can be similar to those pertaining to fatigue, deployment of the same warning and intervention strategies were considered as being acceptable. This will be reviewed when developing the scheme in the future acknowledging the latest developments in sensing and interpretation capability and warning and intervention strategies.

The road safety issue of distraction associated with the use of nomadic devices (mobile/cell phones and tablets etc.) whilst driving is of increasing societal interest because of the perceived risk and media reporting of high profile road traffic collisions. Numerous national and state governments have focused attention on the topic, initiating or ratcheting up penalty schemes for drivers caught using nomadic devices whilst driving to deter use. Practically speaking it makes little difference whether the driver is distracted by a nomadic device, vehicle-borne aspects or an external factor, yet given the high profile nature of the topic, it was decided to specifically address it as a distinct element of the testing and assessment scheme to promote the concept and acceptance of driver status monitoring systems across all road users.

ASSESSMENT SCHEME DEVELOPMENT

Background

Given the emerging nature of driver status monitoring technology, no published literature existed illustrating the nature of the driver inattention to the level of detail necessary to develop an effective test and assessment scheme. To gain the necessary information a process of liaison with relevant research and automotive industry stakeholders was pursued under the auspices of the Euro NCAP Occupant Status Monitoring (OSM) Working Group, with:

- The European Automobile Manufacturers' Association (ACEA) representing Original Equipment Manufacturers (OEMs)
- The European Association of Automotive Suppliers (CLEPA) representing the automotive supply chain
- A sub-group of the supply chain specifically representing global driver status monitoring system technology providers

Given the proprietary nature of the information shared it remains confidential to the Working Group, however the decisions it informed are illustrated. Only previously published information is referenced in this paper.

Noise Variables

An initial priority was to identify the noise variables necessarily covered to promote robust driver detection and status classification. It was deemed that to be effective, the system must monitor a population constituted of different types of drivers, with a range of facial occlusions and driver behaviours. Depending on the complexity of the noise variables, the coverage requirements vary between 'Must', 'Inform driver if degraded', and 'Information only'.

Driver attribute ranges necessarily covered to promote robust driver detection and status classification were identified as:

- Age — Youthful (16 to 18) to aged (≥80)
- Sex — All
- Stature — AF05 to AM95
- Skin complexion — Fitzpatrick skin type 1 to 6
- Eyelid aperture — From 6.0mm up to 14.0mm

A number of typical real world driving variables were identified that may affect driver status monitoring system performance. These occlusions were classified as those potentially obscuring the driver's facial features, for which the system must work:

• Ambient lighting	<1 lux to >100,000 lux
• Eyewear	Clear glasses and sunglasses with transmittance >70%
• Facial hair)	Short <20mm in length

and those potentially obscuring the driver's face, in which case the driver must be informed within ten seconds if the system performance is degraded:

• Hand on wheel	One hand on steering wheel at 12 o'clock position
• Facial occlusion	Facemask, hats, long head hair fringe obscuring eyes
• Eyewear	Sunglasses with a transmittance <15%
• Eyelash makeup	Thick eyelash makeup
• Facial hair	Long >150mm in length

Other driver activities e.g., eating, talking, laughing and singing and smoking/vaping etc. were also considered to understand the effect that may have on the driver status monitoring system.

Driver State

The industry consultations were also used in conjunction with the real world data to identify the inattentive driver states presenting the greatest risk to road safety, considering the eyes off forward road view time, the nature of the glance behaviour and the ability to recover safe control of the vehicle. Three headline driver states were defined:

• Distraction	For the purposes of the initial scheme, eyes off forward road view.
• Fatigue	Builds up over time from drowsiness, through micro-sleep and to sleep
• Unresponsive driver	Onset of sudden illness, or failing to recover from distraction or fatigue

<u>Distraction</u>

Distraction was categorised into three types, with eyes off the forward road view:

• Long distraction	Continuous glance to a single fixed location
• Short multiple distraction	Also known as Visual Attention Time Sharing (VATS) – repeated short duration glances to the same or different locations
• Phone use	Basic (not within the driver's view of the windscreen) and advanced (within the driver's view of the windscreen)

Two types of gaze movement were defined, acknowledging the overt and covert nature of driver glance behaviour, with a view differentiating the ability of systems to discern between facial orientation eye gaze vector [5]:

• Owl type movement	A shifting of visual attention away from the road and forward-facing position that is primarily achieved by head rotation followed by the eyes
• Lizard type movement	A movement in which the driver focuses on a task by moving primarily their eyeline away from the road with their head/face remaining in the forward-facing position.

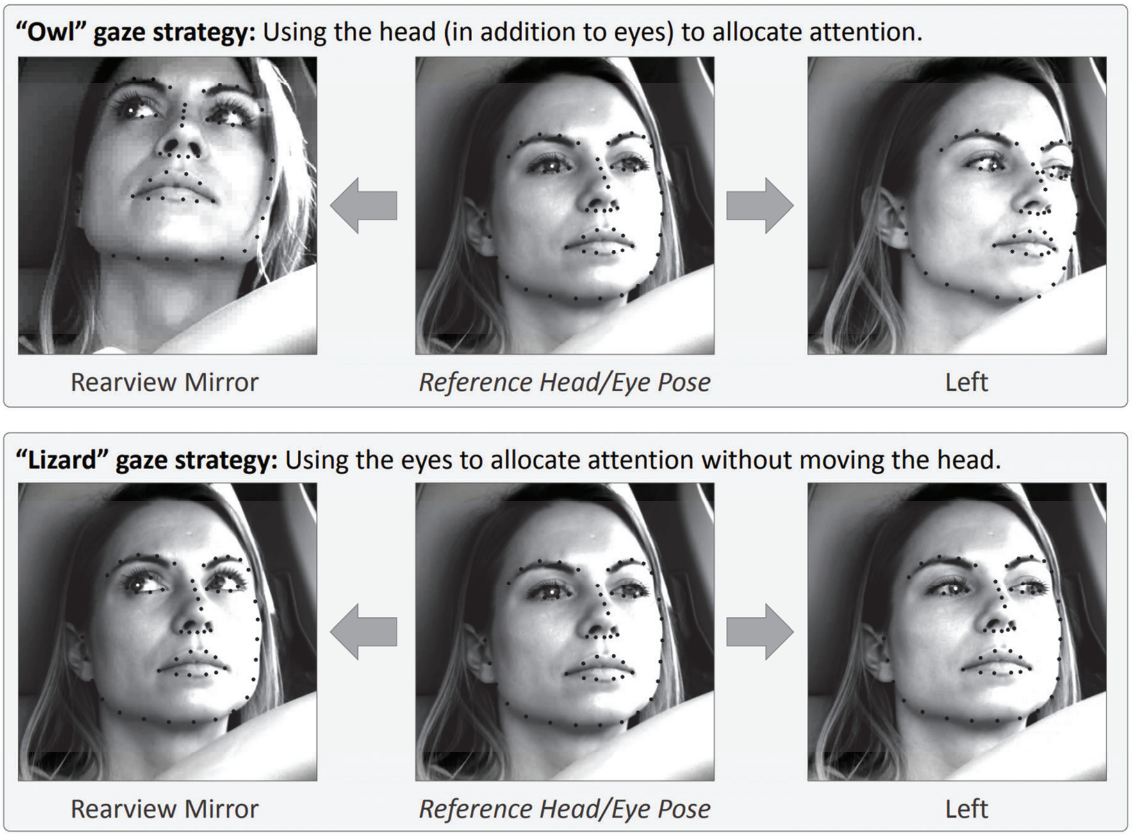

Figure 4 – An illustration of owl and lizard gaze strategies

A range of common gaze locations were identified based on naturalistic driving studies, differentiated by whether they were non-driving related locations e.g., side windows or in-vehicle infotainment system, or driving related tasks e.g., rear view/door mirrors on instrumentation cluster. See the Euro NCAP assessment protocol [6] and technical bulletin [7] for full details.

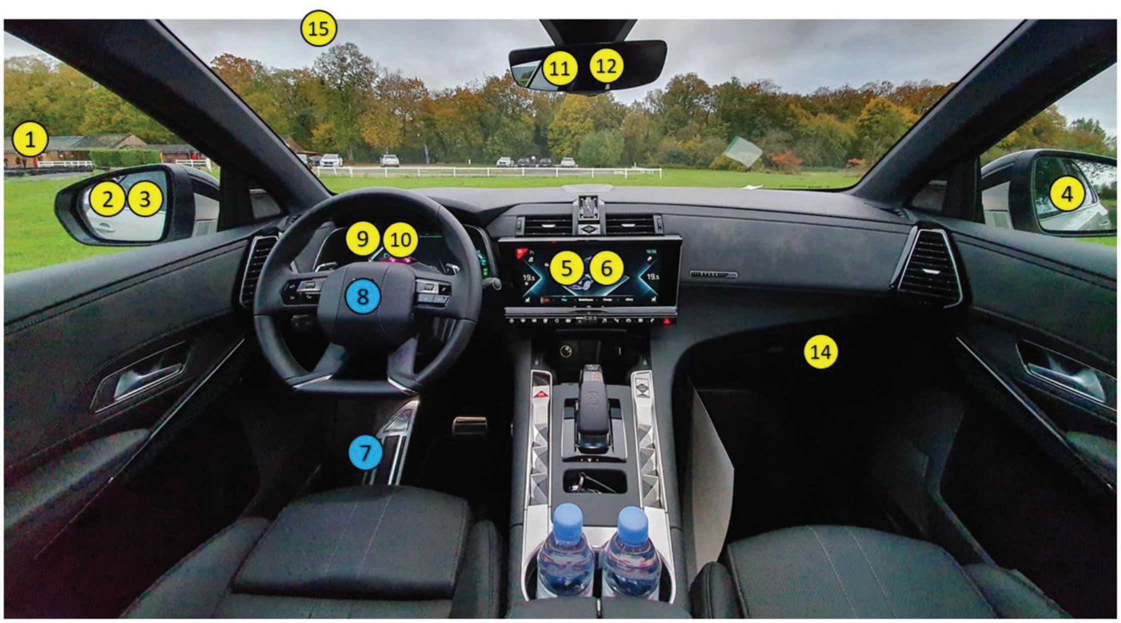

Figure 5 – Example distraction gaze locations (Euro NCAP Technical Bulletin 039)

Regarding long distraction, a critical aspect of the real world effectiveness and acceptance of driver status monitoring systems regarding distraction is the timing of the distraction classification. Too short timing will likely annoy the driver because of perceived unjustified activations, eroding their confidence in and acceptance of the system, ultimately resulting in system deactivation. Conversely too long timing risks only addressing the longest of eyes off forward road view events, limiting system effectiveness in potentially critical situations, and limiting any coaching effect of the driver. Research [8] indicates drivers exhibit a consistent metronomic glance tempo i.e., similar duration on road and other location glances when attending to secondary tasks, however the variation between individual drivers is large, with the slowest tempo being three times slower than the fastest.

Acknowledging this evidence, the timing for classifying long distraction was set at three seconds from the gaze landing on the location, with a tolerance of plus one second where compelling evidence is provided justifying why a later classification was employed. The time taken for gaze to transition from the forward road view to the location is not considered within these three seconds, hence the time for eyes off forward road view is greater than three seconds, falling further into line with the research data.

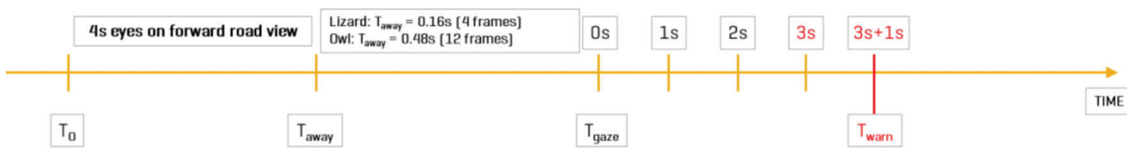

Figure 6 – Timeline for long distraction classification

Short distraction was considered to be repeated glances away from the forward road view either repeated towards one location, or to multiple different locations. A short distraction event is a build-up of multiple glances away from the forward road view and is considered to end when the driver's attention returns to the forward road view for a period long enough for the driver to fully interpret the road situation.

Numerous algorithms for classifying short distraction have been proposed based on cumulative eyes off road time, either allied to current glance location and associated transitions or in conjunction with a buffering and reset concept, as well as considering other information sources available within the modern vehicle. For the purposes of the scheme, a simple example of when a driver glances away from the forward road view for a cumulative period of ten seconds within a thirty second time period was illustrated, where the time period is reset if the driver's glance returns to the forward road view for a period greater than two seconds. However alternative approaches will be considered where compelling evidence illustrating and justifying their efficacy is provided.

Phone use was considered to be a specific type of short distraction event where the driver's repeated gaze is towards their mobile phone, hence the detection and classification requirements mirror those set out for short distraction, albeit with dedication gaze locations for basic and advanced detection.

Fatigue

Fatigue was categorised into three stages, representing the natural development over time:

- Drowsiness — Classification when KSS level greater than seven at the latest, or an equivalent measure
- Microsleep — Eye closure of less than three seconds with loss of conscious control
- Sleep — Continued eye closure greater than three seconds

Acknowledging that as drowsiness develops, its effects are observable over a history, both direct and indirect means of sensing systems are recognised as being suitable to detect the onset, and indeed encouraged to achieve a robust and effective system.

The microsleep threshold of eye closure of less than three seconds was selected based on data illustrating microsleep events whilst driving can be as short as one to two seconds in duration, and to drive technical innovation acknowledging the potential road safety risk associated with even short periods of inattention. It is acknowledged that non-eye closure microsleep events are possible, however given the nascence of driver status monitoring, detection and classification of such events is beyond the current state of the art. For systems less sensitive to short duration eye closure indicating microsleep, the sleep detection threshold was set at greater than three seconds, and up to a maximum of six seconds is permitted to classify a driver as sleeping to promote timely detection and response.

Unresponsive Driver

The unresponsive driver classification is designed to capture the sudden onset of illness. It is likely, but not certain, that initially an unresponsive driver will be display behaviours akin to and be classified as either distracted or asleep. For the purposes of the scheme, unresponsiveness is classified by the driver not returning their gaze to the forward road view within three seconds of an inattention warning being issued, or when the driver gaze has been away from the forward road view or has been eyes closed for greater than six seconds.

Vehicle Response Requirements

The vehicle response requirements illustrate warning and/or intervention strategies to apply in case the driver is classified as inattentive. These strategies vary depending on the type and duration of inattention, with the intention of providing optimised support to the driver in case a critical traffic situation arises whilst they are inattentive, and warning them to reengage if they remain inattentive for an extended period. This warning process may also have a training effect identifying what is an unacceptably long eyes off forward road view glance.

The warning timings for distraction and fatigue were fixed as illustrated previously. More flexibility has been permitted in the intervention requirements acknowledging the nascence of the technology and to encourage the automotive industry to develop innovative strategies. Strategies proposed include:

- High sensitivity FCW setting, to be activated after greater than one second of continuous gaze away from forward road view, until driver attention is restored, or
- Low level braking intervention, where low level braking begins immediately after the driver is classified as distracted and continues until driver attention is restored, or
- Any other intervention that the OEM considers to be appropriate and can justify with supporting evidence as being effective

It is anticipated that the major benefit of driver status monitoring systems will not come from warning the driver in case of inattention, especially distraction, but in incorporating this new knowledge of the driver status into the decision making process when considering how and when to operate active safety warning systems to reengage the driver or intervene on their behalf.

RESEARCH TESTING

With requirements set for driver inattention classification and associated vehicle response, a testing mission was undertaken to develop testing methodology to evaluate the performance of driver status monitoring systems. It was imperative that this methodology enabled repeatable and reproducible testing results to be obtained and was technology independent, to encourage innovation and not favour one type of implementation over another without good reason.

The testing requirements for driver status monitoring systems are novel in that the test driver is necessarily the test subject triggering the system. The behaviours requiring performing are not aligned with safe driving practices on the test track, therefore to manage risk, a lookout was required, either in the vehicle, or externally and in direct communication with the test driver.

The testing requirements for distraction are relatively basic because of the momentary nature of the behaviour, namely recording data to confirm:

- Straight driving at a constant speed
- The driver delivering the appropriate distraction scenario to the gaze location using the appropriate movement type (owl or lizard)
- The timing of the warning or intervention relative to the driver glance

The testing requirements for fatigue proved more complex because of the developing nature of the behaviour, and also depended on the architecture of the driver status monitoring system. Systems that responded to sudden, acted microsleep and sleep were no more difficult to test than for distraction, but arguably potentially less sensitive to the real world naturalistic decay in responsiveness and control. Some required a historical drive cycle of inert driving, maintaining at least moderate speeds with limited dynamic interactivity, reminiscent of highway driving, to establish a potentially drowsy driver scenario ahead of issuing fatigue warnings. Such systems proved particularly challenging to assess repeatably on the test track, both in terms of time taken and consistency of results achieved given the acted driver state. However, the test data requirements for such systems were no more complex than those for distraction, hence distraction scenarios were used to develop the testing methodology and more complex fatigue driving requirements were handled on a case by case basis liaising with the original equipment manufacturer and/or supplier.

Initial testing was completed with a synchronised dual GoPro camera setup, with one rearward facing camera observing the driver glance behaviour and a second fixed observing the instrument panel to identify the warning. Vehicle dynamic data was recorded using a GPS corrected inertial dynamic measurement system. Operating the cameras at 25 frames per second enabled the warning timing to be determined to the nearest four hundredth of a second, adequate given the timeframes involved.

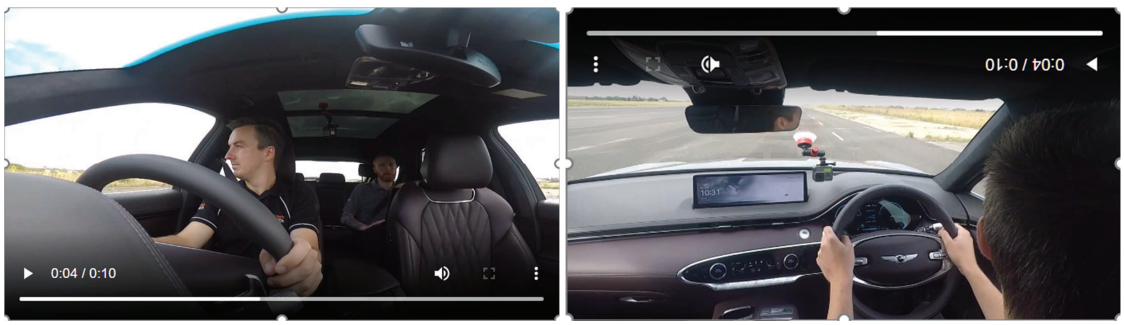

Figure 7 – Example camera views for initial testing

Whilst the camera configuration proved effective at determining the long distraction warning timing for the initial testing, inconsistencies were apparent in the results, both for individual drivers and when comparing between drivers. Reviewing the testing in more detail, three key contributory factors became apparent:

- Although attempting to mimic naturalistic behaviour, the time taken to transition from the forward road view to the gaze location differed between drivers
- With repeated manoeuvres, individual drivers tended to slow their glance transition after delivering the test numerous times
- Using the two camera setup, it was difficult to determine the timing of the driver's glance fixing on the gaze location as required for consistent warning timing analysis

Acknowledging the above findings, the camera setup was developed to include a third camera. Camera one was fixed, observing the driver's gaze on the forward road view and its initial departure. Camera two travelled to each individual gaze location to determine the when the driver's glance arrived at the location. Camera three remained the same as in the initial setup, observing the vehicle warning timing.

Testing was also undertaken with a range of participants and considered by the Working Group to determine typical glance transitions times for the owl and lizard movement types, set at 0.48 and 0.16 seconds respectively. A transition time of one second was also developed for the body lean and viewing the rear seat scenarios, both of which involve greater body movement than the owl and lizard glances.

One vehicle tested was equipped with an almost real time attentiveness meter. It was found that during the normal testing operations e.g., confirming the test scenario, setting cameras recording and checking speed etc. unsurprisingly a reduction in driver attentiveness was recognised, which in turn affected the distraction warning timing. Therefore, to achieve consistent testing, a time period of four seconds eyes on forward road view was specified ahead of initiating the gaze transition. See figure 6 for the complete testing timeline.

With the additional glance timing control limits, refinements to the instrumentation configuration and analysis process, and some test practice delivery by the engineers, repeatably testing was achieved. Owl and lizard glance transitions were being delivered repeatedly to specification and warning timings with a typical spread of

±0.1 seconds around the mean value were consistently measured. The recommendations were wholly adopted into the Euro NCAP testing methodology for driver status monitoring systems [7].

LIMITATIONS

This first iteration of a test and assessment scheme for driver status monitoring systems focuses on tangible forms of inattention, namely distraction, fatigue and unresponsive driver based on the driver's facial orientation, gaze vector and eye opening. The societal issue of mobile phone related distraction is also considered in the scheme. It has been guided by nascent market technology enabling direct monitoring of the drivers face and eyes, and to a certain extent, seating posture.

However inattention whilst driving can take many other forms as illustrated in figure 1 e.g. cognitive distraction such as being preoccupied with one's thoughts, daydreaming, engaging in a conversation with a passenger or on a mobile phone etc., physical distraction such as eating or drinking, holding something, attending to personal hygiene or grooming/preening etc. or impairment through alcohol or drug use. For a future generation of the scheme, expansion to cabin monitoring is recommended and indeed already under consideration to improve the efficacy of driver and occupant status monitoring.

The wider scope may also enable the realisation of benefits beyond those related to driver attentiveness, for example using the additional source of information for more robust confirmation of appropriate seatbelt wearing, optimisation of restraint system deployment acknowledging occupant presence, posture and stature etc. Knowledge of the status of the driver is also a key element of achieving safe automated driving and hand back process to manual driving.

The ultimate achievement for driver status monitoring would be to understand the cognitive state of the driver, e.g., understanding whether not only they have observed something, but have they correctly interpreted it and are they making an appropriate response, to address the so-called 'looked but failed to see' conflicts. An interpretation of the cognitive state of the driver could also enable vehicle parameters to be adapted to their current state of mind to the benefit of all road user safety.

CONCLUSIONS

A test and assessment scheme were developed that was proven to successfully enable the differentiation of pioneer direct driver status monitoring systems for inattention in the form of distraction, fatigue and unresponsive driver. This has been adopted by Euro NCAP to guide the development of new systems entering the market. providing consumers with independent information supporting them making safer vehicle choices.

Parameters for warning and intervention strategies were carefully considered to balance the desire for effectiveness in test scenarios with driver acceptance to achieve real world effectiveness. There is potential for driver status awareness to not only drive performance in critical situations in which the driver is inattentive, but to also quell perceived unnecessary warnings in cases where a driver is attentive and successfully addressing the issue.

The testing requirements for driver status monitoring systems were novel in that the test driver is necessarily the test subject triggering the system. Therefore research testing was conducted to refine the driver glance behaviours, necessary measures and associated instrumentation to deliver repeatable testing.

This initial iteration of the scheme was guided by nascent market technology enabling direct monitoring of the drivers face and eyes, and to a certain extent, seating posture. Future technical innovations will see the monitoring scope increase from that of the driver's face to the cabin of the vehicle, and it is recommended that a future generation of the scheme take full advantage of the opportunities of understanding not only the driver attentiveness, but their seating position and posture, hand position and occupancy etc. as well as the presence and attributes other passengers in the vehicle.

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