SoA and Benchmarking, delivrable 1.1

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Adaptive ADAS to support incapacitated drivers Mitigate Effectively risks through tailor made HMI under automation

D1.1- SoA and Benchmarking

Version number	0.2
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Dissemination level	Public
Lead contractor	CERTH/HIT
Due date	28/02/2017
Delivery date	28/02/2017
Online resource	Link-to-Deliverable

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 688900

Revision and history sheet

Version history			
Version	***Date***	***Main author(s)***	***Summary of changes***
v0.2	28/02/2017	Katerina Touliou	
	Name		***Date***
Prepared	Katerina Touliou, M. Maglavera, C. Britsas (CERTH/HIT) and WP1.1 partners		28.02.2017
Reviewed	Name of reviewer		DD.MM.YYYY
Approved	Name of authorizer		DD.MM.YYYY
Circulation			
Recipient		***Date of submission***	
European Commission		DD.MM.YYYY	
Consortium		DD.MM.YYYY	

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Glossary

Acronym	Full form	Acronym	Full form
AAM	Active Appearance Model	**EI**	Eye Index
ABS	Antilock Braking System	**EIC**	External/Internal Convertible
ACC	Advanced Cruise Control	**EMG**	electromyography
ACEM	European Association of Motorcycles Manufacturers	**EMS**	Electro Mechanical Systems
AEB	Autonomous emergency braking	**EOG**	ElectroOculoGram
AFE	Analog Front-Ends	**EOF**	Eyes-Off-Road
AFEA	Automatic Facial Expression Analysis	**ERP**	Event-Related Potential
AIDE	Adaptive Integrated Driver vehicle Interface	**ERTRAC**	European Road Transport Research Advisory Council
AIC	Akaike's Information Criterion	**ERS**	Everyday Range Stress
ANFIS	Adaptive Neuro-Fuzzy Inference System	**ES**	Erector Spinae
ANOVA	Analysis of Variance	**ESS**	Epsworth Sleepiness Scale
ANS	Autonomic Nervous System	**EV**	Electric Vehicle
AOI	Areas of Interest	**FACS**	Facial Action Coding System
API	Application Programming Interface	**FDR**	Flight Data Recorder
ASM	Active Shape Model	**FER**	Facial Emotion Recognition
ASP	Average Sleep Propensity	**FERET**	Facial Recognition Technology
ASM	Active Shape Models	**FFT**	Fast Fourier Transform
AU	Action Unit	**FLC**	Fuzzy Logic Controllers
AUC	Area Under Curve	**fMRI**	functional Magnetic Resonance Imaging
AVI	Audio Video Interleave	**FRM**	Fatigue Risk Management
AVRB	Amplitude-Velocity Ratio of Blinks	**FPGA**	Field-Programmable Gate Array
BB	Biceps Brachii	**FOV**	Field of View
BAL	Balance	**FS**	Flexor Superficialis
BBS	Bulletin Board System	**GA**	Genetic Algorithms
BT	Bluetooth	**GPS**	Global Positioning System
BEV	Battery Electric Vehicles	**GS**	Gerchberg–Saxton
BF	Biceps Formaris	**GSR**	Galvanic Skin Response
BLE	Bluetooth Low Energy	**HMI**	Human Machine Interface
BVP	Blood Volume Pressure	**HR**	Heart Rate
CLM	Constrained Local Model	**HRV**	Heart Rate variability
CMG	Control Moment Gyroscope	**HA**	Highly Automated
CNN	Convolutional Neural Network	**HF**	High Frequency
CVPR	Computer Vision and Pattern Recognition	**HDRT**	Head-mounted Detection Response Task
CR	Carpi Radialis	**IMU**	Inertial Measurement Unit
CRF	Centro Ricerche Fiat	**ICA**	Independent Component Analysis
CTREE	Classification Trees	**ICEVS**	Internal Combustion Engine Vehicles
CV	cross-validation	**IVIS**	In-vehicle Information System
DAA	Driver Attention Alert	**IAF**	Individual Alpha Frequency
DAQ	Data Acquisition	**KSS**	Karolinska Sleepiness Scale
DCT	Discrete Cosine Transform	**kNN**	K Nearest Neighbour
DIMS	Driver Inattention Monitoring System	**LDF**	Linear Discriminant Function
DMVD	Dead-man's Vigilance Devices	**LF**	Low Frequency
DOA	Domain of Attraction	**LRNN**	Layer-Recurrent Neural Networks
DRN	Dynamic Relational Network	**LDA**	Linear Discriminate Analysis
DRT	Detection Response Task	**LBP**	Local Binary Patterns
DSB	Double Strand Break	**LDW**	Lane Departure Warning
DSM	Driver Status Monitor	**LD**	Latissimus Dorsi
DSMS	DataBase Management System	**LCD**	Liquid Crystal Display
DSP	Digital Signal Processing	**LKS**	Lane Keeping System
DSSQ	Dundee Stress State Questionnaire	**LED**	Light Emitting Diode
DVTCS	Vigilance Telemetric Control System	**LDC**	Linear Discriminant Classifier
ECR	Extensor Carpi Radialis	**LMPC**	Linear Model Predictive Control
EDA	electrodermal activity	**MRF**	Markov Random Fields
EEG	ElectroEncephaloGram	**MW**	Mental Workload

Acronym	Full form	Acronym	Full form
EKG	Electrocardiogram	**MoCC**	Mean of Class classifier
MAEB	Motorcycle Autonomous Emergency Braking	**ROI**	Region of Interest
MPC	Model Predictive Control	**RPM**	Revolutions per Minute
MPEG	Moving Picture Experts Group	**RSME**	Rating Scale Mental Effort
MVC	Model View Controller	**RTLX**	Raw Task Load Index
MySQL	Structured Query Language	**SHRP**	Strategic Highway Research Program
NCAP	New Car Assessment Programme	**SDK**	Software Development Kit
NFC	Near Field Communication	**SDLP**	Standard Deviation of Lateral Position
NMPC	Nonlinear Model Predictive Control	**SDM**	Supervised Descent Method
NN	Normal-to-Normal	**SDNN**	Standard Deviation of NN intervals
NIR	Near Infrared	**SIFT**	Scale-Invariant Feature Transform
PCA	Principal Component Analysis	**SMC**	Symbolic Model Checking
PERCLOS	PERcentage of eyelid CLOSure over time	**SMI**	Senso Motoric Instruments
PD	Pupil Diameter	**SNS**	Sympathetic Nervous System
PHP	Hypertext Pre Processor	**SPS**	Samn Perelli Fatigue Scale
PID	Proportional–Integral–Derivative	**ST**	Skin Temperature
PIS	Powered Two wheeler Integrated Safety	**SVM**	Support Vector Machine
PPE	Personal Protective Equipment	**SWM**	Statistical Wave Model
PRC	Percentage Road Centre	**SURT**	Surrogate Visual Research Task
PSAP	Public Safety Answering Points	**SWAT**	Subjective Workload Assessment Technique
PVT	Psychomotor Vigilance Test	**TETTC**	Time Exposed Time to Collision
PTW	Powered Two Wheelers	**TDRT**	Tactile Detection Response Task
QFT	Quantitative Feedback Theory	**TM**	Trapezius Medial
QT	Quiz Task	**TB**	Triceps Brachii
RBF	Radial Basis Function	**TLC**	Time-to-Line Crossing
RDRT	Remote Detection Response Task	**TTC**	time to collision
RFID	Radio-frequency identification	**TOR**	Take-over Request
RGB-D	Are a specific type of depth sensing devices that work in association with a RGB camera, that are able to augment the conventional image with depth information	**VAS**	Visual analogue scales
RMSSD	Root of the Mean Squared Successive Differences	**VLP**	Variation of Lane Position
RR	Respiration Rate	**VOG**	VideoOculoGraphy
ROC	Receiver-Operating Characteristic	**VRU**	Vulnerable Road Users

Executive Summary

This document does not aim to review automated vehicles' developments and technologies but automated functions in existing vehicles.
Therefore this document reports the results from the benchmarking search carried out within A1.1 for systems that are relevant to the project's preliminary Use Cases of ADAS&ME project. This report reflects the work carried out in order to reach MS2 (M3) of ADAS&ME and the literature review carried out for each affective state. However, it acted as a living document until the submission of D1.1 (M6) to be incorporated in the main body of D1.1. In general, benchmarking is considered a continuous and systematic approach to measure the processes and outputs against the most relevant (and occasionally) toughest competitors in the business, or at least the most prominent/ profitable ones. This is a so called competitive benchmarking approach. Three different types of results are included in this document: a) benchmarking of driver and rider monitoring systems, b) literature search and reviews of literature on drive/rider affective states as defined within DoA and UCs, and, lastly, c) alignment of the SoA collected, systems benchmarked; with key selected organization's priorities and roadmaps about automated vehicle systems and functions.

The deliverable opens with the introduction to automation, the objectives of the document, the working group that was involved in A1.1 and worked towards this compilation and the contribution of this document to the selection and refinement of the ADAS&ME Use Case **(Chapter 1)**.
An overview of addressed affective states per Use Cases, as they are currently agreed upon, are presented in **Chapter 2**, along with their general definitions and driver monitoring techniques and systems.
Chapter 3 presents an introduction to main research findings per affective state, followed by a literature review overview table, including connection to the project and respective Use Cases. The complete compilation per affective state is included in sub-sections of Annex 1. The table at the end of the Executive Summary includes the number of journals reviewed. In addition, a short literature review was carried out to investigate the automation strategies for stabilisation mechanisms for motorcycles. The work and relevant findings are included in main the document and the rest are also in an Annex.
The literatures review is followed by the benchmarking of existing technologies (SoA) for drivers and riders per addressed affective state **(Chapter 4)**. Similarly, an overview of findings is presented in the table at the end of the summary. In addition, studies from other transport modes were reviewed, for their potential of transferring knowledge, methods and techniques. The results are summarised in a Table in **Section 4.3**, but the whole compilation of the studies was annexed.
Chapter 5 presents the alignment of A1.1 results with the efforts of several established organizations, such as ACEM, ERTRAC, NCAP and the international collaborations within CARTRE project.
The Deliverable concludes **with Chapter 6,** where an overview of the results, in terms of numbers and relevance (key categorization) to the project, are presented.

Table 1: *Overview of reviewed publications and systems*

Affective state	Literature Review publications (No.)	Studies reviewed of high relevance per UC (no.)	Systems/ algorithms/ etc. reviewed of high relevance per UC (no.)	Number of systems/algorithms/ etc. reviewed (No.)
Sleepiness	16	3 highly relevant for A, E, F, G	6 systems and 1 subjective (KSS) relevant for A, E, F, G	14 systems, 4 subjective, measures
Range anxiety	9	1 highly relevant for A, C, D, E, F & 1 highly relevant for B	2 systems for UC B	3 systems
Inattention	21	7 highly relevant for A, C, D, E, F, G	3 systems, 7 sensors, 4 algorithms, 1 subjective scale for A, C, d, E, F,	6 systems, 7 sensors, 12 algorithms, 5 subjective scales

Affective state	Literature Review publications (No.)	Studies reviewed of high relevance per UC (no.)	Systems/ algorithms/ etc. reviewed of high relevance per UC (no.)	Number of systems/algorithms/ etc. reviewed (No.)
			G	
Emotions	4	1 highly relevant for C, D, F,G	2 systems relevant, 6 face and speech apps for UCs A, C, D and one for rider UCs (i.e. wristband)	5 systems, 15 apps and APIs
Physiological states	7 (more in compilation)	1 highly relevant for E	2 systems, 5 wearable and accessories and 1 subjective measure highly related to UC E and F	4 systems, 9 wearable and accessories, and 1 subjective measures
Sources per column	57	14	40	85
Total	**196**			

1. Introduction

Vehicle automation is already an existing massive innovation, with highly potential of positively being disruptive and with anticipated exponential impacts to other areas of research, like driving style, travelling patterns and even including autonomous mobility be cars of people that could not normally be "behind the wheel", like very old people, children, people with specific disabilities (i.e. blind), etc.

ADAS&ME is an intermediate step towards full automation and addresses certain automated functions with clearly set Use Cases for different types of vehicles (passenger cars, trucks, buses and motorcycles). Vehicles with (varying levels of) automated functions already exist in the market and they include one of more technologies that aim to increase driver's comfort and safety, and operate by controlling the vehicles applying breaking, steering and throttle control. The driver may (or may not) be actively involved (e.g. switch on/off and take over control). Vehicles that have on-board systems that inform or warn the drivers (e.g. a lane departure warning systems) are not automated because they do not take control or request to take control at any point during driving. Vehicles with automated functions contain similar systems with other cars (e.g. cameras and GPS) but the vehicle takes the control in several or specific occasions. Vehicles can have one or more automated functions (e.g. cruise control is a function found in many vehicles nowadays) or be totally autonomous and self-driving.

With the goal of providing common terminology for automated driving, SAE International's new standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems, delivers a harmonized classification system and supporting definitions that is shown in the table below.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 1: *SAE International's new standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*

Ross (2014) reported that the efforts to develop autonomous driving functionality started almost thirty years, resulting in many semi-autonomous functions and features with a close look to near future launching of connected vehicles (Figure 1).

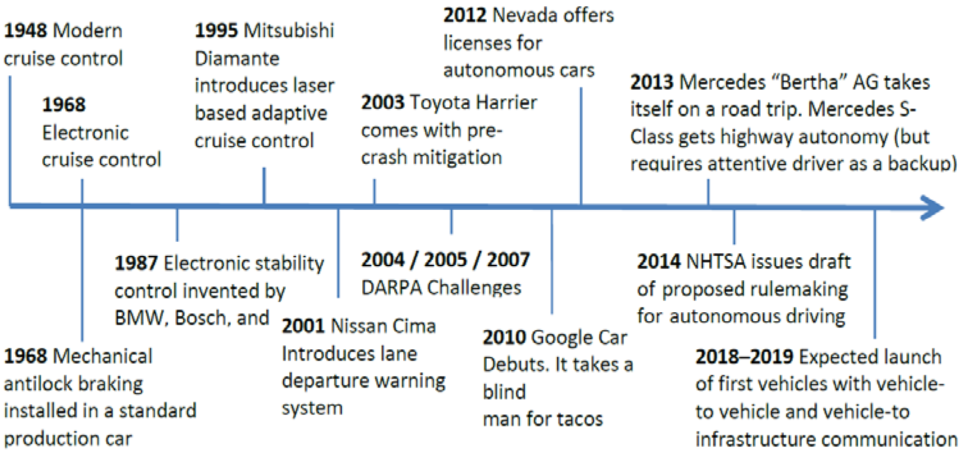

Figure 2: *History and steps taken towards automated functions and driver automation (Ross, 2014)*

This document does not aim to review automated vehicles' developments and technologies but automated functions in existing vehicles.
This report reflects the work carried out in order to reach MS2 (M3). However, it acted as a living document until the submission of D1.1 (M6) and was incorporated in the main body of this document.

In general, benchmarking is considered a continuous and systematic approach to measure the processes and outputs against the most relevant competitors in the business, or at least the most prominent/ profitable ones. This is a so called competitive benchmarking approach. First, it is important to define what benchmarking means for this report. In this report a more generic approach and the method applied are discussed in section 1.2.

Three different types of results will be included in this document: a) **benchmarking** of driver and rider monitoring systems, b) **literature search** and **reviews** of literature on drive/ rider affective states as defined within DoA and UCs, and, lastly, c) **alignment** of the SoA collected, systems benchmarked, and with key selected organization's priorities and roadmaps about automated vehicle systems and functions.

1.1 Objectives

1. The SoA aims to identify existing solutions, their performance and the current state of research with regard to sensors, algorithms, driver monitoring, automation, connectivity and HMI strategies, useful for driver state monitoring in automated vehicle scenarios.
2. The SoA utilised a common template, to perform a literature survey of at least 20 driver impairment (of different types) and 10 automation related sources.
3. It also transferred knowledge from the rail, aviation and maritime transport sectors. Results were aligned to relevant priorities, as well to the ERTRAC Automation Roadmaps.

The following steps were taken:

- Identify industrial and/or already in the market systems that have technical characteristics and specifications that could fulfil the requirements for the work carried out in the project. In particular, the following are of interest: Driver/Rider monitoring systems for various affective states ; Fatigue/ sleepiness/ drowsiness ; Stress and other emotional states.
- Consider the context (UC scenarios) and vehicle of use (i.e. passenger car, PTW, truck, bus)
- Relevance to project's systems (i.e. benchmarking makes sense only if systems are relevant; otherwise no reason to carry out the procedure).

1.2 Methodology

The following diagram presents the method adopted in order to select systems to benchmark against

the ADAS&ME requirements. This is a generic approach, where the aim is to find latest and world-class examples of a product, service or operational system and then adapt/ adjust the ADAS&ME reqirements to meet or surpass the standards set by other products/ systems.
The following diagram (Figure 3) shows the benchmarking process within the project with four main indicator clusters: a) the feedback categories as defined by the columns of the column template (i.e. 'gathered indicators' spreadsheet), b) the connection to the UCs (i.e. selection indicator), c) The 'agreement' and 'gap' indicators (part of the 'gathered indicators'). They are addressed separately, as they represent the benchmarking outcome. By agreement we mean the extent to which this system covers the requirements of the project and its systems (incl. the ones to be developed) and by gap we mean the aspects/ characteristics missing by the systems that will be/ or have to be part of the ADAS&ME systems, in order to fulfil the project aims.

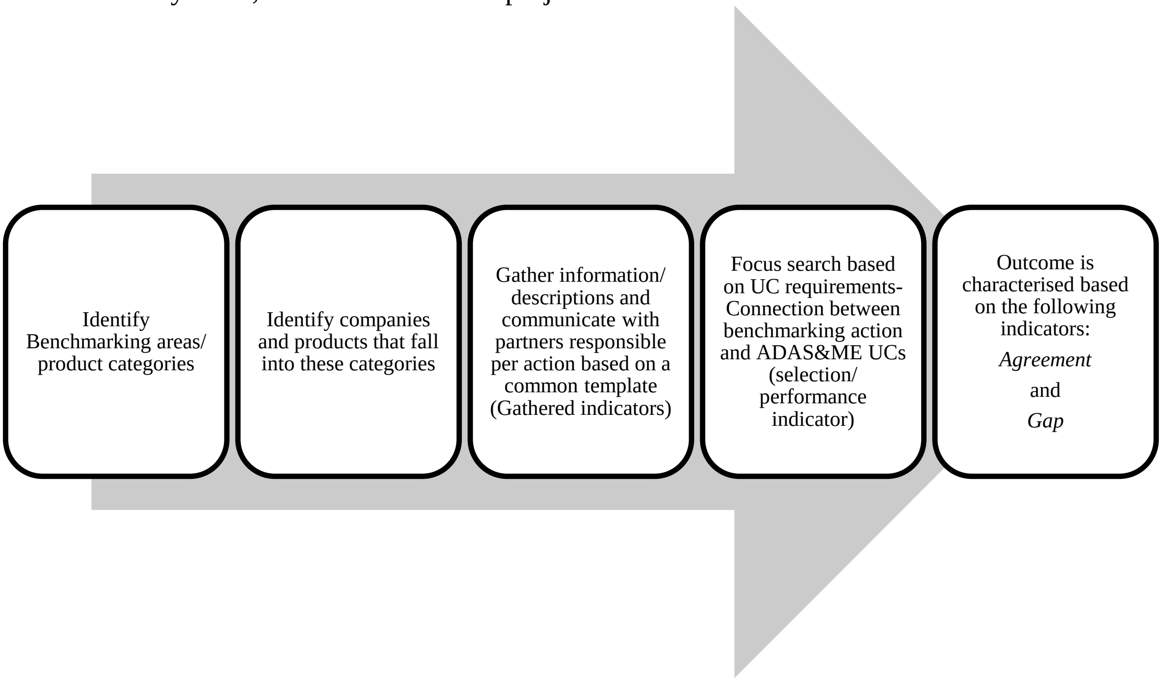

Figure 3:*ADAS&ME benchmarking generic methodology*

1.3 Connection to Use Cases

Our 'vehicle' for the whole process is one of the major selection indicators, their relation to the UCs. It is evident that this is not always so straightforward and at this early stage of the project many assumptions are necessary, in order to accept and include any possible connections to ADAS&ME UCs. First, the project's UCs are not final and their descriptions are not yet of the same depth and concreteness.
The following table presents the requirements for each UC with regards to *affective state*, *vehicle*, and *systems* considered. In conclusion, this table is enriched with suggested systems (or functionalities) to include, in order to improve the outcome for the systems and reach the anticipated outcomes. The following table (Table 2) is an overview and at some point it will probably be revised in order to reflect the updated UCs and respective sensors/ systems. The table can be used for quick reference of systems to UCs. For example, if a system is under the driver distraction section, it means that it relates to UC A, UC C, UC D and UC E.

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Table 2: *Benchmarking selection indicator – connection to UCs*

Benchmarking indicators			
UC (partner)	**Affective state**	**Vehicle / user**	**Considered/ included system**
UC A (SCANIA/ DENSO)	- Drowsiness/ sleepiness - Inattention/ distraction - Workload/stress - State of rest (resting yes/no) - Emotion state/valence	Truck – professional drivers	- Smart Eye: Eye tracking and emotion tracking - Autoliv Steering Wheel: GSR, HR - "Fitwatch": HR, accelerometer - Cognitive Model (DLR) - Stockholm University: Sleep/rest detection - 1 channel EEG (potentially)
UC B (VEDECOM/ VALEO)	- Range Anxiety - Driving style	Electric car / passenger car drivers	Anxiety monitoring Driving style monitoring
UC C (DLR, DENSO, TomTom, FORD)	- Drowsiness/ sleepiness - Inattention/ Distraction - Workload/stress - Impairment/ fainting - Rest	Passenger car/ passenger car driver	Apart from affective states' related monitoring, additionally: - Environmental sensing - Maps and guidance
UC D (DLR, DENSO, TomTom, FORD)	- Workload/ stress - Impairment/ fainting - Rest	Passenger car/ passenger car driver	Apart from affective states' related monitoring, additionally: - Environmental sensing - Maps and guidance (navigation) - V2X communication (for emergency manœuvres) - HMI designs for automation (taking over, control, emergency)
UC E (DUCATI/ DAINESE)	- Drowsiness/sleepiness - Fatigue - Inattention - Stress - Physiological impairments (dehydration, heat exhaustion, hypothermia)	Touring motorcycle/ rider	The PTW will be equipped with the following sensors: • Satellite navigator • IMU • ABS • BBS • BT The PTW will be equipped with the following HMI: • visual feedback • haptic feedback (if necessary) The wearable system will be equipped with the following sensors: • body temperature • ECG sensor • Galvanic Skin Response • GPS

Benchmarking indicators			
UC (partner)	**Affective state**	**Vehicle / user**	**Considered/ included system**
			• D|AIR platform (accelerometer, gyrometer and magnetometer) The wearable system will be equipped with the following HMI: • visual feedback • haptic feedback DAINESE Intelligent Helmet The helmet will be equipped with the following sensors: • head tracking system • eye tracking system The helmet will be equipped with the following HMI: • visual feedback
UC F (DUCATI/ DAINESE)	- Faint	Touring motorcycle/ rider	Same as above
UC G (SCANIA/VTI)	- Stress - Fatigue states	Bus/ bus driver	Driver monitoring systems Map/ stop monitoring and control Wristband reminder

2 Overview of affective state recognition techniques

The following sections in this chapter demonstrate the major areas of interest across affective states, UCs and vehicles in the deliverable.

2.1 Affective states' definitions

Affective states addressed in the project need to be defined in terms of project and Use Cases context and demands. The following definitions are not the ones adopted for the project but they will be further refined (or made specific), in order to accommodate for each UC's requirements. Responsible partners were asked to complete also any definitions they have found of affective states during the literature searches. The initial templates circulated to responsible partners, included two extra columns, aiming to assist the work carried out within A1.3 (affective state definition and ground truth, respectively). The following table presents the definitions of affective states, as currently being defined in the project, the clustering of affective states - depending on their definition and relation to other, as well as the currently undertaken ones within A1.3.

Table 3: *Affective states' definitions*

Cluster	**Affective state**	**Definition**	**UC**
Fatigue	Fatigue	Fatigue refers to tiredness that can be physical and/or mental.	A,E,F,G
	Drowsiness/ Sleepiness	Sleepiness refers to the inability to stay awake even in situations in which wakefulness is required.	E,F,G
	Rest (state of rest)	Rest is a state characterized by relaxation, and in most cases, mental and physical inactivity. Thus, the definition of rest means that no work is undertaken.	A,E

Cluster	Affective state	Definition	UC
Attention	Focus of Attention/Attention	Attention is defined as the allocation of resources to a set of activities, whereat a resource denotes any sensory, actuator, perceptual, motor or cognitive mechanism that is utilized in performing activities. it is characterized by two dimensions: activation and selectivity	A
	Inattention	Described as "a mismatch between the current allocation of resources and those resources demanded by activities critical for safe driving.	E,F,G
	Visual distraction	Three types exist: a) occurs when the driver's visual field is **blocked by objects**, that prevent them from detecting or recognizing objects or hazards in the road environment, b) occurs when the driver neglects to look at the road and instead **focuses on another visual target** for an extended period of time and c) involves a loss of visual "attentiveness", often referred to as **"looked, but did not see"**, and interferes with the driver's ability to recognize hazards in the road environment.	C,D
	Cognitive Distraction	Includes any thoughts that absorb the driver's attention to the point where they are unable to navigate through the road network safely and their reaction time is reduced.	C,D
Emotions	Emotion state/valence	Valence, as used in psychology, especially in discussing emotions, means the intrinsic attractiveness (positive valence) or averseness (negative valence) of an event, object, or situation.	A
	Emotions	An affective state of consciousness in which one or more of the below-mentioned states are experienced, as distinguished from cognitive and volitional states of consciousness. Universality of a facial expression indicates that it is presented in a particular fashion, in the same way among everyone regardless of the age, gender, ethnicity or cultural background. According to Ekman there are six of those emotions: Happiness, Surprise, Anger, Sadness, Fear, and Disgust.	C,D
Stress/ Workload	Anxiety	"Anticipation of a situation that cannot be mastered using available resources" which is characterized by a feeling of strain and pressure.	B
	Stress	"Anticipation of a situation that cannot be mastered using available resources" which is characterized by a feeling of strain and pressure.	C,D,E,F
	Mental effort/ workload	"As perceived distance from a task goal increases and the effective time for action decreases".	A
	Confusion	A disruption of awareness marked by amazement, a lack of cognitive or behavioural clarity, and confusion for place, individual, and time. Commonly referred to as mental confusion.	E,F
Physiologi cal states	Dehydration	Refers to a deficit of total body water, with an accompanying disruption of metabolic processes. Dehydration is also a cause for hypernatremia. The term dehydration is distinct from hypovolemia (loss of blood volume, particularly plasma).	E,F

Cluster	Affective state	Definition	UC
	Hyperthermia	An elevated body temperature due to failed thermoregulation that occurs when a body produces or absorbs more heat than it dissipates. For humans hyperthermia is defined as a temperature greater than 37.5 °C or 38.3 °C, on the reference used, that occurs without a change in the body's temperature set point.	E,F
	Hypothermia	Is defined as a body core temperature below 35.0 °C. Hypothermia usually occurs from exposure to low temperatures, and is frequently complicated by alcohol consumption.	E,F
	Frostbite	The medical condition in which localized damage is caused to skin and other tissues due to freezing. Frostbite is most likely to happen in body parts farthest from the heart and those with large exposed areas. The initial stages of frostbite are sometimes called frostnip.	E,F
	Faint	Syncope, also known as fainting, is defined as a short loss of consciousness and muscle strength, characterized by a fast onset, short duration, and spontaneous recovery.	F

2.2 Driver monitoring

Emergence of sensors within the 90's as well as of increased capacity computers paved the way for new research in vehicle telematics and innovative research in monitoring driver's behaviour and states. Work in European projects, such as DETER-EU (Brookhuis, 1995) and PROCHIP/ PROMETHEYS (Esteve et al., 1995) introduce driver monitoring, the SAVE-project (Bekiaris, 1999) sensor fusion was introduced to monitor driver impairment.As research progressed, more sensors and more indicators were included, like eyelid sensors, steering wheel sensors, vehicle parameters related sensors.
The SENSATION project (SENSATION, 2004) aimed at promoting novel micro and nano sensors for physiological state monitoring. The focus of the work was the detection, the prediction and the management of the sleep and wakefulness states and their boundaries, stress, inattention and hyper-vigilance. The indirect supervision systems are generally based on the analysis of the vehicle's behaviour, that can be correlated to driver actions (steering wheel movement for example) and other information available on the vehicle. It should be noticed that the first Driver Drowsiness Monitoring systems, being already commercialized belong to this category.
Driver activity recognition is the process of determining what the driver is doing, while he/she is in the vehicle. With the introduction of in-vehicle information systems, as well as smartphones drivers often are distracted from their main activity, this situation will become even more common with the introduction of autonomous vehicles that are decreasing the workload of the driver. Systems available currently can detect head pose (Zhu and Fujimura, 2004), (Murphy-Chutorian and Trivedi, 2008), (Baker, 2004), targetng detection of fatigue and sleepiness by measuring the head pitch. For driver activity monitoring, image processing methodologies were proposed in (Veeraraghavan et al., 2007) for driver activity classification in safe and unsafe (Park and Trivedi, 2005) with classifier algorithms used for activity identification as gear shifting, changing the radio channel, swerving or driving forward- backward. More recently RGB-D sensors were used for driver monitoring in (Ikoma, 2014) An RGB-D sensor was used in a driving simulator, while in (Kondyli et al., 2013) the sensor was used in the vehicle with very promising results based on the driver motion capture, proposing the development of a framework in order ADAS to take into account not only the vehicle state but also the driver's activity. The placement of the RGB-D sensor did not allow a second passenger in the vehicle, however a more appropriate placement of the sensor with the use of mirrors is feasible.

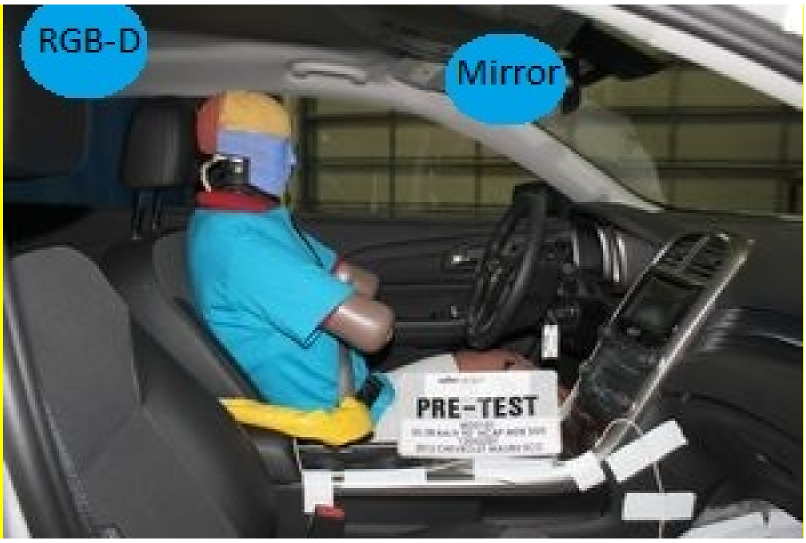


Figure 4: *RGB-D placement for driver activity identification*

3 Literature review on driver impairment and monitoring

The chapter is divided in to two major sections: a) review of research in driving impairment and driving, and b) driver monitoring systems and driving/ riding.

3.1 Driver impairment

Driver impairment's literature survey because of induced or existing affective state was conducted by each partner responsible for each affective state and the review results are briefly presented below per reviewed publication. A short summary is added for each study. This section includes a short literature review of primarily relevant aspects for the specific impairment cluster and a detailed literature review. The full compendium of literature follows in Annex 1. The aim of this work is to contribute references to the work carried out in the rest of WP1 activities.

3.1.1 Fatigue, drowsiness and sleepiness

There is no concrete definition of such definitions that are universally accepted. However, early definitions have been taken up and will be further discussed in D1.2. The end result is that regardless of any of these definitions or states, they all reduce driver's vigilance/ arousal and negatively affect their driving performance. Several parameters have been identified to diagnose sleepiness and is presented in the following diagram (SENSATION EU project, 2004-2008) and monitors the involuntary transition from wakefulness to sleep. Overall, there are different types of indicators, either directly measuring any of these states or indirectly, through other channels. The following table stems from the SENSATION project (Deliverable 1.2.2; Muzet, 2006), where the authors defined the most appropriate measures and indicators to detect sleepiness. These were the best candidates for developing systems or prototypes in order to measure and detect sleepiness in drivers. The last column reports any related weaknesses in the proposed measuring process and/ or indicator. This table serves as a baseline and reference list and the literature review will enhance and further the described systems and indicators.

Table 4: *List of most valuable sleepiness physiological indicators and techniques (SENSATION EU project)*

Physiological system	Physiological function	Physiological indicator	Measurement technique	Comment	Weakness

Physiological system	Physiological function	Physiological indicator	Measurement technique	Comment	Weakness
Sensorial system	Vision	Gaze fixity	Gaze direction VOG (videooculography)	Camera looking to driver's face	2 cameras with quite resolution are necessary to perform a good reconstruction of the eye gaze
		Eye lid closure and blinks	Eyelid sensor	Camera looking to driver's face	Results obtained are different depending onConditions of the recording. Globally, main reasons for low detection rate are bright incident illumination by daytime driving (e.g. sundown), glasses, fast head movement, driver specific behavior (hand on face, inclination of the head).
Motor system	Body motility	Body posture	Sensitive matress	Implementation in the seat	Problems with the reliability of the signals. The measurements are strongly dependent on the subjects
Autonomous nervous system	Cardiovascular function	Heart rate	Pulse detection	Sensor in the steering wheel or in the seat	Implementation of the sensor is critical
	Respiration	Respiration movement	Strain gauges	Sensor in the seat or linked to the safety belt	Sensitivity
	Electrodermal activity	Skin conductance	Electrodes	Sensor in the steering wheel	Movement of the hands create artifacts
		Skin resistance	Electrodes	Sensor in the steering wheel	
		Skin potentials	Electrodes	Sensor in the steering wheel	
Behaviour			Videometry	Camera looking at the driver	Complex image processing

For a complete list of indicators and techniques, please read respective SENSATION deliverable D1.2.2).

Key milestone aspects of sleepiness that have to be addressed are: a) Eye closure and thoracic effort characteristics and b) driving performance parameters as indirect measures of sleepiness.
In addition, the Support Vector Machine (SVM) method has been applied, in order to monitor driver's fatigue in real time based on physiological measures, such as EEG and ECG. The results of the SVM model are used to recognize the levels of fatigue in drivers (Shiwu et al, 2008).

a) Eye closure and thoracic effort characteristics

These characteristics have traditionally been used across studies with potential for several parameters to be extracted. The spontaneous eye blink comprises of 3 phases: i) *the closing phase* (the eyelid goes down to close), ii) *the close phase* (the eyelid is down and eye is closed), and iii) *the opening phase* (the eyelid is going up and the eye is opening). It is obvious from the following shape (Figure 5) that the eyes close faster than they open, with a difference of 200 mm/sec (Speedclosing = 350 mm/sec and Speedopening 150 mm/sec). Therefore, the speed of closing and opening of the eyelid are measures very sensitive to change because of sleepiness and, more specifically, the peak velocities are measured. The velocities decrease considerably when the driver is sleepy but the variability across participants is high, therefore considerable and repeated measures per person are required, in order to ensure correct detection.

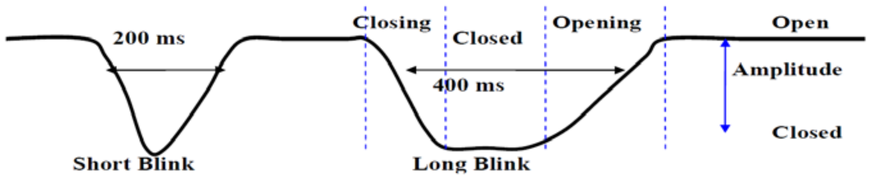


Figure 5: *Eye blink shape*

Blinks are affected by the driver's vigilance state (Blinksleepiness =1.5Blinknormal) with blinks referring to sleepiness when they are above 600 ms whereas the ones that are between 120 and 250 ms are considered as normal ("tired" corresponds to 300 and 600 ms). As the driver becomes sleepier, blinks become longer and their duration also increases. The increase is not linear and depends on personal characteristics. Blink amplitude, rate and interval are characteristics that are affected by sleepiness but are sensitive to other factors as well. The most common surrogate variable encountered in studies is the so-called PERCLOS (PERcentage of eyelid CLOSure over time), proposed by Wierwille back in 1999. Another commonly used estimate was proposed by Johns and colleagues (2005) and is called AVRBs and measures the blinks' amplitude/ peak closure velocity ratio that changes with drowsiness levels, including parameters such as duration of eyelid closure and amplitude velocity ratio.
Hargutt (2003) proposed another estimate, the drowsiness index, where coils are placed on both eyelids (i.e. upper and lower), the movements are measured and analysed and the eye-opening level is calculated based on an drowsiness detection algorithm that identifies four stages (i.e.fatigue, drowsiness and sleepiness can be also viewed as stages of the same affective state for the algorithms calculations). The stages are: from being awake (Stage 0 – eyes open, short blink durations, low blinking frequencies), to hypovigilant (Stage 1 – eyes open, short blink durations, high blinking frequency), to drowsy (Stage 2 – eyes half closed, long blnk durations, high blinking frequency), as to sleepy (Stage 3 – eyes nearly closed, very long blink durations, microsleeps).
Another type of important biomedical signal, widely used in sleep research, is the thoracic effort. The thoracic signals become irregular when moving from awake to drowsy or sleepy state. The increase of yawns shows that the driver has entered a fatigue state. Changes in the amplitude and signal frequency are lower when compared to the first line (i.e. baseline state). The TEDD algorithm / index is used to estimate the respiratory rate variability for each person, based on normalizing the individual's baseline data (i.e. collected in normal conditions). Moreover, the Gold Standard signal is used to create a reference, in order to categorise drivers to states. The GS algorithm incorporates measurements from PERCLOS, EEG, and video observation of the same instance (i.e. 1 minute window). The GS enables the creation of fatigue and drowsiness thresholds against driver's baseline signals in fully awake stage (i.e. stage 0 for awake stage; stage 1 is for fatigue and stage 2 for drowsiness) whilst being robust to driver's movements, head turns, etc.; making it valuable in application in real-life driving scenarios.

Video recordings constitute a timely and not cost-efficient method and its sensitivity in detecting fatigue is not very high (i.e. transition phase; 49.3%), but when it does is with high specificity (88.7%).

b) Driving performance parameters as indirect measures of sleepiness

Vehicle parameters have been gathered and measured for many decades in road safery research and they are completely unobtrusive to the driver as well as they do not interrupt or disrupt their driving experience. Vehicle parameters are collected for many aspects of driving behaviour through sensors (e.g. braking, steering wheel turing, lane deviation, headway, etc.). Not much focus will be placed on such measures because they have βεεν extensively gathered and reported in literature (e.g. SENSATION, AKTIV, AIDE EU projects). The following table presents the different types of vehicle parameters that can be collected in order to investigate sleepiness whilst driving.

Table 5: *Vehicle parameters to detect sleepiness*

Measure / Control	Activity measures	Performance measures
Longitudinal	Braking, accelerating, decelerating, braking reaction time, errors	Headway (distance/time)
Lateral	Magnitude and frequency of steering, slow and fast steering corrections	Standard Deviation of Lateral Position (SDLP), Time-to-Line Crossing (TLC), Lane crossing no., mean yaw rate, mean lateral position.

A summary of the literature review is presented in Table 6. Each publication is categorized with a key with regards to its relevance to the project and relevant UCs. A group of five experts discussed and categorized each publication based on this categorization. The same categorization scheme was applied for all publications reviewed in this Deliverable.

Key:	✓ - Must have	× - Not needed	■ - Good to have	◆ - Highly recommended

Figure 6: *Key categorisation for literature review*

Table 6: *Summary of literature review-Sleepiness affective cluster*

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Key:	✓ - Must have	× - Not needed	■ - Good to have	◆ - Highly recommended		
Jackson et al. (2016)	The study aims at the comparison of two drowsiness monitors (Copilot and Optalert)	PERCLOS KSS JDS	Since the optalert systems outperform PERCLOS, it may be possible to boost the performance of remote camera systems by using the same sleepiness metric (JDS) as optalert does.	Composite measures, consisting of several (eye) parameters, should be used in ADAS&ME. PERCLOS alone does not seem to be a good choice.	Consideration for the compilation of indicators to be used in order to measure sleepiness. Related mostly to A, E and less with F, G.	◆
Selvakumar et al. (2016)	A new partial least squares based algorithm for classifying open/closed eyes is presented	PERCLOS	Eye detector has a true positive rate of 96%, out of these; between 90-100% accuracy is acheived. Worst performance in darkness with glasses due to reflections (about 90%).	A closed-eyes detector has been developed. It is not really revealed how well it operates in realistic conditions.	The algorithm is based on PERCLOS which may not be an ideal measure of sleepiness. If it really is a robust closed-eyes detector then it can at least be used as a late-stage sleepiness or actual sleep detector. Related mostly to A, E	×
Schömig et al. (2015)	Use of secondary tasks can prevent drowsiness in highly automated vehicles	Mean Drowsiness Index in test phases and transitions	Interesting and motivating tasks can prevent increase of drowsiness.	Interesting for take-over HMI strategies and measurements for both drowsiness but potential also for rest identification.	Persuasive HMI implementation might increase alertness whilst resting in automated function mode A, E	◆
Åkerstedt et al. (2014)	Review article comparing KSS ratings with physiological and behavioural measures in	KSS Lane departures, slow eye	Subjective ratings of sleepiness are put forward as a sensitive and valid indicator of	Subjective ratings of sleepiness are put forward as a sensitive and valid indicator of sleepiness, which is easy to	KSS should be used as a reference measure of sleepiness in the ADAS&ME evaluations.	■

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	different settings, including car driving	movements EEG alpha power Subjective ratings on eye symptoms (heavy eye lids, gravel-eyed, difficulties keeping eyes open)	sleepiness, which is easy to use and just as valid as other sleepiness measures.	use and just as valid as other sleepiness measures.	Relevant to A, E, F, G	
Naeubauer et al. (2014)	Use of games and conversation to energize (when fatigued) driver during automated driving	Reaction time SDLP Dundee Stress State Questionnaire (DSSQ)	The study showed that usage of secondary media devices may improve vehicle control and reduce driver fatigue	HMI design that support secondary task in low-workload driving can reduce driver fatigue and increase task engagement. Though media usage is not associated with faster response time or lasting driver alertness.	Persuasive HMI implementation might increase alertness whilst resting in automated function mode A, E	
Halvig et al. (2014)	Investigate unintentional lane departures with various measures	KSS blink duration KDS Lane departures	KSS is the best indicator of lane departures. Blink duration can also be used when customized to an individual. KDS (EEG+EOG-based) is not successful in predicting lane departures	Measures of sleepiness should be individualized.	KSS remains a strong indicator meaning it can be used with any type of vehicle. HMI strategies could consider its usefulness incorporated to driver/rider's regime. A, E, F, G	
Jung et al. (2014)	Measure sleepiness through steering wheel	ECG (HRV) along with	Only descriptive, not conclusive.	Similar to the steering wheels provided by Autoliv. Other	Textile sensors need validation, therefore not very	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	textile sensor.	subjective measures		studies, using medical ECG equipment, have had trouble providing reproducible results.	useful for A, E-there are other techniques more powerful and already validated- but mostly relevant for F, G (though not for steering wheel but for other type of clothing/wearable)/	■
McDonald et al. (2014)	Compare algorithms that best predict driver's involuntary lane departures because of drowsiness in a simulator study	PERCLOS Subjective sleepiness Steering wheel angle measures ORD scale	Performance is comparable, but random forest is the best in terms of AUC. Accuracy of the algorithm was 79% (PERCLOS 55%) and positive predictive value was 80% (PERCLOS 88%)	The steering wheel angle alone, without taking road geometry into account, provides a decent estimate of driver sleepiness. However, the results also indicate that a lack of steering is the key feature used to predict sleepiness. This appears to be a poor indicator on long monotonous motorways (where little steering is needed and where sleepiness is a large problem).	Vehicle measures should not be ruled out for drowsiness detection, but despite what the authors claim, it is probably wise to take road geometry into account. Mostly relevant to A, E.	■
Jin et al. (2013)	Classify alert vs. sleep restricted conditions with SVM	PERCLOS Gaze direction Blink rate Fixation time features for SVM	Individual models were derived with 85% accuracy.	The lesson to be learned from this paper is that we can gain a lot by individualized models. Performance drops when a general (group-level) model is applied to an individual driver.	Indicators /features to be used for individuals models of sleepiness, relevant to A, E, F, G.	◆
Marina etal. (2013)	Forearm muscle fatigue patterns and relating maximal voluntary contraction with EMG	EMG of flexor digitorum superficialis (FS) and carpi	Forearm discomfort might affect inattention.	To monitor rider's inattention, relevant and important to clearly distinguish inattention due to distraction (external	Measure of fatigue and inattention directly affecting riders could be useful for E and F. As there are other	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	among motorcycle riders.	radialis (CR) were monitored		cause) and inattention due to fatigue (internal cause).	already established techniques for monitoring these two states in drivers, then no need to apply to drivers. It could be interested though to investigate if there is any relevant ground truth with regards to state of rest.	■
Craig et al. (2012)	Investigate regional brain wave activity changes associated with fatigue	EEG	Changes in EEG can be used to detect severe fatigue, but the actual difference is small between alert and fatigued	Even with EEG it is difficult to design a sleepiness detection system.	The paper says nothing about the transition phase from alert to fatigued but the analysis methods could be useful –for the two states- for UC A, E.	■
Dong et al. (2011)	Review SoA technologies related to both fatigue and inattention	Subjective Biological Physical Perfofmance Hybrid	Hybrid measures give more reliable Results	Monitoring systems Variation in data sources	Fatigue is better measured with hybrid measures A,E,F,G	■
Senaratne et al. (2011)	Comparison of classification approaches versus optical flow to estimate eye state (open/closed	PERCLOS	Classification: Eye pixels or wavelet coefficients are classifed as open/closed using MoCC, kNN, SVM, NBC.	The classification approach is more accurate but requires large amounts of training data. If such data are unavailable, the optical flow approach is preferable.	The algorithm is based on PERCLOS which may not be an ideal measure of sleepiness. If it really is a robust closed-eyes detector then it can at least be used as a late-stage sleepiness or actual sleep detector.	✖
Golz et al. (2010)	Investigate how electrophysiological signals can be used to validate video-based	PERCLOS, KSS, SDLP, EEG, EOG	PERCLOS in itself is practically not very usfeul for fatigue monitoring	The authors recommend complementing PERCLOS with other eye/face measures that can also be extracted from	Selection of combination of data for ground truths of fatigue for A, E, F, G.	◆

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	fatigue monitoring systems			the camera, such as pupil diameter and eye movements. Off-the-shelf products are not good enough for sleepiness detection.		
Liu et al. (2009)	This is a review article aimed to assess whether it is possible to predict driver sleepiness using vehicle measures.	KSS EEG SDLP SWM	Composite vehicle measure has to be explored further. The time window used for deriving the sleepiness estimate was high.	It is very beneficial to adapt driver monitoring systems to individual drivers.	Simple vehicle functions will not do for any type of vehicle; ground truth should be based on composites. Important for all sleepiness related UCs, i.e. A, E., F, G. (same as above publication)	
May & Baldwin (2009)	Identifying causal factors of fatigue	Theoretical paper	Several systems available to detect and counter fatigue.	PERCLOS and lane departure/collision avoidance systems are useful to counter multiple driver impairments such as task related fatigue and inattention. Automation at levels 0-3 may counter active task related fatigue. Head-nodding and deadman switches are only able to detect sleepy drivers after sleep has set in. Automation at levels 0-3 may cause passive task related fatigue.	An effective countermeasure technology has to take the cause and type of fatigue into account. Mostly relevant to A,E. Indirectly can reveal indicators for F,G.	

3.1.2 Stress

Stress in drivers can be detected by measuring bio-signals with the Dynamic Bayesian Network method (Rigas et al., 2008). The implemented framework (based on probabilistic reasoning) showed strong correlation between levels of stress in drivers and the model’s outcome. Heart Rate Variability (HRV), easily derivng from the variation in R-R interval of ECG, is used extensively in stress research as a real-time detection of electrocardiogram (ECG), opening the way to new signal processing features and techniques, in order to extract meaningful physiological signals (Jeong et al., 2007), as well as being sensitive in cognitive workload (Kumar et al., 2007). Another method, named Page’s technique (Singh et al., 2012) is used, to categorise data in two separate levels of stress based on a self-organized map. Another method proposed by Deng and colleagues (2012), is based on feature selection, by using the following classification algorithms: a) Linear Discriminant Function (LDF), b) Support Vector Machine (SVM), c) Naïve Bayes, d) K Nearest Neighbour (KNN), and e) induction tree C4.5. Continuous collection in real driving environment of a combination of physiological signals (ECG, EMG), including skin conductance and respiration, was used, in order to measure stress levels, showing that they constitute adequate and appropriate stress metrics for drivers (Healy & Picard, 2005).

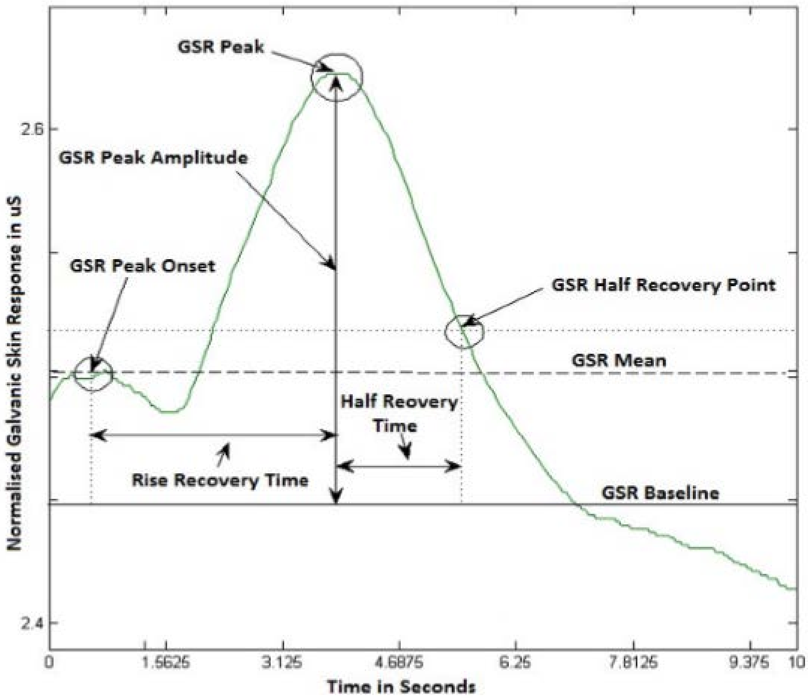


Figure 7: *Galvanic Skin Response (GSR) normalised responses as a function of time (sec)*

As in the previous section, the following table (Table 7) presents an overview of the main findings and a final verdict (key) about the utility of publication to the specific UCs where this affective state will be measured and taken into consideration.

3.1.2.1 Range anxiety

Although, stress results into anxiety and, thus, having a causational relation, range anxiety constitutes a separate category and is related to anxiety produced because of not knowing/ controlling charging frequency and selection. It is anticipated that this state might not exist in a few years, due to increasing construction of charging infrastructure that are appearing already throughout Europe. This state is relevant only to electric vehicles and relevant literature review results are presented in Table 7 and in Annex 1.2.

Table 7: *Summary of literature review- Stress affective cluster*

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Key:	✓ - Must have	x - Not needed	■ - Good to have	◆ - Highly recommended		
Giannakakris et al. (2017)	To develop an automated identification of a set of facial parameters (semi and non-voluntary)	Facial parameters in different conditions (i.e. social exposure, emotion recall, stressful images/mental task and stressful videos)	The results in terms of classification accuracy varied between 80-90 % taking into account the most effective classifier.	This systematic review provides evidence that adverse psychosocial work conditions are negatively associated with ANS function as indexed by HRV.	The use of different classification across various contents but not contexts. Real driving requires increased sensitivity and accuracy and no evidence exists; only potential for transferability. Relevant for C,D,E,F	■
Rodrigues et al. (2015)	A mobile sensing approach was designed to detect georeferenced stress responses and facilitate memory recall of the stressful situations	ECG sensors (Vital acket + Physionet), GPS and button for self-reporting stress event and were driving every day a daily route	The findings suggest that the system can be a promising tool to support applied occupational health interventions for public bus drivers and guide authorities' interventions to improve these aspects in "future" cities.	The system show promising results combining HRV and GPS information with stress button.	Good for bus drivers understanding. Highlighting the most stressful contributors. Relevant for C,D,E,F but also A (bus driver).	◆
Wickens et al. (2015)	This study replicated the findings of the in situ methodology using a between-	Time urgency, lack of perceived control, and trait susceptibility	Driving style and loci of control are of key importance of how stressed	Driving style and loci of control are of key importance.	The main outcomes (e.g. lack of perceived control, trait susceptibility)	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	subjects research design in high and low congestion conditions		someone can be. Congestion can be a factor.		can be used to build up the current driving style as part of the driver's behaviour that can directly or indirectly affect the affective state the driver experiences. Relevant mostly to UC B	
Rigas et al. (2011)	A methodology for detecting drivers' stress and fatigue and predicting driving performance is presented	physiological signals (ECG, EDA, and respiration) Video recordings (face) Environmental information	Results based only one driver; reliability is not sufficient. Association of fatigue states with driving performance	Classification of states based on extracted features is extremely relevant to the FER that the project has uptake.	The approach is validated and thus within the project we may replicate or replicate parts of it. Relevant to A, E, C, D.	
Benoit et al. (2009)	This paper presents a driver simulator study and taking into account the information about the user's state of mind (level of attention, fatigue state, stress state)	Video data and biological signals	Not clear, not described.	The simulator-based approach is interesting and the combination of video and physiological (especially which data types have been chosen) in relation to feedback output.	Difficult to define the relationship with this project as processes and outcomes are not clearly discussed. However, the choice for measuring stress and its relation to multimodal attention is interesting not only for identifying the driving impairment per se because of stress but also the effect it can have in designing the	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
					respective HMIs within the project (i.e. multimodality in information/ warning and stress). Relevant to C, D, F. it would be highly recommended because the approach is interesting but there no results supporting the efficacy of this approach.	
			Range Anxiety			
Franke et al. (2016)	Measure range anxiety as part of everyday range anxiety	Subjective measures in stress-related events	Less frequent encounter with critical range situations, higher practical experience, subjective range competence, tolerance of low range, and experienced trustworthiness of the range estimation system were related to lower ERS.	Moreover, range stress was found to be related to range satisfaction and BEV acceptance.	Address variables related to lower range stress in UC B.	
Günther et al. (2016)	Which eco-driving strategies users know before and after driving a BEV for 3	Driving test	The results imply that eco-driving strategies for ICEVs have to be adapted	The strategies are more important for training EV drivers rather than	Not directly applicable but can help in selecting the indicators that are	

Publication	**Objective**	**Mesured**	**Results**	**Relevance to ADAS&ME**	**Contribution to UCs**	**Key**
	months		for BEV eco-driving and that drivers gain a deeper understanding of factors that influence energy consumption by experiencing the BEV for a longer period of time.	measuring range anxiety.	more resilient to change. Relevant to UC B.	
Franke et al. (2012)	Investigate how range affects drivers of electric vehicles	Stress-buffering personality traits Coping skills	Scientific conceptualization of range experience.	Pproviding drivers with a reliable usable range may be more important than enhancing maximal range in an electric mobility system.	Measures are interesting to take into consideration for Use Case B	
Khan et al. (2012)	Role of HMI in range anxiety in EV	Questionnaires	Importance of adequate HMI design is emphasized.	However accuracy is a key factor to gain trust in range information. EV drivers need dynamic information on factors that influence available range.	HMI design should enhance trust and often information. UC B.	

3.1.3 Emotions

In this chapter we largely focus on face recognition methods and processes, which are new and innovative techniques to capture and recognise emotions. ***It is a very innovative area of research with increased potential in automation and this the reason why an in-depth review was conducted compared to other traditionally more research areas.***

Automatic Facial Expression Recognition (FER) is the research area of detecting the emotional state of a subject by analyzing his/her facial features. Since some years recognition of facial characteristics as eye blinking and eyelid movement, face orientation, and gaze (pupil) movement, has been applied in the field of automotive safety, in order to detect fatigue (Ji et al., 2004), (Ji and Yang, 2002), (Bergasa et al., 2006). However only until recently researchers have started to explore FER applications. In vehicle simulators FER was used in laboratory condition in (Kolli et al., 2011), (Vural et al., 2007) and (Jabon et al., 2011). FER was used in the Toyota fv2 concept vehicle, however without any other published information. The only available publication for facial recognition in real driving conditions is from (Gao et al., 2014), in which FER was used to detect stress by detecting anger and disgust in experiments performed with a near infrared camera, in order to compensate lighting condition, installed on the dashboard of a vehicle while a pose normalization step was used to overcome different head poses. The correct detection of stress in the vehicle was as high as 85%, however no information is given on how different were the poses from the normal pose and for the accuracy in case of facial occlusion e.g. from glasses or hair. In (Li et al., 2013) a low resolution RGB and Depth near infrared camera is used for a robust face recognition algorithm, overcoming problems related to capturing images in an uncontrolled environment, as varying poses (up to 90° off the normal pose), facial expressions, illumination and disguise. With the use of a higher resolution RGB and Depth camera, that is already available on the market, more robust face expression recognition algorithms is possible.

3.1.3.1 Face detection and facial expression recognition in images

The concept of *Affective Computing* has entered our lives the late 1990's, and it has constituted an important research and application area, as a bridge between computer science, signal processing, wearable device technology, psychology and neuroscience, among many others. It is defined by Rosalind Picard as computing that relates to, arises from, or influences emotions; in her famous work, that is considered to have introduced the term (Picard, 1997). Affective computing can be performed using three main modalities: audio, physiological or visual signals, that are also commonly used in combination to each other, in a multimodal fashion. Audio cues, that are used in affective computing, can be verbal (the actual words) as well as non-verbal, as in features of the voice, such as the intonation, or the speed and duration of the speech and its segments. Some physiological signals related to emotions are the electroencephalography (EEG), electrocardiography (ECG), Galvanic Skin Response (GSR), electrodermal activity (EDA), heart rate (HR), breathing rate or even brain imaging techniques, such as the functional Magnetic Resonance Imaging (fMRI). Visual cues, on the other hand, may involve the pose, displacement and gestures of the various body parts (or the whole body) and sometimes the identity of person involved.

Among those, facial cues are arguably the richest and most effective sources of information in terms of affective computing. In terms of real-world applications, facial information is more continuously accessible compared to audio cues, for instance, which are absent when the person is not speaking or producing a sound. It is non-invasive, as opposed to physiological signals, which require special equipment attached to the body and whose performance is easily affected by noise. Finally, it is less subject-dependent and contains more affect related material compared to gestures of other body parts. Automatic Facial Expression Analysis (AFEA), therefore, is an essential branch, or component, of affective computing.

In this text we review the existing methods, tools, databases and applications related to AFEA systems. Note that, facial analysis systems (including face recognition) can be performed on 2-dimensional (2D) or 3-dimensional (3D) data; 2D being the grey-level or RGB images and 3D meaning additional depth information. Since industrially available hardware does not provide the 3D information yet, we mainly include the state-of-the-art in 2D face analysis systems. An AFEA system consists of three main parts:

- Face acquisition (detection and/or tracking),
- Facial feature extraction, and
- Classification according to the task.

All these components involve a training phase (to learn the parameters or to learn the class separation), for which a (great) number of data with ground-truth is needed. The ground-truth information is obtained by manual or semi-automatic methods. Thanks to the research effort by the facial analysis community, many databases have been published with annotations available for either the basic emotions, two (or more) continuous emotion dimensions or Action Unit presence, which can be used for training, validation and testing new AFEA systems. In the rest of the text we review important examples of all these components mentioned, the existing databases and proposed applications.

3.1.3.2 Face and Facial Points Detection Methods

Face localization and detection methods can be sub-categorized in as holistic and local (or part-based) approaches. Holistic approaches aim to model the whole face as a single object and look for the complete face in an image. Local approaches, on the other hand, are able to localize parts or landmarks on the face and from there estimate the location of the face. They can, in turn, be said to be better handling partial or occluded views of faces. The term face detection refers to detecting the presence and location of all faces in an image, while localization refers to finding the location of a single one. Facial points refer to salient landmarks on the face, that can be consistently identified across different faces. Facial points' detection can be classified as shape, appearance and regression based methods. In this section we give a short review and explain three important facial point detection methods: Active Appearance Models (AAM), Constrained Local Model (CLM) and Supervised Descent Method (SDM).

Earlier approaches to face detection used information, such as skin color or motion. Modern techniques rely on learning methods and classifiers that utilize appearance-based descriptors of the face or its landmarks. The most commonly known and used face detection system is the one by Viola & Jones (2004). It had drawn a lot of attention when it was published, as it is the first real-time face-detection method and since then has been integrated in many facial analysis systems, including those on mobile platforms, and is still commonly employed as the initialization method for newer and more precise methods. It is based on learning a cascade of weak classifiers, using Adaboost Schapire & Singer (1999). The weak classifiers use Haar-like features, which can simply be explained as horizontal and vertical pixel differences at different scales. The face detector performs an exhaustive search in the image and outputs the square with the highest score to be the closest to a face. The downside of the Viola-Jones algorithm is that its training is tedious and requires thousands of face and non-face images, it usually outputs multiple detections for a single face, and, consequentially the output is not precise enough for further facial analysis methods (e.g. expression recognition or AU detection). In addition, the method is not very robust against occlusions or variations of head-pose, especially if relevant samples had not been included in the training.

3.1.3.3 Active Appearance Models (AAM)

The AAM, proposed by Cootes et al. (2001), aims to represent or explain an object (the face in this case), in terms of a set of model parameters, which are obtained by constraining solutions to be valid instances of a model. Active appearance models are statistical models of deformable objects, which contain both the shape and texture variation among a set of training images of the object. It is well suited for applications in facial analysis, since it provides positions of the facial features, such as eyes, brows, nose, mouth, etc., as well as the strict boundaries of the face. They can be seen as an extension to the Active Shape Models (ASM), which proposed such a statistical modeling of the shape variation for the first time (Cootes et al., 1995). The images in the training set are first of aligned for the shape and then texture normalized to reduce the effect of the change in lighting conditions. Then, the model is built by a Principal Component Analysis (PCA) on each pixel value of the images of the training set. This results in an AAM made of the mean object (mean face image in this case) and the admissible variations around this mean face, modeled by a principal modes of variations (eigenvectors of the covariance matrix of the training images – called *eigenfaces* in face detection) of combined shape and texture data. A given face is thus modeled as the mean face plus some variations around it, parameterized

by a set of parameters of the AAM. The idea of the AAM search algorithm is then to synthesize a new example by the adjustment of these model parameters, and it is generally treated as a minimization problem of the difference between the synthesized image and the original unseen image, so that the two are as close as possible.
The main limitation of the original AAM is that the fitting is constrained by the variation among the training set. Therefore, it is more accurate in person-specific applications (Gross et al., 2005). The original AAM was proposed as a 2D model trained for faces with near-frontal poses. This, of course is not sufficient for real life applications. One of the solutions is to include many pose configurations in training, but then the accuracy of landmark detection decreases for all. In addition, some pose variations result in self-occlusion of certain landmarks and AAM is not flexible enough to handle this issue. To overcome this problem many methods have been proposed, namely 3D (Ramnath et al. (2008)), the multi-view nonlinear active shape model or the use of multiple AAM and adequate model switching according to the pose (Yüce et al. (2011)). Still, this detection remains global, and hardly handles local occlusion. To address this, another very successful family of models has been proposed, the Constrained Local Models.

3.1.3.4 Constrained Local Models (CLM)

CLM is the name given to the ensemble of methods that aim at localizing a set of points on a given image, constrained by an overall statistical shape. The first CLM was proposed by Cristinacce & Cootes (2006), where again a Point Distribution Model (PDM) is generated like in the AAM, but this time local appearance patches around the shape points are tried to match in the image using feature templates, instead of the actual pixel values of the whole image, compared to the AAM, which naturally leads to a better generalization. The original method can be summarized as replacing the texture vector of the AAM with a vector that is the concatenation of patches extracted around each feature and normalised to have zero mean and unit variance. Each of these patches output a *response image* that defines a cost term. The total cost is optimized by manipulating the shape parameters, explaining the constraint coming from the overall shape. These response images can also be created using other appearance descriptors, such as Local Binary Pattterns or Histogram of Oriented Gradients (HoG). A notable adoption of the technique is by Saragih et al. (Saragih et al., 2011), where they have proposed a non-parametric distribution to approximate the response image and the shape fitting is reduced to a regularized mean-shift. This method is very efficient, is robust against partial occlusions and a larger variety of head-poses, and is therefore frequently employed in facial analysis applications. Open source code is available at: https://github.com/kylemcdonald/FaceTracker

3.1.3.5 Regression based methods – Supervised Descent Method (SDM)

Another efficient approach to facial point detection and tracking is regression-based methods. Regression-based methods learn a mapping from local image patches to a probability over the parameter space, the 2D position of the facial points on the next frame, in this case. Due to their efficient computation and robustness against variability of head-pose and image resolution they have been effectively used recently for facial point detection. In a relatively early attempt Cristinacce & Cootes (2007) have extended the ASM with a GentleBoost regression scheme. In Valstar et al. (2010) SVM regression is combined with conditional Markov Random Fields (MRF). In Dantone et al. (2012) the authors use Conditional Regression Forests that are conditional to the global face properties, such as the head-pose. Cao et al. (2014b) propose a two-level boosted regression with explicit shape correction, which was further extended by Richter et al. (2014), to allow for different feature channels and include head pose information to improve detection performance. Xiong & De la Torre (2013) proposed to use the Supervised Descent Method (SDM) for the minimization of non-linear least-squares problems and applied it successfully to the problem of facial point tracking. The real-time performance and the publicly available implementation make it the most commonly used SoA face and facial point tracking system (Available at: http://www.humansensing.cs.cmu.edu/intraface). It is an extension of Newton's gradient descent method, which aims at minimizing a function by sequential updates or cascaded regression. SDM carries out this function in a supervised manner, i.e. for a training set of known facial point locations and corresponding templates or appearance features (e.g. SIFT), SDM learns a series of parameter updates and generic descent directions and for an unseen image the extracted templates are projected onto the learned descent direction to obtain the displacement update of the facial features. Common to all regression-based methods, for tracking the points in a sequence it requires an initial estimate of the positions, which is typically chosen as the mean shape of the training set, scaled and translated using a face detector. For the rest of the frames, previous locations of the facial points are used to regress from.

3.1.3.6 Feature extraction

Once the face is located, its content (e.g. the facial expressions) need to be recognized by analyzing features extracted from different locations on the face. Feature extraction is the process of obtaining representations from images, or sequences of images, that are ideally relevant to the discrimination task and that can be formulated in a fixed-size vector form, to be used in a classifier or regressor. For facial analysis systems the features used in the literature can be categorized in two: Geometric features and Appearance based features. Geometric features are the ones that are calculated through the locations of certain points (landmarks) on the image and do not include any pixel intensity information (except for being used to locate these landmarks). Appearance based features, on the other hand, rely on these pixel intensities either directly or via image transformations on a global level or extracted locally. Geometric and appearance based features can also be used in combination (in feature-level or classifier- level fusion) and have even shown better performance in certain cases compared to their individual usage.

3.1.3.7 Geometric Features

The geometric features of the face consist of the ones that involve the actual location of facial landmarks. This location information is then converted in a feature representation either via normalized direct coordinates of the image or as a function of the distance between multiple points. The geometric features can be calculated in a single frame or can be calculated over two or more frames as a difference or trajectory function. Features of this type, that have been used in various works can be listed as follows:

- Locations of facial landmarks (e.g. eyebrows, mouth contours, etc.).
- Distance between landmark-pairs (e.g. distance between two mouth corners or uppermost and lowermost points of the eye contours).
- Angle of the lines joining landmark-pairs.
- Angle between edges of polygons joining 2+ landmarks.
- Difference of these features in the current frame and a reference frame.
- Trajectory of these features along a sequence frame, represented in a fixed size feature vector, e.g. via coefficients of a polynomial fit.
- Coefficients of a shape model fitted on the specific image.

Since the efficacy of geometric features is directly related to the precision of the facial landmark detection system, geometric features are not very suitable to detect subtle facial expressions. The feature vectors contain the accumulated noise introduced by the face tracker, for example when using the evolution of locations in two or more frames. When the landmark detector is accurate, however, geometric features are very effective in detecting Action Units (AU) (especially some AUs that are marked relatively more by movement of salient facial points) and even the temporal phases of AUs (e.g. Pantic & Patras (2006), Valstar & Pantic (2012)), particularly on data where the head-pose does not vary significantly over sequences.

3.1.3.8 Appearance Features

Appearance features are based on the texture information in an image, that is the pixel intensities. These pixel intensities can be used as they are directly as features for facial action recognition. However, this requires an accurate registration of the faces, as well as intensity normalization for illumination and individual skin color differences. Feature transformations are in general less influenced by these aforementioned factors and they are able to represent effectively additional information on the face, such as edges, corners, frequency, etc. This information is more *meaningful* and discriminative in terms of facial actions, therefore it is common to apply a transformation on a face image and form a feature vector through this transformation. Chew et al. (2012) have investigated

the benefits of using feature transformations compared to using raw pixel information for the task of AU detection and they have concluded that feature transformations are useful in cases of alignment errors and illumination variations, but not so much when these conditions are *perfect*.
The most commonly used appearance descriptors in the literature are the HoG (Dalal & Triggs, 2005), Discrete Cosine Transform (DCT) (Ahmed et al., 1974), LBP and its variants in 3D and the frequency domain, filter banks (Gabor wavelets in particular) and SIFT features. The construction of the HoG features are similar to that of the SIFT and an example of usage in the facial action context can be found in Chew et al. (2012).

3.1.3.9 Feature selection and classification

Once the features are extracted, they can be used as inputs to a classifier, trained to recognize the facial content (e.g. expressions). However, most of the time, the features may be too many and potentially contain redundant information. Keeping them all may dramatically decrease the classifier performances. Therefore feature selection if needed. This can for instance be performed in an unsupervised manner by PCA or in a supervised manner by linear discriminate analysis (LDA). Some classification methods, called boosting methods, can be used both for feature selection and classification. Boosting is the term that is used to define the ensemble of methods that aim at combining multiple classifiers to produce a *committee* of decisions, that is used as the final classifier and whose performance is ideally better than any of the *"base"* classifiers. These base classifiers are generally chosen from *weak learners*, which are very simple classifiers with only better than random performance, and still can create very powerful classifiers when combined in a boosting scheme. The most well-known and commonly used boosting algorithm is AdaBoost or adaptive boosting, that was developed by Freund *et al.* (1996). It is the method that is also used in the Viola & Jones (2004) face detection method. The main idea is to give emphasis by weighting the instances that are misclassified at each step of the classifier, i.e. adapt the classifier to better handle problematic instances. Variations of this idea are also found in the well-known GentleBoost algorithm, proposed by Friedman et al. (2000).
Finally, like in many other classification tasks, a very popular classifier is the Support Vector Machine (SVM). The Support Vector Machine (SVM) is a maximum margin binary classifier, which tries to separate two classes by a margin whose width is maximized so as to decrease the generalization error over all training instances. SVM is a very successful machine learning tool that has been effectively used for a variety of classification and regression problems (Bishop, 2006).
As an example of a complete system to automatically recognize Action Units (AU), the individual facial shape features used in the canonical facial action coding system (FACS), our group at EPFL has develop one of the most effective AU detectors currently available. Once the full set of features (shape + texture using LBP) is obtained, we perform feature selection using the GentleBoost algorithm (Friedman et al. (2000)) to choose the most relevant features for each of the AUs. We therefore perform this process 15 times independently, for the action units 1, 2, 4, 5, 6, 7, 9, 12, 15, 17, 20, 23, 24, 25 and 27. Feature selection is a crucial step in the AU detection process, since it discards the irrelevant and redundant features which constitute a huge portion of the total number of features extracted, due to the large number of LBP windows and inter-point relations we use for building our features set. For each action unit 200 features are extracted in total as result of the GentleBoost, then the optimal number of features is chosen by performing leave-one-subject-out tests with 30, 50, 100, 150 and 200 features for each AU separately. For the detection of action units using these selected features, we train 15 Support Vector Machine (SVM), once again for each AU. The SVM are binary, the classes being if the specific AU is present in the image sequence or not. As kernels we use Gaussian RBF, and optimize the SVM classifier parameters using a 5-fold cross validation on the training set. The detailed analysis of the performances of such a method can be found in (Yüce, (2015).

3.1.3.10 Existing databases for facial expression recognition

Facial expression databases are crucial tools for facial analysis research, both for training and testing. Publicly available image and video databases help advancements in the field and allow for objective comparison of system performances. Creating a database of facial expressions is a tedious task mainly due to providing the ground-truth. Databases currently available to the community come with annotations for the six (or seven) basic expressions, the emotional dimension (valence, arousal, dominance, etc.), AU existence or intensity, or a specific condition or state, for instance pain, interest, engagement, distraction. In the earlier years of automatic face analysis research the databases mostly consisted of posed expressions, i.e. the subjects were given explicit instructions to perform a certain facial action combination. Although this provides convenience in terms of data annotation (since the sequence-level ground-truth labels come automatically during data acquisition), the data obtained is not natural and quite different from what one observes in real-world applications. The later trend, therefore, is to obtain expressions in a spontaneous manner, that is either by emotion elicitation or by having human-raters annotate the data through visual observation. Human annotations, of course, bring along the problem of subjectivity, even in the case of FACS annotations, which is the most objective and well-defined system to date. For this purpose some databases use multiple human raters that annotate the same data and a measure of reliability is provided along with the annotations. Table 1 below gives a list of some commonly used publicly available databases, the type of annotations (ground-truth) provided, the existence of spontaneous expressions and 3D data.

Database	Basic Exp.	AUs	Val. - Arou.	Dynamic	3D	Spontaneous	Other
AR-FACE (Martinez, 1998)	✓	✗	✗	✗	✗	✗	Occlusion
JAFFA (Lyons *et al.*, 1998)	✓	✗	✗	✗	✗	✗	-
KDEF (Lundqvist *et al.*, 1998)	✓	✗	✗	✗	✗	✗	Multiple views
Multi-PIE (Gross *et al.*, 2007)	✓	✗	✗	✗	✗	✗	Multiple views
SAL (Douglas-Cowie *et al.*, 2007)	✗	✗	✓	✓	✗	✓	Multimodal
BOSPHORUS (Savran *et al.*, 2008)	✓	✓	✗	✗	✓	✗	Occlusion & Pose
CK+ (Lucey *et al.*, 2010)	✓	✓	✗	✓	✗	Partially	-
MMI (Valstar & Pantic, 2010)	✓	✓	✗	✓	✗	Partially	Side-view & AU temporals
NVIE (Wang *et al.*, 2010b)	✓	✗	✗	✗	✗	✓	Near-Infrared Lighting
UNBC-McMaster (Lucey *et al.*, 2011)	✗	✓	✗	✓	✗	✓	Pain Scores
GEMEP-FERA (Valstar *et al.*, 2011)	✓	✓	✗	✓	✗	Partially	Multimodal
SEMAINE (McKeown *et al.*, 2012)	✗	✓	✓	✓	✗	✓	Dyadic interaction
RECOLA (Ringeval *et al.*, 2013)	✗	✗	✓	✓	✗	✓	Multimodal
DISFA (Mavadati *et al.*, 2013)	✗	✓	✗	✓	✗	✓	AU intensities
AVEC (Valstar *et al.*, 2013)	✗	✗	✓	✓	✗	✓	Depression Scores
BP4D (Zhang *et al.*, 2014)	✗	✓	✗	✓	✓	✓	AU intensities (partial)

Figure 8: *List and Comparison of Publicly Available Databases of Facial Expressions and AUs.* Basic Exp.: annotated for the 6 (or 7) basic expressions, AUs: annotated for the AUs, Val. - Arou.: annotated for the valence and arousal dimensions (might also be annotated for other dimensions), Dynamic: involves sequences of images, 3D: involves 3D data, Spontaneous: involves spontaneous (non-posed) expressions, Partially: only in a portion of the data, or partially fulfilling the condition.

3.1.3.11 Applications of facial expression recognition

General application

In this section we provide a short review of some of the application areas in the literature, that use automatic detection of AUs or facial expressions as a source of information. Note that this review does not include applications of face recognition (e.g. in forensics or face verification). Automatic facial expression analysis is firstly an essential component of HCI (which can also be called Human-Machine Interfaces (HMI) in this case). Systems that are able to understand affective and cognitive states of users use this information to mediate and adapt their behaviour for a more user-friendly and efficient system. HCI applications range from gaming to medical and learning assistance. One of the most commonly encountered use of automatic analysis of facial expressions is in the field of marketing. Analyzing people's facial reactions when they watch advertisements or browse a product allow measuring their liking and intent to purchase the product. Using this information producers, retailers or online shopping sites can build marketing strategies, reorganize product placements and infer about their target population. This idea does not only apply to direct purchasing behaviour, but also to assessment of liking multimedia content in general. For example, as a very interesting recent application, a comedy club in Barcelona, Spain has placed cameras in front of the audiences' faces, detects every time you smile, and charges you according to your number of smiles / laughs during the performance. Another field of application is in the health-care area. Certain psychopathologies have been shown to have as symptoms flat or abnormal affect. Abnormal affect is defined as not feeling or expressing a feeling in an expected way, for example getting extremely raged as response to an amusing stimulus with no apparent side reasons. Flat affect, on the other hand, is the deficiency to lack to feel or express a feeling when you are expected to. Flat and abnormal affect is encountered in patients with schizophrenia, depressive disorder, manic-depressive disorder and certain types of autism spectrum disorder (e.g. Asperger's syndrome). These disorders are also characterized by not being able to recognize others facial expressions (Sander & Scherer (2009), Kring & Stuart (2005)). Automatic facial expression recognition tools can be used for the diagnosis and treatment of those psychopathologies and evaluation of psychiatric intervention. Another application in the healthcare area systems that measure the pain level, for instance after surgeries or during regular monitoring of the elderly, and help take appropriate measures (Sikka *et al.* (2015)). A similar type of approach is also used to model, understand and provide feed-back to learning and teaching systems, the main idea being that understanding and being able to interpret the student's feelings and cognitive states (e.g. distracted, confused) one can adapt their behaviour for a more efficient interaction.

Another application field, that is on the rise, is driver and pilot monitoring systems via facial analysis. These systems detect particular states of the drivers (e.g. fatigue, distraction, rage) that can be hazardous for driving and allow for taking appropriate measures. This is presented in detail in the next section.

Visual Driver Monitoring

This section presents a brief review of existing work on visual driver monitoring. An extensive review is given in Dong *et al.* (2011) and Kang (2013), the interested reader is referred to these publications for more approaches and applications not listed here. Over the years most of the research on visual driver monitoring systems have focused on fatigue detection, which is a critical factor for human error in driving. An approach on fatigue detection, rather close to ours is the work by Vural *et al.* (2007), where the authors use many AUs, including head-pose, and analyzed their relation to fatigue during a three-hour simulator driving experiment after midnight. As expected, the most relevant features were related to eye-blink (AU45) and also outer brow raise (AU2), as the subjects tried to remain awake. In Rongben *et al.* (2004) an automatic mouth movement analysis is performed to detect fatigue related actions, and also speaking, while in Gu & Ji (2004) AUs are used within a Dynamic Bayesian Network (DBN) to detect driver vigilance. The head pose dynamics have also been successfully exploited in a real-time driver awareness detection system (Murphy-Chutorian & Trivedi, 2010). Another commonly used visual cue for fatigue detection is the Percent Eye Closure Measure (PERCLOS), as used for instance in Bergasa *et al.* (2006).

As for automatic detection of distraction, a non-vision based system is presented in Tango et al. (2010) where the driving information, such as the speed, position of the pedal and steering wheel have been used to detect visual distraction tested with various machine learning methods. Wöllmer *et al.* (2011) also used the driving information and non-vision based head tracking data to detect cases of visual distraction while performing various tasks. In Liang et al. (2007) the authors used eye movements and driving performance data within a Bayesian Network framework to predict ∼ 80% of distraction cases while interacting with an in-vehicle information system (IVIS). A similar study is presented in Jimenez et al. (2012) where the gaze angle and fixation data was used once again to recognize distraction induced by the IVIS. In D'Orazio et al. (2007), the eye movements are analyzed to predict visual inattention using Neural Networks. The gaze information was used along with head movements and lane position of the vehicle in Kutila et al. (2007) to detect induced visual and cognitive distraction using a stereo-vision system integrated in trucks and passenger cars. For cognitive distraction, the authors achieve 68% on the truck experiments and 86% for the passenger car exper- iments. However, the low number of drivers tested (3 for the passenger car, 12 for the truck) is insufficient to discuss the generalization capability of the system. In Jabon et al. (2010) several features related to the coordinates of 22 facial landmarks and driving data were used to predict accidents. In Ragab et al. (2014) the arm position, eye closure, eye gaze, facial expressions, and orientation provided by Kinect to detect visual and manual distraction on 6 subjects. The approach by Li & Busso (2015) use AUs, gaze and head pose information to detect visual and cognitive distraction. With the experiments performed on 20 subjects, the F-score for detection cognitive distraction is 73.8% and for visual distraction 80.8% (Li & Busso, 2015).

3.1.3.12 Speech recognition

As smartphones and infotainment systems became part of our lives, the ability to use them with voice commands creates the potential of detecting emotions from the driver's voice. Speech emotion recognition has been proven to result in successful recognition of the speaker's emotion in laboratory conditions. In (Pierre-Yves, 2003) and (Nwe et al., 2003) above 80% successful emotions' recognition is reported; however in both studies a quiet environment was required and a high quality or a mouthpiece microphone was used. Inside a vehicle speech emotion recognition was evaluated in (Kamaruddin and Wahab, 2010). Speech emotion recognition was performed with accuracy detection of 73% for sadness and 67% for anger, (Tawari and Trivedi, 2010), using noise cancelling technologies in gender specific and drive context information, they were able to recognize emotions with a higher accuracy. Toyota fv2 concept vehicle support speech emotion recognition, however no other published information is available.

Table 8: *Summary of literature review-Emotions affective cluster*

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Key:	✓ - Must have	x - Not needed	■ - Good to have	◆ - Highly recommended		
Koo et al. (2015)	Explores the interaction between the driver and semi-autonomous driving actions	Tested different messages that provided advance explanation of the car's imminent autonomous action	These results suggest that, to increase overall safety, car makers need to attend not only to the design of autonomous actions but also to the right way to explain these actions to the drivers.	Reasons for an action is as important as the action in order drivers to trust and continue to use function, i.e.need to establish connection. i.e. affective design.	Mostly related to HMI design to incorporate affective strategies in order to increase trust, especially for handing over control (UC C)	■
Mesken wt al. (2007)	Investigate the frequency, determinants and consequences of anger, anxiety and happiness in traffic	Speed Heart rate Environment through video Self-reports	Anxiety is the most frequent state very much related to emotional traits, goal congruent events resulting to increased perceived risk and increased heart rate.	The study does not consider assistive or support systems but guides us towards theories and state-trait differences in emotions that we might consider in defining the emotions and selecting the appropriate indicators.	Anxiety is more often registered than other emotions. Important to evaluate emotional traits. Relevant to A, C, D. Especially for professional driver a standardized emotional traits questionnaire could be used.	■
Vaw et al. (2007)	Evaluation of the emotional states of car-racing drivers	facial electromyograms Electrocardiogram Respiration	Classification worked using SVMs and ANFIS with	However, the clusters selected: high/ low stress, disappointment and euphoria may be	But it is still to be decided if this clustering will work for everyday drivers, professional	◆

Publication	**Objective**	**Mesured**	**Results**	**Relevance to ADAS&ME**	**Contribution to UCs**	**Key**
		Electrodermal activity	adequate rates.	very relevant for race car drivers.	drivers and leisure riders Relevant to A, C, D and even for F, G	
Jonsson, I., & Harris, H. (2005)	Investigate emotion recognition through speech based systems with real users taking into consideration both linguistic and paralinguistic features.	Experiments are conducted in simulated but still driving environment.	The data from these studies are evaluated both for driving performance, are the voice systems helpful, and attitude, are the voice system well liked and will hence stay turned on	Testing set up is interesting and especially the categories of prompts can be used to categorize speech outputs and help design the HMI for certain driving instances.	Use of similar prompts to induce emotions in controlled conditions. Relevant to A, C, D and HMI strategies (A5.1).	

3.1.4 Inattention/ distraction/ Workload

In a study conducted by Dingus (2004), it was found that 78% of the accident was linked to a driver's inattention, during the 3 sec before the accident. Distraction is perceived as a sub-category of inattention with three different categories: a) *visual*, where outside visual stimuli attract the driver's attention, e.g. looking at something outside/ inside the vehicle, b) *Auditory* (e.g. listening to radio) and c) *Cognitive* (thinking, talking on the phone, etc.).

Visual distraction becomes critical when it lasts longer than 2 seconds (Simons-Morton et al., 2014). However, this is not a definite and cut-off decision; the driving task is complex and affected by many contextual, situational and other factors. Camera-based approaches are the most abundantly used in order to detect and measure distraction. In particularly, eye gaze is a common measure that requires high precision cameras with stereoscopic vision. These camera systems need to be able to be used in driving contexts (e.g. Seeing Machine and smart eye and are already commercialised). A basic assumption governs visual distraction; glances longer than 2 seconds are accompanied by head turn, as otherwise is not comfortable. Therefore, head turning and orientation has been shown to be a reliable indicator of visual distraction.

Apart from camera-based approaches, task-demand based performance can be evaluated, and if found impaired, then it is assumed that the driver is no longer attentive to the primary driver task. However, the connection is not so direct, as impaired driving is not always evident. This is more difficult to measure when cognitive distraction is involved. Similarly, observing the driver whilst completing in-vehicle tasks (e.g. taking on the phone, interacting with in-vehicle technologies) with camera-based systems, may lead to inattention identification.

Table 9: *Summary of literature review- Inattention/ distraction affective cluster*

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Key:	✓ - Must have	× - Not needed	■ - Good to have	◆ - Highly recommended		
van der Meulen et al. (2016)	Investigate the implementation of a method to monitor driver distraction based on a stereo camera to estimate the face pose and gaze of a driver in real time	Reaction times and gaze focalisation behaviour patterns measured on a sample of professional drivers	Evaluated truck driver's distraction under a set of various situations.	System allowing evaluating truck drivers distraction.	Method especially relevant for UC A.	■
Craye & Karray (2015)	Driver distraction detection and recognition using RGB-D sensor	Eye behaviour (detecting gaze and blinking) Arm position (is the right arm up, down, right of forward) Head orientation Facial expressions	Qualitative and quantitative results showed accurate detection and recognition capacity (85% accuracy for the type of distraction and 90% for distraction detection).	The system based upon Kinect sensor, computer vision and machine learning is suitable for context aware human-machine interaction.	Each module developed to detect distraction is obtained independently and could be used for other types of inference, such as fatigue and detection Relevant to A, C, D,F, G	◆
Gold et al. (2015)	The study investigated whether different tasks are impeding the drivers' capabilities of	T-react time Minimum/ maximum longitudinal/lateral acceleration Minimum occurring time to collision (TTC) Visual motoric SURT	The study provides a good understanding on how non driving tasks influence the driver behaviour during take over.	The cognitive demanding tasks are impeding the take-over in cognitive demanding take-over situations and the influence of cognitive	The study investigated on method on how to use gaze behaviour as an indicator of driver readiness to take over control	■

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	regarding control intake over situations.	tasks Cognitive n-Back task	The secondary tasks are quiet interesting and the method of evaluating the distraction is also very informative.	tasks is less easy in well-practiced take over conditions.	during automated driving. The study also showed that how specific gaze parameters are suitable to assess the adequacy of driver monitoring strategy. This could be useful in ADAS for investigating use case driver monitoring (driver distraction).	
Gonçalves, J., & Bengler, K. (2015)	The main contribution of this paper is to provide an overview on DSM from a HAD point of view	Review paper	Advantages of reviewed monitoring systems: Eye metrics is valuable due to the ability to obtain relevant data associated with fatigue in a non-intrusive way, and has broad community acceptance. Behaviour based metrics is recognised as a promising source for detecting	Eye based metrics will remain an important DSMS for fatigue detection. For distraction detection, monitoring body posture and head rotation is a possible alternative.	Image processing/cameras for detecting body postures (fatigue detection) and eye tracking for monitoring fatigue and distraction. Behaviour based metrics is a promising information source for detecting drowsiness but should not be used alone, since these activities are person dependent. Use	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
			drowsiness - drivers' change behaviour to counter the fatigue progression.		generic algorithms for detecting driver behaviour. Relevant to UCs A, c, D, E, F, G	
Mok et al. (2015)	The study investigated driver monitoring capability from a highly distracted state	Drivers' emotional state captured using GoPros camera inside the cabin to provide additional video feed of the drivers face for automated emotion analysis. Emotion coding is performed using FACET algorithm (Attention tool software)	After a take-over request visually distracted drivers initially avert their gaze on secondary tasks to the road way and simultaneously establish motor readiness to intervene in the vehicle guidance. Drivers who distribute their visual attention appropriately between driving and the secondary task and regular monitoring the roadway should be able to acquire and maintain high situation awareness. Cognitive and not motor process determines the take-over performance.	The study provides a good understanding on how the number and the maximum duration of off road glances seem to be suitable gaze parameters to assess and categorise the drivers monitoring behaviour in highly automated driving situation. The study also provides good understanding on the method that should be used to measure the gaze behaviour of visually distracted drivers.	The study investigated on method on how to use gaze behaviour as an indicator of driver readiness to take over control during automated driving. The study also showed that how specific gaze parameters are suitable to assess the adequacy of driver monitoring strategy. This could be useful in ADAS for investigating use case driver monitoring (driver distraction).	◆

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Rashid et al. (2015)	This case study was conducted to determine signal transfer challenges and limitations that researchers tend to experience while using a wireless Myon 320 sEMG system during a real on-road motorcycle riding experiment	Upper trapezius (T), triceps brachii (TB), erector spinae (ES), latissimus dorsi (LD), extensor carpi radialis (ECR), sternocleidomastoid (S), gastrocnemius (G) and biceps formaris (BF) muscle groups	As a conclusion, this study provides an insight of what to expect during performing wireless sEMG experiments on real roads involving two moving vehicles.	Finally, any procedures and experimental setups involved in such on-road experiment should be observed carefully for the safety of all parties and road users.	To monitor rider's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause). Relevant to F, G	
Lorenz et al. (2014)	The study investigated whether augmented reality information can positively influence the take-over process.	Lane keeping or speed choice PERCLOS PRC TETTC	The study provides a good understanding on how the number and the maximum duration of off road glances seem to be suitable gaze parameters to assess and categorise the drivers monitoring behaviour in highly automated driving situation. The study also provides good understanding on the method that should be used to measure the gaze	The study provides a good understanding on how the number and the maximum duration of off road glances seem to be suitable gaze parameters to assess and categorise the drivers monitoring behaviour in highly automated driving situation. The study also provides good understanding on the method that should be used to measure the gaze behaviour of visually distracted	The study investigated on method on how to use gaze behaviour as an indicator of driver readiness to take over control during automated driving. The study also showed that how specific gaze parameters are suitable to assess the adequacy of driver monitoring strategy. This could be useful in ADAS for investigating use case driver	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
			behaviour of visually distracted drivers.	drivers.	monitoring (driver distraction). Especially relevant for UCs C, D	
Wu et al.(2015)	Drivers use of voice interfaces within their own vehicles was explored using contextual interviews.	Video recorded interviews (identification of errors) NASA TLX (Task Load Index)	Accuracy of speech interface can impact safety	Voice communication with systems is recommended but has to be robust with high quality	Measures used and voice commands are important for HMI strategies and resulting workload. Especially for UC C.	
Strayer et al. (2015)	Establish a systematic framework for measuring and understanding cognitive distraction in the automobile, defining relationship between mental workload, cognitive distraction, and impaired driving	Detection Response Task (DRT), Brake reaction time, following distance, glances at hazard locations, subjective workload rating (NASA-TLX), physiological measures (EEG)	Definition of a cognitive distraction scale.	Framework to measure driver distraction associated with differentin-vehicle activities.	An established framework across 3 studies that could be adapted or partially adopted in UCs where distraction is measured. Especially relevant for UCs C and D.	
Naujoks et al. (2014)	The study investigated the effectiveness of visual and visual-auditory take-over requests during highly automated	Time until driver takes hands back on the steering wheel	Time until driver takes hands back on the steering wheel are lower if visual-auditory take-over requests are used in comparison to	Visual-auditory warning modality seems to be beneficial for take-over requests.	Very important result for HMI strategies for take-over when driver was previously distracted because the car was under	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	driving under distraction conditions		purely visual ones purely visual take-over requests may not be sufficient to ensure safe transitions.		automation. Especially relevant for UC C.	
Bucchianico (2014).	Investigation of the effects of ADAS, specifically Lane Departure Warning (LDW), on driving performance while participants performed a secondary task (mental math) designed to simulate cognitive effort while driving.	Test the capacity of ADAS such as LDW and ACC to potentially compensate loss of vehicle control linked to driver's distraction in real driving context; the results are not convincing but the approach is valuable	In real driving context but through a maybe too short appropriation experiment, ADAS technologies happened to be not successful in fully compensating impaired driving capacity linked to high cognitive workload.	Importance of the phase of appropriation of ADAS technologies while running experiments to test the efficiency of these systems.	Automated functions limitations in high distraction can be enhanced by effective HMI strategies, therefore relevant for UC C and A5.1.	
Othman et al. (2014)	Development of a driver inattention detection system using dynamic relational network	Synchronous data such as video, speech, driving control and physiological signals in real road context	Test on real road for the driver inattention detection system showed a percentage of the confidence score of the system output very high, between 80 to 70%.	Usefulness of a driver model to be included in a driver inattention detection system in addition to sensor diagnosis module to monitor driver's state in the car.	Interesting not only for Use Case E, F, G buteven more for the development of the driver and rider models (A1.3)	
Ranney et al.	to evaluate the	Head-mounted DRT	Overall, the TDRT	Test of sensitivity of	The variants of this	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
(2014)	sensitivity of Detection Response Task (DRT) metrics to differences in attentional load	(HDRT), Remote DRT (RDRT), and Tactile DRT (TDRT)	was consistently more sensitive than other DRT variants, albeit marginally, in the driving simulator	DRT variant metrics to evaluate driver's distraction to be used at an international level in the framework of the NHTSA Driver Distraction Guidelines	metric DRT may be used in several Use Cases of the project, especially C and D.	
Dong & Hu (2013)	This paper is a review of current state of the knowledge about driver inattention monitoring, with inattention classified into 2 categories: distraction and fatigue	Driver physical variables Driving performance Variables and information from IVIS	As the goal of a driver's inattention monitoring system is to reduce driving risk, it is recommended to combine the 3 data sources.	Several systems available to evaluate in real time driver's distraction and driver's fatigue.	To monitor driver's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause). Relevant to A, C, D.	
Tango & Botta (2013)	Real-time detection system of driver distraction using machine learning	Data for training the models were collected using a static driving simulator, with real human subjects performing a specific secondary task [i.e., a surrogate visual research task (SURT)]	Usefulness of a ML model to detect driver's distraction without using eye-tracker data but rather nonintrusive and real-time vehicle dynamic data.	This model SVM can be useful to define driver's distraction in the objective of design of adaptive PADAS.	Best machine learing models is important also for the work carried out within WP4 apart from UseCases C and D.	
Mbourna et al. (2013)	Visual analysis of eye state and head pose for driver alertness and	Eye index (EI), pupil activity (PA), and Head Pose (HP)	Head pose (HP) provides useful information on the lack of attention,	A support vector machine (SVM) is useful to classify a sequence of video	Use a single camera in addition to combination of information coming	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
	distraction monitoring		particularly when the driver's eyes are not visible due to occlusion caused by large head movements.	segments into alert or non-alert driving events.	from driver's eye and head in order to achieve correct identification of distraction state. Convincing method applicable in real road driving context to evaluate driver's distraction state. Relevant to A, C, D, E	
Di Stasi et al. (2011)	method of estimating the mental workload (MWL) of a motorcycle rider was proposed, through the application of machine learning methods	Saccade duration, eye fixation (short stop), tracking frequency, saccade amplitude, and most frequency eye movement velocity	As a result, discrimination functions were found through machine learning methods that allow us to detect increasing MWL with an accuracy of over 80%, under set experimental conditions.	Measurements of rider's mental workload through machine learning methods.	Comparison to ADAS&ME: The method of measurements with the helmet (included in project) Relevant to F, G	
Jain & Busso (2011)	Assessment of driver's distraction using perceptual evaluations, self-assessments and multimodal feature analysis	Self-assessments Subjective evaluation of localized recordings of the drivers CAN Bus signals, eye glance behaviour Acoustic signal, giving unbiased metrics to describe the deviation in	Identification and description of relevant metrics to describe distracted drivers.	Methodologies to assess driver's distraction are multiple: self-assessed, observation by experts, objective data from the vehicle.	To be robust, it is possible to use the combination of the 3 of them. Relevant to UC C and D.	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
		behaviour's observed when the driver is involved in the secondary task				
Ahlstrom and Dukic (2010)	Comparison of eye tracking systems with one and three cameras	Advantages with a one-camera system are that it is cheaper, easier to operate and easier to install in a vehicle. A multi-camera system will, on the other hand, provide higher availability and accuracy for areas that are far from the road centre	Both accuracy and availability deteriorated with distance from the central gaze target, with a larger decrease for the one-camera eye tracking systems as compared to the three-cameras	Better understanding of limits and advantages in terms of accuracy in using one-camera or three-camera eye tracking systems.	: Comparison of 2 systems that could be used in the project to evaluate driver's distraction state. Relevant to UC C and D.	
Tofetti et al.(2009)	An experiment was conducted to compare the two eLane interfaces. (City Mobil project)	Interface evaluation questionnaire Driving performance evaluation questionnaire	The study showed the method to investigate two different interfaces: Acoustic and Vocal and its effect of driving performance. AIDE- HMI questionnaire measures were used for the investigation.	Driving in automatic mode with the vocal modality is considered safer than acoustic one. At the same time vocal modality can be bit annoying, but this can be solved with dedicated design that allows the deactivation to expert users. In case of automation system fault the vocal modality seems to be the better one because it shortens drivers' reaction time. The	An interface design with a mixed automatic-manual modality is recommended for situation like automated driving in case of medium and low traffic, straight and high velocity streets and manual driving for medium and high traffic in the urban context, overtaking and for mountain streets.	

Publication	Objective	Mesured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
				visual information for the acoustic modality is considered more necessary than for the vocal modality. The labels such as «automatic overtaking", "fault" are not problematic and requires a pre warning.	Especially relevant for UC C.	
Hancock et al. (1990)	The work reported here examines the behaviour of car drivers during different driving sequences, in particular during left-turn maneuvers	Video-taping of the driver and the forward-looking scene	Results indicated that there were significant increases in head movements and mental workload during turn sequences compared to straight driving.	Results indicated that there were significant increases in head movements and mental workload during turn sequences compared to straight driving.	Consideration for Use Case scenarios. Includes both objective and subjective measures. Identification of relation between head movements and increase in workload. Important for UC A.	

3.1.5 Physiological states

Physiological signals, as ElectroCardioGraphy (ECG), Heart Rate (HR), Respiratory Rate (BR), Galvanic Skin Response (GSR), Blood Pressure (BP), Body Temperature (BT) and ElectroEncephaloGraphy (EEG), Grip Pressure (GP) were used in the past in experiments, in order to assess the physiological conditions of the driver and to estimate his/her fatigue, sleepiness, stress levels and drivers workload, (O'Hanlon and Kelley, 1977), (Egelund, 1982), (Brookhuis and De Waard, 1993), (Apparies et al., 1998), (Healey and Picard, 2005), (Papadelis et al., 2007). Ubiquitous and affective computing has created a new generation of less expensive and easily to integrate sensors (Bekiaris and Nikolaou, 2004). Prototypes were created with the non invasive use of physiological sensors in cars. (Lin et al., 2007) used a BT, BR, HR and GP sensor on a steering wheel for a simulator. (Osaka et al., 2008),(Matsuda and Makikawa, 2008) and (Jeong et al., 2007) used ECG electrodes either on two sides of the steering wheel or the seat. (Watson et al., 2011) created a prototype for a simulator with a steering wheel that integrates HR, GSR and BT sensors and seatbelt, that can measure the BR. Further, a biometric steering wheel reference design is available from Texas Instruments and Exmovere has developed a steering wheel, that combines a GSR and a HR sensor. The fusion of many sensors is used for emotion recognition, since the combined data they provide is useful for different emotions (Leng et al., 2007), (Katsis et al., 2008). Issues with the use of the physiological signals sensors, mentioned by researchers of the above publications, include unreliability in the measurement with motions of the driver (motion artifacts), as well as not functioning of the measurement when the skin contact is not possible, e.g. with the GSR and ECG sensor, when the driver is wearing gloves. Wearable equipment, as smart-watches (Exmovere Holdings Inc, 2011) or bracelets (Ouwerkerk et al., 2013), can be used for physiological signal tracking, however they need to be paired with the integrated system of the vehicle, adding to the workload of the driver. NFC technology may be used in this case for seamless function. Also the investigation of extremely low or high temperatures that may lead to hypothermia/ hyperthermia is not available and medical evidence for studies do not necessarily transfer knowledge from other activities or clinical studies to riders. In addition, faint, frostbite and other conditions are similarly not studied in the past, therefore any studies included are from other disciplines. Transferability of knowledge and technologies need to further be investigated under the prism of the work to be performed within these contexts.

Table 10: *Summary of literature review- Physiological states' affective cluster*

Publication	Objective	Measured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
Key:	✓ - Must have	× - Not needed	■ - Good to have	◆ - Highly recommended		
Balasubramanian & Jagannath (2014)	Detecting motorcycle rider local physical fatigue and discomfort using surface electromyography and seat interface pressure	Surface electromyography (sEMG) Seat interface pressure	The authors find that the occurence of fatigue can be measured on postural muscle groups	Measuring sEMG might give information about fatigue and related conditions (e.g. faint because of fatigue).	If connection between these variables is clear, then they could be used to measure fatigue in riders but still not clear what type of sensors are more appropriate (relevant to UC F and G).	■
Zwolińska (2013)	Investigation of the effect of clothing gear to increase of rider's temperature.	Selected physiological parameters Thermal insulation Thermal comfort	The research confirmed the problem related to high values of thermal insulation of motorcycle clothing and transport of moisture from the skin surface. by decreasing the thermal insulation of motorcycle clothing, as well as by increasing the effectiveness of channeling	Rider's high temperatures and hyperthermia are taken into consideration in UC E.	Thermal comfort can be enhanced by taking out a membrane or, alternatively, by using a membrane which maintains optimal air permeability (to transfer sweat from the body) with improved protective properties against external conditions.	◆

Publication	Objective	Measured	Results	Relevance to ADAS&ME	Contribution to UCs	Key
			humidity off the skin surface			
Bogdan et al. (2012)	This article proposes a method for a comprehensive assessment of the effect of integral motorcycle helmets on physiological and cognitive responses of motorcyclist	heart rate, local skin temperature, core temperature, air temperature, relative humidity in the space between the helmet and the surface of the head, and the concentration of O2 and CO2 under the helmet motorcyclists' reflexes, fatigue, perceptiveness and mood	Measurements of mean skin temperature revealed that this was a reliable indicator for evaluating the effect of an integral helmet on a motorcyclist's physiological parameters.	Temperature inside the helmet, to be significant, has to be measured with great precision.	Investigate the applicability to Use Case E.	
Di Stasi et al. (2011)	Behavioural and eye-movement measures to track improvements in driving skills of vulnerable road users: First-time motorcycle riders.	behavioural and eye-related measures that are sensitive to both long-term experience and training in motorcycle riders	As expected, training led to an improvement in the riding skills of first-time riders, reducing the number of accidents, improving their capacity to adapt their speed to the situation, reducing trajectory-corrective movements, and	This multidimensional methodology can be useful for the design of the rider model and the rider monitoring system	Classification of states based on extracted features is extremely relevant to the FER that the project has uptake. The approach is validated and thus within the project we may replicate or replicate parts of it. Relevant to UCs E. F. G/	

Publication	**Objective**	**Measured**	**Results**	**Relevance to ADAS&ME**	**Contribution to UCs**	**Key**
			changing their pattern of gaze exploration.			
Airaksinen et al. (2007)	Modeling human thermal comfort	In this paper, a method based on Hui (2003) is presented to calculate local and overall human body thermal sensations in time dependent and nonuniform	The researchers determined comfort temperatures for every part of the body.	Thermal sensation values can be used for the definition of low and high temperatures for riders.	To know the comfort temperatures for every body region, linked with overall comfort sensation, could be very useful for UC E (i.e. ground truth definition)	
Woods, R. I. (1983)	Cooling of motorcyclists in various clothing during winter in Britain	Skin and ear-canal temperatures	The rate at which riders' feet cooled was not closely related to the rates their bodies cooled.	Differences in several parts of body can direct were to measure first in order to identify very low temperatures for hypothermia.	The model to calculate skin and body temperature is interesting and could be used in UC E.	
Parry, M. (1982)	Skin temperature and motorcyclists' braking performance	Time to brake	Cold weather affected signficantly braking time.	Low temperature are interesting measure for the whole body, not only for hands and braking behaviour but for hypothermia phenomenon. Study is also very old and the technologies used.	Could be feasible for ADSA&ME to measure hands temperatures to give a feedback in UC E.	

4 Applications (driver's/ rider's monitoring systems)

4.1 Passenger car & trucks

Each presented system will include information collected through the template whereas the title (brackets) identifies the relation to specific project's UCs. This section is structured around the affective states addressed.

4.1.1 Fatigue/ Drowsiness/ Sleepiness

Sleepiness constitutes one of the major causes of road accidents and can lead to severe physical injuries, deaths and significant economic losses.
Statistics indicate the need of a reliable driver drowsiness detection system, which could alert the driver before a mishap happens. Researchers have attempted to determine driver drowsiness using the following measures: (1) vehicle-based measures; (2) behavioural measures and (3) physiological measures.
This section includes systems, sensors, subjective measures and algorithms developed to detect this cluster of affective states. Not all of the technologies, measures, and batteries included in this section target vehicles and drivers but those mentioned potentially could. It is important to note that some of the technologies discussed have not be implemented/ used in road transport but there is potential for market expansion to the automotive industry.
Various technologies can be used to try to detect driver drowsiness.
Steering pattern monitoring: Primarily uses steering input from electric power steering system.
Vehicle position in lane monitoring: Uses lane monitoring camera.
Driver eye/face monitoring: Requires a camera watching the driver's face.
Physiological measurement: Requires body sensors for measure parameters like brain activity, heart rate, skin conductance, muscle activity.
As sleepiness detecting systems were the first to be investigated in the literature, we are far more informed than any other area of interest within the project. Thus, we will place less emphasis on this area in the benchmarking report. Distraction is also researched but not as much as sleepiness and therefore more information is included about sensors and algorithms. However, in many cases, it is obvious that many systems aim to address both safety risks (i.e. distraction and sleepiness). It is important to note, that ADAS&ME movee towards to a hybrid territory, that many systems can address many affective states or aspects of these states, therefore a consensus on how these affective states are linked and their indicators overlap should be reached.

4.1.1.1 In-vehicle systems/ sensors/algorithms

Product name – Delphi's Driver State Monitoring System

Producer/ Manufacturer

Delphi Automotive PLC (NYSE: DLPH) is a major Tier 1 ADAS supplier.

Contact information / Website (URL)

Headquartered in Gillingham, U.K., Delphi operates technical centers, manufacturing sites and customer support services in 44 countries.
URL: http://www.delphi.com/manufacturers/auto/sensors

Short description

The Delphi's Driver State Monitoring System monitors the driver's fatigue and distraction level and then reacts. The driver can be warned via seat and steering wheel vibrations or the system can offset driver workload or take specific action to help ensure safety. It is reported to be an automotive-grade, real-time, vision-based driver state monitor. Upon detecting and tracking the driver's facial features, the system analyzes eye-closures and head pose to infer his/her fatigue or distraction.

Images

Figure 9: *Delphi's Driver State Monitoring System*

Technical specifications / requirements

The information is used to warn the driver and to modulate the actions of other safety systems. The purpose of this monitor is to increase road safety by preventing drivers from falling asleep or from being overly distracted, and to improve the effectiveness of other safety systems. Eyetracking: 3 sensors in dashboard; 2 sensors in A-Pillar; 1 sensor near the radio.

ADAS&ME relevance (aspects covered):
Relevant to UCs: A,E,F,G;
A system that addresses two clusters of affective states within the project (sleepiness and distraction);
Facial recognition/ expressions are also considered in the system.
ADAS&ME irrelevance (aspects not covered): No automated functions, just detection/ recognition.
Price: Not available.

Product name – Seeing Machines

Producer/ Manufacturer

Seeing Machines, (AIM: SEE) – An ADAS Tier 1 supplier with specialization on driver monitoring.

Contact information / Website (URL)

Headquartered in Australia
24/7 Telephone Support
Call +1 855 377 4636 (toll-free US number)
Call +61 2 6103 4700 (Australia)
URL: https://www.seeingmachines.com/

Short description

Seeing Machines Driver Safety is a stand-alone system for preventing distraction and fatigue in professional truck drivers.

Images

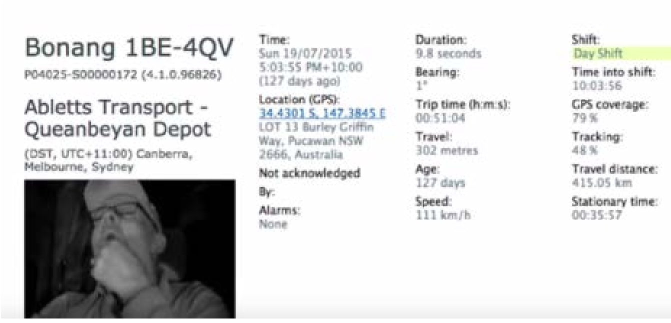


Figure 11: *Driver information and camera detecting fatigue*

Figure 10: *Seeing Machines Driver Safety System on board*

Technical specifications / requirements

- Driver fatigue and distraction detection technology;
- In-cab sensor and forward-facing camera;

- Real-time intervention;
- 3-tier SafeGuard Program.

ADAS&ME relevance (aspects covered)
Relevant to Ucs: A,E,F,G;
Relevant to two major affective states' clusters;
Existing product (stand-alone) and not vehicle integrated.
ADAS&ME irrelevance (aspects not covered)
No automation, though the fleet version includes potential intervention by the operators.
Price
Not available.

Product name – Anti Sleep Pilot®

Producer/ Manufacturer
Asp Technology Ltd
Contact information / Website (URL)
Apex House, Timothys Bridge Road, Stratford-Upon-Avon, Warwickshire, England, CV37 9BF.
Short description
The anti Sleep pilot by Asp Technology Ltd, is Stand-alone system for preventing distraction and fatigue, by scheduling break intervals, i.e. when having a break will have the greatest effect on drowsiness. Anti Sleep Pilot® claims that calculates how tired the driver is, maintains his/her alertness and lets him/her know when it is time to take a break.
While driving the Anti Sleep Pilot continuously calculates driver's fatigue level and keeps him/her informed of this via the display. The calculation is based on 1) driver's personal risk profile, which is determined by completing a short questionnaire, 2) driver's fatigue status before the trip and 3) data from driving behaviour that Anti Sleep Pilot automatically registers via built-in sensors. Anti Sleep Pilot maintains alertness using driver's alertness maintaining tests. The driver receives alertness maintaining tests at 10 to 25 minute intervals, depending on his/her risk profile and fatigue status. His/her reaction time is registered once he/she touches the top of the Anti Sleep Pilot. Anti Sleep Pilot records the reaction times and includes these in the calculation of driver's fatigue level.
When driver's fatigue level begins to reach a critical point the Anti Sleep Pilot uses both audible and visual signals to let him/her know it's time to take a break. A subtle light and sound indication is given when it is safe to continue driving.
Images


Figure 12: *The anti Sleep pilot device (right) locked on dashboard (left)*

Technical specifications / requirements
- Calculates driver's fatigue level
- Maintains driver's alertness
- Recommends a break
- Touch sensor – for interaction with the driver

ADAS&ME relevance (aspects covered):
Relevant UCs: A,E,F,G;
Driver needs to enter information to be built a driver profile;
Visual and auditory signals are sent;
Driver has to perform tasks while driving (tapping the system) to help defining level of attentiveness.

ADAS&ME irrelevance (aspects not covered):
No automated function; vehicle does not take control at any point.
Price: 240 Euros; Box Contains: Anti Sleep Pilot, Instructions.

Product name – Anti sleep driving alarm

Producer/ Manufacturer

Nap Zapper

Contact information / Website (URL)

Sales@NapZapper.com | Phone: 914.NAP.ZAPP (914.627.9277) | Los Angeles CA.
URL: *http://napzapper.com/*

Short description

The Nap Zapper anti sleep driving device sounds on alarm when the driver's ehad falls forward in drowsiness.

Images

Figure 13: *An anti-sleep device*

Technical specifications / requirements

Manufacturer Specifications:

- Main Function: Anti Sleep Alarm
- Alarm mode: Vibration
- Dimensions: 75 x 22 x 15mm
- Angle of Protection: 15~ 30
- Battery: Replaceable button cell battery
- Life Time: 30,000 nods Product Notes
- There is no vibration when the driver keeps normal driving status with eyes looking forward

ADAS&ME relevance (aspects covered):
Easy design and non-obtrusive;
Relevant to UC and affective state: A,E,F,G;
Simple stand-alone product; right of self; mainly for sleepiness – drowsiness (not fatigue);
ADAS&ME irrelevance (aspects not covered):
No automated functions;
Not appropriate for prediction – only for detection.
Price: Several prices, depending on company and model: from 10 to 70 Euros.

Product name – Anti sleep alarm Stop Sleep

Producer/ Manufacturer

StopSleep.biz

Contact information / Website (URL)

Sergej Kusnezow
Bernsteinstr.22
70619 Stuttgart
E-mail: admin@stopsleep.biz
Web: www.stopsleep.biz
Telefon: +49 170 / 1723188
URL: http://stopsleep.biz/

Short description
Anti Sleep Alarm StopSleep aims to recognise the loss of concentration and to prevent falling asleep. It is a stand-alone, small device to be worn on the fingers. It has 8 skin sensors, to detect electrodermal activity, in order to detect tiredness and warn the driver of sleep onset.

Images

Figure 14: *The StopSleep device (left) and worn while driving (right)*

Technical specifications / requirements
Anti-sleep alarm measures the conductivity of the skin (electrodermal activity - EDA). EDA reflects brain activity. Electrical conductivity of the skin varies, depending on the activity of the brain. The processing algorithm of the signal, which is used in the anti sleep alarm StopSleep is used for the detection of the following two states:

- **Falling asleep**, characterized by a strong signal decrease;
- **Reduction of reaction**, which can be called by the start of drowsiness, deep thought or simply boredom.

Both conditions are considered as dangerous for the driver, and therefore generate anti sleep alarm StopSleep, by warning signals (sound, vibration).
To work properly it is important for the driver to start to use StopSleep in a time, when he/ she is still active, and not when already being tired. The fatigue detection takes 3-5 minutes to measure current brain activity and then fatigue is estimated from this level.

ADAS&ME relevance (aspects covered):
Relevant to UCs and affective state: A,E,F,G.
Independent product; not vehicle type bound;
Warns drivers with an audio and vibration alarm;
Warns the driver before onset of sleep.
ADAS&ME irrelevance (aspects not covered):
No automation of functions or vehicle taking over for an action.
Price: Ranging from 170 € to 250 €

Product name – Vigo

Producer/ Manufacturer
Originally developed at the University of Pennsylvania. Built on principles of machine learning and statistics, Vigo's algorithm learns from individual differences, with a calibration phase, and adapts to individual driver's unique characteristics.

Short description
Vigo tracks driver's eyes and head motion to measure his/her levels of alertness. When Vigo senses the driver getting drowsy, it stimulates the driver with a combination of vibrations, music, audio, flashing light or phone calls. Vigo tracks over 20 parameters to measure variations, such as blink rates, blink durations and drooping eyelids. By analyzing biosignal patterns, Vigo senses driver's drowsiness. Vigo's 6-axis accelerometer and gyroscope measures movements of driver's head. Vigo also monitors head nods, lowered gaze and slouched postures.
Vigo exists also for fleets and professional drivers and operators. In addition to assessing the real-time alertness status of each driver, it measures his/her safe driving habits such as, scanning the road, checking side mirrors and taking rest breaks between long trips. Drivers get notified for bad behavior such as driving while operating a phone, harsh acceleration and braking, and speeding.

Images

Figure 15: *The Vigo device*

Figure 16: *Real time performance monitoring (for fleets)*

ADAS&ME relevance (aspects covered):
It stimulates the driver with a combination of vibrations, music, audio, flashing light or phone calls;
Stand-alone product;
Multi-type of warning (i.e. interesting for HMI strategies to be developed within the project);
Relevant to UCs and affective states and more than one type of vehicles: A, E ,F , G.
ADAS&ME irrelevance (aspects not covered):
No automated functions/ just warning.
Price: 97 Euros

Product name – Volvo's Driver Alert Control (DAC)

Settings are made from the centre console display screen and its menu system (MY CAR).

Producer/ Manufacturer

Volvo Car Group (Volvo Cars)

Contact information / Website (URL)

Volvo Car Corporation
405 31 Göteborg
Sweden
+46 31 59 00 00
URL: www.volvocars.com

Short description

This function alerts driver when they start losing concentration
The Driver Alert function can be set in standby mode via the menu system MY CAR:

- Checked box - function activated ;
- Unchecked box - the function is deactivated.

Driver Alert is activated when speed exceeds 65 km/h and remains active as long as the speed is

over 60 km/h.
If the vehicle is being driven erratically, the driver is notified by an acoustic signal plus the text message: “Driver Alert”, “Time for a break”, whereas the linked symbol (Figure 17) is illuminated in the combined instrument panel at the same time. The warning is repeated after a time if driving ability does not improve. The warning symbol can go off by pressing the left stalk switch OK button.

Images

Figure 17: *Volvo’s Driver Alert linked symbol (left) and camera continuously recognises lane markings (right)* (Source:https://www.youtube.com/watch?v=EJA1KSrhzNU)

Technical specifications / requirements

- Cameras recognise lane markings on the road (measures distance between car and lane markings) and assesses if the vehicle is driver in a controlled way;
- Steering wheel inputs.

ADAS&ME relevance (aspects covered):
Relevant to UC A;
Used on roads with higher speeds (not in urban roads);
HMI features: audible alert with visual feedback;
Displays 5 concentration levels.
ADAS&ME irrelevance (aspects not covered):
In-vehicle systems – not separate; so it can be examined/and implemented in ADAS&ME
Not suitable for use in every type of road;
Not related to automation level or functions (take-up/ continuous, etc.)
Price: Integrated in the vehicle price.

Product name – Ford’s Driver Alert

Offers a safety system which warns if the driver is at risk of falling asleep.

Producer/ Manufacturer

Ford Motor Company

Contact information / Website (URL)

Board of Directors
Ford Motor Company
P.O. Box 685
Dearborn, MI 48126-0685
U.S.A.
URL: http://www.ford.com/

Short description

The Driver Alert system comprises a small forward-facing camera connected to an on-board computer. The camera is mounted on the back of the rear view mirror and is trained to identify lane markings on both sides of the vehicle. When the vehicle is on the move, the computer looks at the road ahead and predicts where the car should be positioned relative to the lane markings. It then measures where the vehicle actually is, and if the difference is significant, the system issues a warning. The software detects this change in the vehicle's behaviour, triggering a two stage warning process. First a soft warning will pop up in the instrument cluster as a text message and will stay there for 10 seconds with an accompanying chime. If the driver continues to demonstrate drowsy behaviour, a hard warning will appear in the instrument cluster, which the driver must acknowledge by pressing an okay button! If the driver fails to acknowledge the hard warning, the system can only be re-set by stopping the car and opening the driver's door. The system then recognises that perhaps you have changed drivers or that you have had a rest and can continue.

Although Driver Alert's camera is trained to look for lane markings on both sides of the road it will function if markings on just one side are detected. The system can be switched off via the instrument cluster. It's been programmed to recognise intentional lane changing manœuvres, so it won't issue a warning whenever you overtake, for example. Because Driver Alert works by detecting sideways deviations, in theory a driver could fall asleep and not trigger the system, if the vehicle continues in a straight line.

Images

Figure 18: *Ford's Driver Alert warning*

Technical specifications / requirements

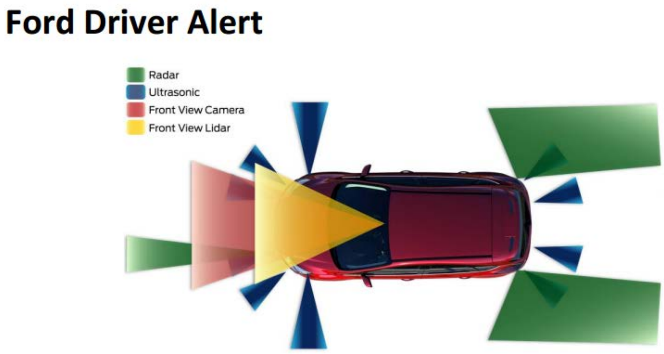


Figure 19: *Ford Driver Alert technologies*

(Source:http://www.euroncap.com/en/ratings-rewards/euro-ncap-advanced-rewards/2011-ford-driver-alert/)

- Front camera
- Vehicle movement parameters

ADAS&ME relevance (aspects covered):
Relevance to UC A;
Two-stage alert: a) icon in the display; b) (when alertness further decline) icon and chime;
Alert information recalled on the display.
ADAS&ME irrelevance (aspects not covered):
No automation related functions; however can operate using vehicle automation sensors.
Price:
In-vehicle implemented technology; no stand alone price.

Product name - Rest recommendation system

Producer/ Manufacturer

The Audi Group

Contact information / Website (URL)
http://www.audi.com/corporate/en/etc/contact.html
URL: http://www.audi.com/en.html
Short description
This system analyses driving behaviour based on steering, pedals and gear lever movements. If the system detects a change in driving patterns, it, via audio and visual effects, notifies the driver of the possible need to take a break. It shows a warning if it detects a decline in attentiveness. The system will activate above 40mph, but can be switched off by the driver.
Images

Figure 20: *Audi's Rest Recommendation System*

(Source: http://www.audi.in/sea/brand/in/models/a3/a3-cabriolet/safety-and-security.html)

Technical specifications / requirements

- Forward-facing camera
- Steering, pedals and gear level movements

ADAS&ME relevance (aspects covered):
Relevant to UC A;
Activated for speeds between 65 and 200 km/h;
Turned off by the driver if desired;
Audible and visual alert;
Support drowsy and distracted drivers.
ADAS&ME irrelevance (aspects not covered):
Vehicle parameters based;
Price: In-vehicle implemented technology; no stand alone price.

Product name –Active Driving Assistant and Active Driving Assistant Plus
Producer/ Manufacturer
Bayerische Motoren Werke AG (BMW)
Contact information / Website (URL)
URL:
http://www.bmw.com/com/en/newvehicles/x/x3/2014/showroom/driver_assistance/driving_assistant.html
Short description
Active Driving Assistant with **Attention Assistant** analyses driving behaviour and, if necessary, advises the driver to rest. The advice to take a break is provided in the form of graphic symbols shown on the Control Display. The Driving Assistant with the light city braking function high is seeing the surrounding vehicles. The Lane Departure Warning detects lane markings and may warn also with alerts the driver to an unintentional lane change at speeds above approx. 70 km/h by means of vibrations in the steering wheel. The warning is not activated if the lane change is deliberate, that is, when the turn indicator has been activated.
The Driving Assistant Plus feature (only available with Steptronic transmission) includes not only approach control warning and Lane Departure Warning, but also Active Cruise Control with Stop&Go function. This provides assistance when driving on motorways in both critical and stable traffic situations.
This option is only available in conjunction with the Navigation system Business or Professional. The approach control warning responds in stages. Should the car begin to change lanes unintentionally, the

Lane Departure Warning quickly provides a warning by means of vibrations in the steering wheel.
The Active Cruise Control maintains a constant selected speed between 30 km/h and 210 km/h or automatically adjusts to conform to the cars driving in front if the distance control is activated. The Stop&Go function even controls speed down to a standstill, accelerating again easily when the gas pedal is pressed, for example in dense moving traffic.

Images

Figure 21: *Active driving assistant menu (BMW)*

Technical specifications / requirements

- External camera-based systems;
- Puts together several systems/system functions: a) Lane Departure Warning, b) approach control (risk of collision with cars), and c) light city braking (risk of collision with pedestrians);
- Driving assistant plus (uses ACC with Stop& Go).

ADAS&ME relevance (aspects covered):
Relevance to UCA and UCD
For speeds above 70 km/h (System=Lane departure is activated)
Not activated if turning indicator is active
Speeds between 10 - 60 Km/h (System=Light city brake operates)
For speeds between 30 and 210 km/h (System= driving assistant plus:
Two-stage alert: symbol in the instrumented cluster + acoustic alarm
For city collision risks the system applies brakes
Completes stand-still for version Driving assistant plus
Multi-assistance with consideration of combination of vehicle variables
ADAS&ME irrelevance (aspects not covered):
Overall assistance for assisting the driver to control the driver but not specific to certain affective states;
Existing vehicle implementation for specific car models.
Price:
In-vehicle implemented technology; no stand alone price.

Product name - Fatigue detection system

VW has incorporated a system to assist drivers in the physical and mental well being when behind the wheel. The system monitors driver behaviour closely, noting deviations that may be warning signs to driver fatigue.

Producer/ Manufacturer

Volkswagen (shortened to VW).

Contact information / Website (URL)

URL:http://www.volkswagen.com.au/en/technology_and_service/technical-glossary/fatigue-detection.html

Short description

The driver Fatigue Detection system automatically analyses the driving characteristics and, if they indicate possible fatigue, recommends that the driver takes a break. The system continually evaluates steering wheel movements along with other signals in the vehicle on motorways and others roads at speeds in excess of 65 km/h, and calculates a fatigue estimate. If fatigue is detected, the driver is warned by information in the Multi-function Display and an acoustic signal. A driving time of 15 minutes is required in order to assess the driver correctly. The functionality of the system is restricted given a sporty driving style, winding roads and poor road surfaces. The manual includes also advice on effective breaks.

Images

Figure 22: *Visual and acoustic warning when the system finds the driver is waning* (source: https://www.youtube.com/watch?v=W12qBrtypb8)

Technical specifications / requirements

System continually evaluates steering wheel movements, along with other signals in the vehicle.

ADAS&ME relevance (aspects covered):
Relevant to UCA;
When vehicle speeds in excess of 65 km/h;
The driver is warned by information in the Multi-function Display and an acoustic signal;
The warning is repeated after 15 minutes if the driver has not taken a break;
A driving time of 15 minutes is required in order to assess the driver correctly.
ADAS&ME irrelevance (aspects not covered):
Functionality of the system is restricted given a sporty driving style, winding roads and poor road surfaces.
No function is automated, only suggestions are included.
Price:
In-vehicle already implemented technology; no stand alone price.

Product name – Nissan's Driver Attention Alert (DAA)

Nissan's Driver Attention Alert system analyzes driver steering behaviour to provide an alert if signs of drowsiness or inattention are detected. A system that could also be included in the previous section, where systems relevant to drowsiness and sleepiness are presented.

Producer/ Manufacturer

Nissan Motor Co., Ltd.

Nissan Motor Co., Ltd., is headquartered in Yokohama, Japan, and is part of the Renault-Nissan Alliance.

Contact information / Website (URL)

URL: http://www.nissan-global.com/EN/

Short description

Nissan's DAA system adapts to each individual driver. DAA monitors steering input patterns (using steering angle sensors) during a period of driving to establish a baseline. It continuously compares subsequent driving patterns to a baseline using a statistical analysis of steering correction errors.

If it detects driving behaviour consistent with a drowsy driver, the system uses an audible chime sound and displays the amber coffee cup with a message reading, "Take a break?" in the vehicle's information display. The DAA includes logic to help address false detection, road curvatures, lane changes, braking and even poor road conditions. The system automatically resets when the engine is turned off. It can also be turned off by the driver, if desired.

Images

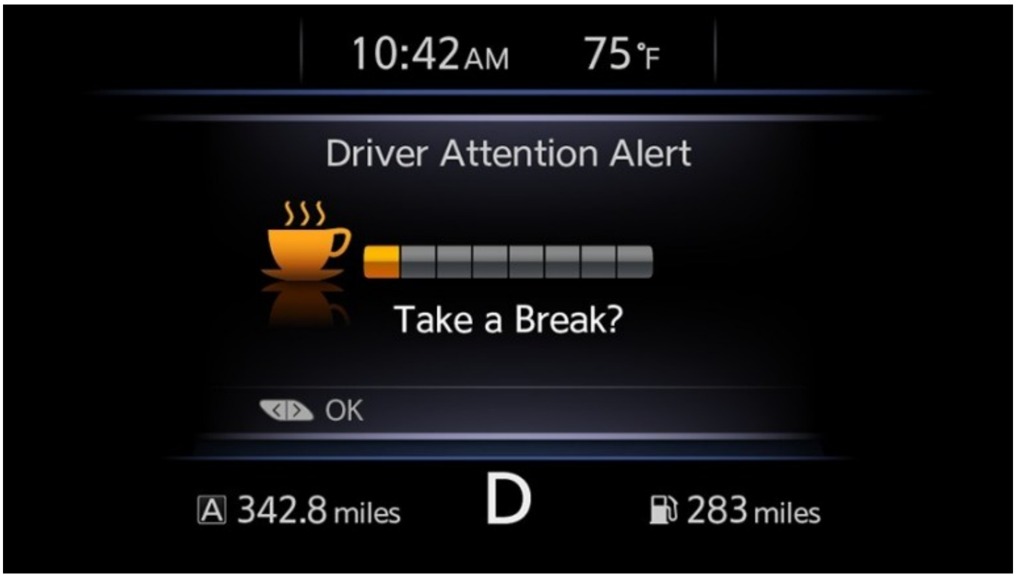


Figure 23: *Nissan's DAA informs the driver when it is time to take a break* (Source: http://nissannews.com/en-US/nissan/usa/releases/nissan-s-driver-attention-alert-helps-detect-erratic-driving-caused-by-drowsiness-and-inattention?la=1)

Technical specifications / requirements

Using steering angle sensors, DAA monitors steering input patterns to establish a baseline or a "snapshot" of how you were driving. Then, it continuously compares subsequent driving patterns to the most recent snapshot using a statistical analysis of steering corrections.

If DAA detects driving behaviour consistent with drowsy driving, it will let you know by:

1. Sounding an audible chime
2. Displaying an amber coffee cup in the instrument panel
3. Displaying the message "Take a break?" next to the coffee cup

The system also includes logic to help address false detections such as lane changes, braking events, and even poor road conditions. It's even smart enough to know when you may be drowsy, and also know when your driving patterns have to be adjusted to fit the circumstances.

ADAS&ME relevance (aspects covered):
Relevant to UC E and A, C, D (for inattention / distraction);
Detection of drowsiness and distraction through steering wheel indicators;
HMI to communicate and advice drivers to take a break;
Can be turned on/ off.
ADAS&ME irrelevance (aspects not covered):
In-vehicle systems – not separate so they can be examined/ and implemented in ADAS&ME;
Only warn the driver based on collection of only one indicator (i.e. steering wheel);
Not related to automation.
Price: Part of the passenger car technologies.

Other automotive manufacturers

The Saab Driver Attention Warning System (Nabo, 2015) detects visual inattention and drowsy driving. The system uses two miniature IR cameras integrated with Smart Eye technology to accurately estimate head pose, gaze, and eyelid status. When a driver's gaze is not located inside the primary attention zone (which covers the central part of the frontal windshield) for a predefined period, an alarm is triggered. Toyota has equipped their luxury Lexus models with their Driver Monitoring System (Ishiguro et al., 2006). The system permanently monitors the movement of the driver's head when looking from side to side using a NIR camera installed at the top of the steering wheel column. The system is integrated into Toyota's pre-crash system, which warns the driver when a collision is likely to happen. More recently, a Hyundai concept car (the Hyundai HCD-14) incorporates Tobbi Technologies to track the eyes.

ADAS&ME relevance (aspects covered):

Relevant to UC A, C, D (attention also);
Includes Smart Eye technology (partner);
Steerng wheel sensors;
Use of NIR camera;
Automated functions, pre-crash system.
ADAS&ME irrelevance (aspects not covered): -
Price: In-vehicle already implemented technology; no stand alone price.

Product name - Texas Instruments Biometric Steering Wheel

Producer/ Manufacturer

Texas Instruments Incorporated is a global semiconductor company operating in 35 countries.

Contact information / Website (URL)

Texas Instruments Incorporated
Executive Offices: 12500 TI Boulevard Dallas, Texas 75243 USA
Mailing Address: P.O. Box 660199 Dallas, TX 75266-0199
Phone Number: 972-995-2011 (not for semiconductor support)
URL: http://www.ti.com/

Short description

Texas instrument has come up with a design for a concept demonstration of how a driver's pulse rate, respiration rate, and ECG based heart rate can be obtained from a vehicle steering wheel. The company's AFE4400 and AFE4300 biometric analog front-ends (AFE) enable the acquisition of all three parameters via simple hand contacts on the steering wheel. The design includes a full BLE connectivity design for easy interface to smartphones and tablets.

The current collaboration between TI, Autoliv, and Neonode is bring in a prototype that is a new type of steering wheel that offers gesture recognition and multi-touch control.

Images

Figure 24: *The TI biometric steering wheel*

Technical specifications / requirements

- Features AFE4400 for measuring pulse from the palm;
- Features AFE4300 for measuring heart rate and respiration rate;
- MSP430F5528 MCU for holding algorithm data for each measurement;
- BLE module connection featuring TI's CC2541;
- This design is tested and provides everthing you need to complete your design including Schematics, Layout and Gerber files, and BOM.

ADAS&ME relevance (aspects covered):
Unobtrusively gathers physiological data to monitor driver's state;
Related to all passenger car related UCs.

ADAS&ME irrelevance (aspects not covered):
No automated function related.
Price: N/A (only prototype so far).

BioRICs

Producer/ Manufacturer

BioRICS was created in 2006 as a spin-off of the research unit Measure, Model and Manage Bio Responses (M3-BIORES), the former Laboratory for Agricultural Buildings Research, of the Department Biosystems of the Katholieke Universiteit Leuven.

Contact Info / Website URL:

Location:
BioRICS NV
Technologielaan 3
3001 Heverlee
Belgium
Phone number:
016/395854
URL: https://www.biorics.com

Short Description

The BioRICS algorithm for sleepiness' detection is reported to predict which driver is going to fall asleep and raise an alarm up to 15 minutes before the driver reaches a state of heavy drowsiness. The technology is aimed to be implemented in different means of transport, such as trucks, ships, trains and airplanes

Images

Figure 25: *The BioRICS algorithm used to detect sleepiness in truck drivers*

Technical specifications / requirements

By monitoring the driver's biological responses (ECG, biorythm, heat balance and/or driving performance) in real-time during the driving activity using wearable technology, and putting these data into a mathematical algorithm, changes in the individual driver's body functions are detected and allow to predict when sleep will set in.

ADAS&ME relevance (aspects covered):
High relevant to UCA;
Uses biological responses in real-time driving;
Uses wearable technologies.
ADAS&ME irrelevance (aspects not covered):
No automated function related.
Price: N/A.

4.1.1.2 Subjective measures

Subjective measures that evaluate the level of drowsiness are based on the driver's personal estimation and many tools have been used to translate this rating to a measure of driver drowsiness.

Karolinska Sleepiness Scale (KSS)

The most commonly used drowsiness scale is the Karolinska Sleepiness Scale (KSS), a nine-point scale that has verbal anchors for each step, as shown in Table 2 (Otmani, 2005). Hu *et al.* measured the KSS ratings of drivers every 5 min and used it as a reference to the EoG signal collected (Hu et a., 2009). Bekiaris *et al.* evaluated EEG data by confirming driver drowsiness through both a questionnaire and a licensed medical practitioner (Bekiaris et al., 2007). Some researchers compared the self-determined KSS, which was recorded every 2 min during the driving task, with the variation of lane position (VLP) and found that these measures were not in agreement (Sommer et al., 2010). Ingre *et al.* determined a relationship between the eye blink duration and the KSS collected every 5 min during the driving task (Ingre et al., 2006).
Researchers have determined that major lane departures, high eye blink duration and drowsiness-related physiological signals are prevalent for KSS ratings between 5 and 9 (Ingre et al., 2006). However, the subjective rating does not fully coincide with vehicle-based, physiological and behavioral measures.

Table 11: *Karolinska Sleepiness Scale (KSS)*

Rating	Verbal descriptions
1	Extremely alert
2	Very alert
3	Alert
4	Fairly alert
5	Neither alert nor sleepy
6	Some signs of sleepiness
7	Sleepy, but no effort to keep alert
8	Sleepy, some effort to keep alert
9	Very sleepy, great effort to keep alert, fighting sleep

Because the level of drowsiness is measured approximately every 5 min, sudden variations cannot be detected using subjective measures. Another limitation to using subjective ratings is that the self-introspection alerts the driver, thereby reducing their drowsiness level. In addition, it is difficult to obtain drowsiness feedback from a driver in a real driving situation. Therefore, while subjective ratings are useful in determining drowsiness in a simulated environment, the remaining measures may be better suited for the detection of drowsiness in a real environment.

Epsworth Sleepiness Scale (ESS) (Johns, 1997)

The ESS is a self-administered questionnaire with 8 questions. Respondents are asked to rate, on a 4-point scale (0-3), their usual chances of dozing off or falling asleep while engaged in eight different activities. Most people engage in those activities at least occasionally, although not necessarily every day. The ESS score (the sum of 8 item scores, 0-3) can range from 0 to 24. The higher the ESS score, the higher that personal average sleep propensity in daily life (ASP), or their average daytime sleepiness. The questionnaire takes no more than 2 or 3 minutes to answer. It is available in many different languages.

Samn-Perelli fatigue scale (SPS) [Samn & Perelli, 1982).

In the Samn-Perelli fatigue scale, the driver has to mark his/her relation to all of the 10 statements given on the screen. Fatigue assessed by this scale has a score between 0 and 20. The Samn-Perelli scale is standardised and has been used mainly in aviation, but not with drivers. Both the Karolinska sleepiness and the Samn-Perelli fatigue scales can be manipulated by the drivers towards better results, especially when it is known, which results can restrain the driver from starting his duty. Subjective scales are more demanding than filling in the checklist, but are usually completed in a shorter time.

Visual analogue scales (VAS)

The **visual analogue scale** or **visual analog scale** (**VAS)** (Reips et al., 2008) Generator. is a psychometric response scale, which can be used in questionnaires. It is a measurement instrument for subjective characteristics or attitudes that cannot be directly measured. When responding to a VAS item, respondents specify their level of agreement to a statement by indicating a position along a continuous line between two end-points. The test is represented by a line with "No Fatigue" and "Fatigue labelled" on two ends. The respondent will then draw a mark where h/she feels to be.

Advantages of subjective scales:
Relevant to UCs A, E, F, G.
-quick and easy to administer;
-either paper-based or computer-based;
-minimal BUT disruptive to driver – cannot measure during driving, unless in controlled conditions (e.g. simulated with co-driver;)
-many studies have used the SPS and KSS, and provide data for comparison.
Disadvantages of subjective scales:
-relatively easy to cheat;
-may lack face validity;
-do not always reliably reflect objective performance measures.
Price: for free.

4.1.2 Inattention/ Distraction/ Cognitive Load

4.1.2.1 In-vehicle systems/ sensors/algorithms

Pupil-Based Driver Monitoring System

Product name **-** HARMAN introduced a pupil-based tracking system that monitors a driver's cognitive workload.

Producer/ Manufacturer

HARMAN International is a Tier 1 supplier for OEM's, as well as consumers and business products.

Contact information / Website (URL)

CORPORATE HEADQUARTERS
HARMAN International
400 Atlantic Street
Stamford, CT 06901, USA
URL: http://www.harman.com/contact-us

Short description

The camera records fluctuations of the pupil for the calculation of the cognitive workload. ARMAN's new proprietary eye and pupil tracking system measures high cognitive load and mental multitasking in the driver's seat, and signals the car's other safety systems to adapt to the driver's state.

Images

Figure 26: *HMI feature for in-vehicle central mirror (left) and HMI showing increase in cognitive workload (right)*

Technical specifications / requirements

The camera continually captures the driver's pupil dilation, and a proprietary software algorithm analyzes the pupil reflex using advanced filtering and signal processing. The filter isolates and identifies responses triggered by high cognitive load. The calculated outputs are used to intuitively adjust user interfaces, like placing mobile devices in do-not-disturb mode or adjusting ADAS intervention thresholds, to minimize physical and mental distraction to the driver.

ADAS&ME relevance (aspects covered):
Relevance to UCs A, C and D.
Easy configurable, off the self product.
ADAS&ME irrelevance (aspects not covered): No automation related, single indicator related.
Price: Not known.

Product name - A-Class: Attention assist

Producer/ Manufacturer

Mercedes Benz Original (Daimler AG)

Contact information / Website (URL)

Daimler AG

Mercedesstraße 137

D-70327 Stuttgart

E-mail: dialog@daimler.com

URL: http://techcenter.mercedes-benz.com/en/attention_assist/detail.html

YouTube channel videos:
https://www.youtube.com/watch?v=uMZDV3JL7IE
https://www.youtube.com/watch?v=nu1Ax3Z7zyY
https://www.youtube.com/watch?v=A66zgJ4Oj8o
https://www.youtube.com/watch?v=mf8JYVa7f1w

Short description

ATTENTION ASSIST creates an individual driver profile, detects by reference to over 70 measured variables when the driver is becoming tired and duly prompts him/her to take a rest. The system is active at speeds between 80 and 180 km/h, analysing a number of indicators to monitor the driver's gradual transition from alertness to tiredness.

Images

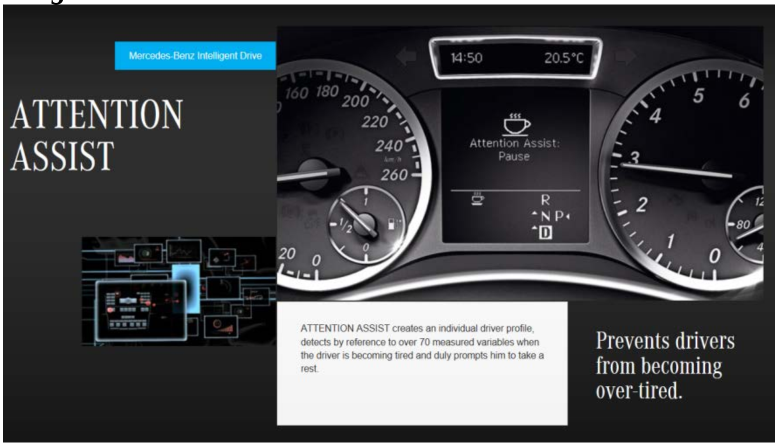


Figure 27: *A class: Attention Assist*

Technical specifications / requirements

The algorithm is based on driving parameters (steering movements and steering speed, trip duration, use of other systems/instruments in the car that show signs of activity). This information is used to define the driver's state (principle: more monotony, higher risk).

ADAS&ME relevance (aspects covered):
Relevance to UCs A, C, and D.
Continuous personalised monitoring of the transition from awake/alarmed to fatigue;
Complete HMI to warn and inform driver;
Uses profile of driving style defined in the first few minutes of driving;
Speeds between 80-180 Km/h or 60-200 Km/h, depending on models.
Cofiguration Mode: standard & Sensitive;
Visual and audiable warning;
Information on dashboard with 5 levels of attention;

Activated by the driver.
ADAS&ME irrelevance (aspects not covered):
Existing product for A-Class Mercedes not open for integration; vehicle parameters and drowsy behaviour based.
Price: Not relevant; no stand alone function.

Product name - Mazda i-ACTIVSENSE: Driver Attention Alert (DAA)
DAA Mazda's Driver Attention Alert aims to help improve the safety of longer distance journeys by monitoring driver's attentiveness.
Producer/ Manufacturer
Mazda Motor Corporation
Contact information / Website (URL)
Company name: Mazda Motor Corporation
Founded: January 30, 1920
Headquarters: 3-1 Shinchi, Fuchu-cho, Aki-gun, Hiroshima 730-8670 Japan
Representative: Masamichi Kogai, Representative Director; President and CEO
URL: https://www.mazda.com.au/innovation/i-activsense/
YouTube URLs:
https://www.youtube.com/watch?v=yXyhdnYB1xQ
Short description
Driver Attention Alert is designed to reduce accidents caused by inattentiveness due to driver fatigue. The system comes into play at speeds above 65 km/h and begins to "learn" the driver's habits, watching inputs and the vehicle's movements in the early stages before fatigue is a factor. Later, if the system detects changes in vehicle behaviour that suggest the driver may be losing concentration, it will suggest a rest stop by sounding a chime and displaying a warning in the Multi-Information Display.
DAA is designed to alleviate the burden of driving and reduce damage resulting from accidents and is predicated on the driver operating the vehicle in a safe manner.
Images

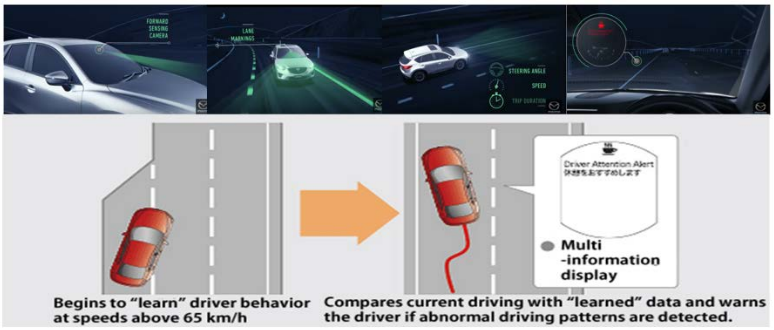


Figure 28: *The i-ACTIVSENSE in action*

(source: http://www.mazda.com/en/innovation/technology/safety/active_safety/daa/)

Technical specifications / requirements

- Sensors and forward camera to measure distance to lane marking.
- Parameters: steering angle, speed, trip duration, position on the lane.

ADAS&ME relevance (aspects covered):
Uses profile of driving style;
Activated when speed is higher than 65 Km/h for trips longer than 20 minutes;
Warning with advice to rest;
Activated by the driver;
Relevant for UC A, C, and D.
ADAS&ME irrelevance (aspects not covered): In-vehicle commercial system; it is part of embedded technologies. However, it addresses behaviour only for long and leisure journeys and driving style sensors based only.

Price: Part of the passenger car technologies; no stand alone price.

Product name - EyeSight Driver Assist

Producer/ Manufacturer

Subaru.

Contact information / Website (URL)

http://www.subaru.com/company.html

URL: *http://www.subaru.com/guides/forester/my16/Life/EyeSight*

Short description

EyeSight®1 Driver Assist Technology integrates multiple convenience and safety features and aims to give a virtual second pair of eyes on the road that can warn the driver of potential danger ahead—and apply the brakes, if necessary. It involves the following technologies:

- **Pre-collision braking**: provides automatic braking that prevents a collision or reduces the severity of a frontal impact.
- **Pre-collision throttle management:** provides automatic acceleration reduction in order to minimize the severity of certain frontal impacts.
- **Adaptive cruise control:** like conventional cruise control, the driver sets the desired speed with the steering wheel switch. When the driver reaches a halt at traffic by switching it again, the car accelerates and keeps the pre-selected distance from the leading vehicle.
- **Lane departure and sway control:** alerts driver when they depart the lane (without signaling) and when the driver drifts back and forth, then another alert is signaled in order to inform the driver to become attention (it may be a sign of inattention).

Images

The photos in this section are all taken by the following url: http://www.subaru.com/guides/forester/my16/Life/EyeSight

Figure 29: *Eye sight camera*

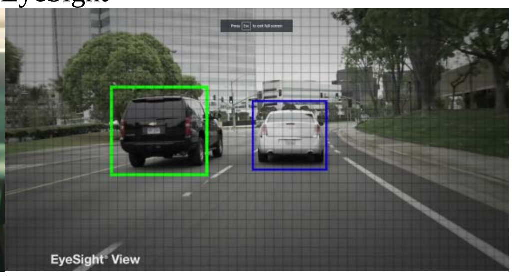
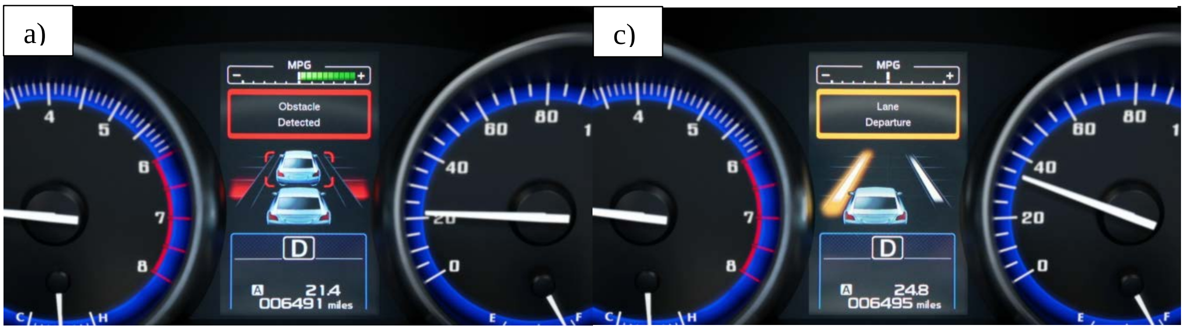


Figure 30: *Eye sight camera detects a probably critical frontal event*



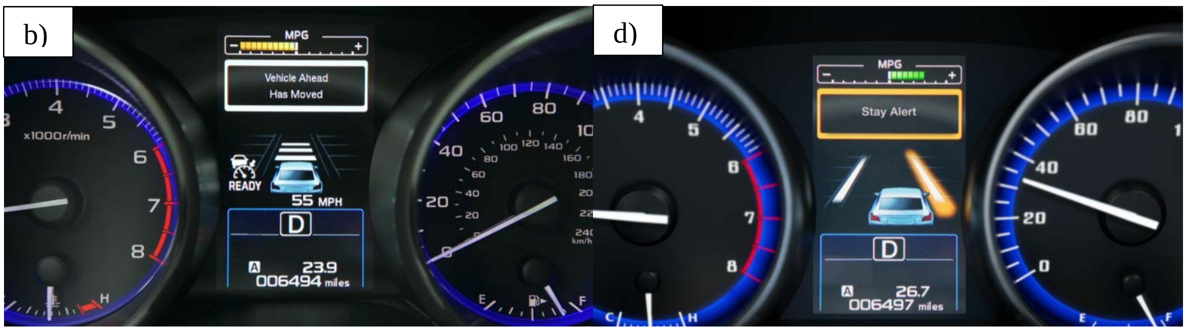


Figure 31: *Subaru with Eyesight dashboard: a) Pre-collision braking alert, b) Adaptive cruise control, c) Lane departure warning, d) Drifting back and forth warning*

Technical specifications / requirements

- Camera-based technologies;
- Puts together several in-vehicle systems: a) pre-collision braking; b) pre-collisions throttle management; c) Adaptive Cruise control; d) Lane departure & Sway warning.

ADAS&ME relevance (aspects covered):
Relevant to UCs A, C, D;
Warns the driver and intervenes if driver does not react.
ADAS&ME irrelevance (aspects not covered):
Provides a whole set of functions that informs, warns and automatically takes control of vehicle; probably the most complete set of function for the driver's safety and potentially targets a driver's affective state. However, the focus is overall safety and not addressing a specific affective state per se. The latter was found in other technologies but without an automated function.
Price: Vehicle implemented technology.

Product name – zForce DRIVE™ Steering Wheel Sensor

Producer/ Manufacturer

Neonode develops and licenses optical touch solutions.

Contact information / Website (URL)

Neonode Inc
2880 Zanker Rd,
Suite 362, San Jose
CA 95134
USA
Phone: +1 408 496 6722
URL: http://www.neonode.com

Short description

zForce DRIVE steering wheel sensor allows the car to know exactly where on the wheel the driver has his/her hands at any given moment. It's a scalable HMI toolbox, that can be integrated to the center stack and Head Up Display – or even replace the center stack altogether.

Images

Figure 32: ***Neonode zForce steering wheel sensor***

ADAS&ME relevance (aspects covered):
UCs A, C, D and vehicle relevant;
Interesting HMI interactions.
ADAS&ME irrelevance (aspects not covered): No automated function related
Price: N/A (prototype).

4.1.2.2 Commercial sensors

Smart Eye

The Smart Eye system consists of a multi-camera system running on a single PC and on a single algorithm. The system is scalable from 2 up to 8 cameras allowing 360 head and eye tracking. A typical configuration inside a vehicle cabin is composed of four cameras with two IR lightings, located on the dashboard on either side of the steering wheel. Smart Eye offers a sampling rate of 60 Hz (up to 8 cameras) or 120 Hz (up to 4 cameras). The field of view, depending on the number of cameras, is in the range of 90 –360. The data output includes over 145 values covering, among others, gaze, eyelid, pupilometry and head tracking, raw and filtered gaze, blinks, fixations and saccades.

EyeAlert

EyeAlert has been conceived to detect driver inattention using computer vision and to generate a warning signal in case of dangerous situation. The EyeAlert system focuses entirely on the driver's alertness levels or inattention to the road ahead, regardless of the time of the day or the weather conditions. Three models are available: EyeAlert EA410 detects both distracted and fatigue driving. The EA410 has an IR camera, a computer, an image processing unit and an alarm. The system will also respond in case the driver does not focus on driving. EyeAlert EA430, with GPS, detects both distracted and fatigue driving. Moreover, a minimum speed threshold is programmed into the internal GPS to prevent false alarms in urban environments. Additionally, minimum speed threshold, sensitivity, volume and data can be remotely programmed.

Seeing Machines

SeeingMachines builds image-processing technology that tracks the movement of a person's eyes, face, head, and facial expressions. It monitors fatigue and distraction events in real-time and uses IR technology to provide fatigue and distraction monitoring at any time of the day. The system can also combine multiple camera sensors, to detect a wider range of movements. The Seeing Machines' system continuously measures operator eye and eyelid behaviour to determine the onset of fatigue and micro sleeps and delivers real-time detection and alerts. Apart from the sensor the monitoring system is presented in a previous section of this report.

Visage Technologies AB

Visage Technologies AB provides a commercial head tracker based on feature-point detection and tracking of the nose boundary and eye regions. Visage SDK finds and tracks the face and facial features, including gaze direction, in video sequences in real time. It provides pupil coordinates, 3D gaze direction as well as (with a calibration step) screen-space gaze point. Visage Technologies also features support for embedded systems like FPGA and IR light tracking for poor lighting conditions.

Delphi Electronics Driver Status Monitor

Delphi Electronics developed a single camera Driver Status Monitor (DSM) (Edenborough et al., 2015). By detecting and tracking the driver's facial features, the system analyzes eye-closures and head pose to infer his/her fatigue or distraction. This information is used to warn the driver and to modulate the actions of other safety systems. The system includes the use of NIR illumination, an embedded processing unit, as well as the camera (resolution of 640 480 pixels).

Tobii Technologies

Tobii Technologies develops Tobii's eye-tracking technology for integration into volume products, such as computers, computer games, virtual reality and cars. The Tobii platform consists of two-camera sensors, placed at different angles, and operating at IR frequencies to eliminate interference from external light. The system can distinguish whether the driver's eyes are open or closed or if the driver has turned his/her head. The sensors work even when the driver is wearing glasses or sunglasses. By observing the specifics of eyelid closure, in combination with eye gaze patterns, an active safety system powered by Tobii's eye tracking sensor can reliably detect if a driver is falling asleep and warns him/her properly. Moreover, Tobbi Technologies provides the Tobii EyeChip, which is a dedicated eye tracking SOC ASIC.

SensoMotoric Instruments

SensoMotoric Instruments GmbH (SMI) Eye and gaze tracking systems. Their eye tracking solutions can measure head position and orientation, gaze direction, eyelid opening, and pupil position and diameter. Eye trackers use a sampling rate of 120 Hz for head pose and gaze measurement, 120 Hz for eyelid closure and blink measurement, and 60 Hz for combined gaze, head pose, and eyelid measurement. It also provides PERCLOS information for drowsiness detection. It is a computer-based system and needs user calibration. In [Juhola et al., 2013) SensoMotoric was used to recognize the pupil in each image in order to measure horizontal and vertical eye movements.

4.1.2.3 Algorithms

The following tables are from a recent review carried out by Fernandez et al. (2016) and refer to algorithms developed to identify distraction within the vehicle. The interest for this project is the comparison of several algorithms on aspects (classifiers) relevant to the project. (Fernández et al., 2016). The highlighted in blue, are the algorithms with higher success rate based on the comparison indicator chosen in each table. The aim is to identify the algorithms with higher success rate in relation to the ones already included in the project. The information added in section might of greater interest for WP4 partners. We did not go into detail in each algorithm but for a detailed accound, please refer to (Fernández et al., 2016). These algorithms are relevant for UC C and D (cognitive distraction).

Table 12: *Computer vision algorithms to detect cell phone usage. High recognition rates are usually obtained using very different approaches*

Algorithm	**Features**	**Classifier**	**Recognition Rate (%)**
Zhang et al. [1]	Features from the driver's face, mouth and hand	Hidden Conditional Random Fields (HCRF)	91.20 91.2
Artan et al. [2]	Image descriptors extracted from a region of interest around the face	SVM	86.19
Berri et al. [3]	Percentage of the Hand and Moment of Inertia	FV	91.57
Xu et al. [4]	DPM	FV	**95**
Seshadri et al. [5]	Raw pixels and HOG features	Real AdaBoost, SVM, RF	93.86

[1] Zhang, X.; Zheng, N.; Wang, F.; He, Y. Visual recognition of driver hand-held cell phone use based on hidden CRF. In Proceedings of the 2011 IEEE International Conference on Vehicular Electronics and Safety (ICVES), Beijing, China, 10–12 July 2011; pp. 248–251.
[2]Artan, Y.; Bulan, O.; Loce, R.P.; Paul, P. Driver cell phone usage detection from HOV/HOT NIR images. In Proceedings of the 2014 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), Columbus, OH, USA, 23–28 June 2014; pp. 225–230.
[3]Berri, R.A.; Silva, A.G.; Parpinelli, R.S.; Girardi, E.; Arthur, R. A Pattern Recognition System for Detecting Use of Mobile Phones While Driving. 2014, arXiv preprint arXiv:1408.0680.
[4] Xu, B.; Loce, R.P. A machine learning approach for detecting cell phone usage. In Proceedings of the IS&T/SPIE Electronic Imaging, International Society for Optics and Photonics, San Francisco, CA, USA, 4 March 2015.
[5] Seshadri, K.; Juefei-Xu, F.; Pal, D.K.; Savvides, M.; Thor, C.P. Driver Cell Phone Usage Detection on Strategic Highway Research Program (SHRP2) Face View Videos. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, Boston, MA, USA, 7–12 June 2015.

Table 13: *Hands recognition in different regions inside the car using CVRR-HANDS 3D dataset [1]*

Algorithm	**Features**	**Classifier**	**Regions**	**Recognition Rate** (%)
Ohn et al. [1]	RGB data	SVM	5	52.1
Ohn et al. [1]	RGB combined with depth data	SVM	5	69.4
Martin et al. [2]	Hands cues	SVM	3	83
Martin et al. [2]	Hands and head cues	SVM	3	91
Ohn et al. [3]	Hands cues	SVM	3	90
Ohn et al. [3]	Hands and head cues	SVM	3	**94**

[1] Ohn-Bar, E.; Trivedi, M.M. The power is in your hands: 3D analysis of hand gestures in naturalistic video. In Proceedings of the 2013 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), Portland, OR, USA, 23–28 June 2013; pp. 912–917.
[2] Martin, S.; Ohn-Bar, E.; Tawari, A.; Trivedi, M.M. Understanding head and hand activities and coordination in naturalistic driving videos. In Proceedings of the 2014 IEEE Intelligent Vehicles Symposium Proceedings, Ypsilanti, MI, USA, 8–11 June 2014; pp. 884–889.
[3] Ohn-Bar, E.; Martin, S.; Tawari, A.; Trivedi, M. Head, eye, and hand patterns for driver activity recognition. In Proceedings of the IEEE 2014 22nd International Conference on Pattern Recognition (ICPR), Stockholm, Sweden, 24–28 August 2014; pp. 660–665.

Table 14: *Supervised algorithms for cognitive distraction detection*

Algorithm	**Features**	**Classifier**	**Accuracy (%)**
Zhang et al. [1]	Eye gaze-related features and driving performance	Decistion Tree	81
Zhang et al. [1]	Eye gaze-related features	Decistion Tree	80

Algorithm	Features	Classifier	Accuracy (%)
Zhang et al. [1]	Pupil-diameter features	Decistion Tree	61
Zhang et al. [1]	Driving performance	Decistion Tree	60
Liang, Reyes, et al. [2]	Eye gaze-related features and driving performance	SVM	83.15
Liang, Reyes, et al. [2]	Eye gaze-related features	SVM	81.38
Liang, Reyes, et al. [2]	driving performance	SVM	54.37
Liang, Lee, et al. [3]	Eye gaze-related features and driving performance data	DBNs	80.1
Miyaji et al. [4]	Heart rate, Eye gaze-related features and pupil diameter	AdaBoost	**91.5**
Miyaji et al. [4]	Eye gaze-related features	SVM	77.1 (arithmetic task)
Miyaji et al. [4]	Eye gaze-related features	SVM	84.2 (conversation task)
Miyaji et al. [4]	Eye gaze-related features	AdaBoost	81.6 (arithmetic task)
Miyaji et al. [4]	Eye gaze-related features	AdaBoost	86.1 (conversation task)
Yang et al. [5]	Eye gaze-related features and driving performance data	ELM	87.0
Yang et al. [5]	Eye gaze-related features and driving performance data	SVM	82.9

[1] Zhang, Y.; Owechko, Y.; Zhang, J. Driver cognitive workload estimation: A data-driven perspective. In Proceedings of the 7th International IEEE Conference on Intelligent Transportation Systems, Washington, DC, USA, 3–6 October 2004; pp. 642–647.

[2] Liang, Y.; Reyes, M.L.; Lee, J.D. Real-time detection of driver cognitive distraction using support vector machines. IEEE Trans. Intell. Transp. Syst. 2007, 8, 340–350.

[3] Liang, Y.; Lee, J.D.; Reyes, M.L. Nonintrusive detection of driver cognitive distraction in real time using Bayesian networks. Transp. Res. Rec. J. Transp. Res. Board 2007, 2018, 1–8.

[4] Miyaji, M.; Kawanaka, H.; Oguri, K. Effect of pattern recognition features on detection for driver's cognitive distraction. In Proceedings of the 2010 13th International IEEE Conference on Intelligent Transportation Systems (ITSC), Funchal, Portugal, 19–22 September 2010; pp. 605–610.

[4]Yang, Y.; Sun, H.; Liu, T.; Huang, G.B.; Sourina, O. Driver Workload Detection in On-Road Driving Environment Using Machine Learning. In Proceedings of ELM-2014; Springer: Berlin/Heidelberg, Germany, 2015; Volume 2, pp. 389–398.

Table 15: *Mixing types of distraction detection algorithms*

Algorithm	Features	Classifier	Average Accuracy (%)
Li et al. [1]	AU and head pose	LDC (visual distraction) and SVM (cognitive distraction)	80.8 (LDC), 73.8 (SVM)
Craye et al. [2]	eye behaviour, arm position, head orientation and facial expressions using both color and depth images	Adaboot and HMM	89.84 (Adaboot), 89.64 (HMM)
Liu et al. [3]	Head and eye movements	SVM, ELM and CR-ELM	85.65 (SVM), 85.98 (ELM), 86.95 (CR-ELM)
Ragab et al. [4]	arm position, eye closure, eye gaze, facial expressions and head orientation using depth images	Adaboost, HMM, RF, SVM, CRF, NN	82.9 (RF—type of distraction detection), 90 (RF—distraction detection)

[1] Li, N.; Busso, C. Analysis of facial features of drivers under cognitive and visual distractions. In Proceedings of the 2013 IEEE International Conference on Multimedia and Expo (ICME), San Jose, CA, USA; 15–19 July 2013; pp. 1–6.
[2] Craye, C.; Karray, F. Driver distraction detection and recognition using RGB-D sensor. 2015, arXiv preprint arXiv:1502.00250.
[3] Liu, T.; Yang, Y.; Huang, G.B.; Lin, Z.; Klanner, F.; Denk, C.; Rasshofer, R.H. Cluster Regularized Extreme Learning Machine for Detecting Mixed-Type Distraction in Driving. In Proceedings of the 2015 IEEE 18th International Conference on Intelligent Transportation Systems (ITSC), Las Palmas de Gran Canaria, Spain, 15–18 September 2015; pp. 1323–1326.
[4] Ragab, A.; Craye, C.; Kamel, M.S.; Karray, F. A Visual-Based Driver Distraction Recognition and Detection Using Random Forest. In Image Analysis and Recognition; Springer: Berlin/Heidelberg, Germany, 2014; pp. 256–265.

4.1.2.4 Subjective measures

Subjective measurement of levels of workload is based on the use of rankings or scales to measure the amount of workload a person is feeling. Subjective workload measures are devoted primarily to the intermittent question and answer type response to varying levels of workload. The two main types of scales used to measure subjective workload are unidimensional and multidimensional scales. Unidimensional rating scales are considered the simplest to use because there are no complicated analysis techniques. The unidimensional scale has only one dimension. Generally, the unidimensional scale is more sensitive than the multidimensional scale. The multidimensional workload scale is considered to be a more complex and more time consuming form of measurement, and has from 3 to 6 dimensions. The multidimensional scale is generally more diagnostic (De Waard, 1996).

Several simple subjective mental workload scales have been developed to measure an individuals' perceived workload. Some of the main scales used in the driving domain include **NASA-task Load Index (TLX), Rating Scale Mental Effort (RSME), Situation Awareness Global Assessment Technique, Driving Activity Load Index (DALI)**.

NASA Task Load Index Scale (NASA-TLX)

The NASA Task Load Index uses six dimensions to assess workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Twenty-step bipolar scales are used to obtain ratings for these dimensions. A score from 0 to 100 is obtained on each scale. This scale uses a weighting process that requires a paired comparison task. The task requires the operator to choose which dimension is more relevant to workload for a particular task across all pairs of the six dimensions. The workload scale is obtained for each task by multiplying the weight by the individual dimension scale score, summing across scales, and dividing by the total weights (Hill et al., 1992).

Generally, the NASA-TLX is an extremely good multidimensional scale for measuring mental workload (Byers, 1989; Hill et al., 1992). Hill et al. (1992) found that the TLX was well liked, sensitive to changes in workload, and had high diagnosticity. One drawback is the time needed to complete and analyze the test. Another drawback with the TLX scale, as with any other subjective scale, is consistency. Hankins & Wilson (1998) reported that the TLX ratings "lacked internal consistency from the effort and frustration levels reported to the performance scale."

NASA-RTLX or RNASA-TLX

A different type of TLX scale was developed, called the NASA Raw Task Load Index (NASA RTLX). This scale was developed because the collection and analysis of the original TLX scale was cumbersome and labor intensive. The RTLX computes a score by taking the sum of the TLX test and dividing it by six. This new way to score the NASA-TLX was found to be almost equivalent to the original TLX scale R= .977 ($p<10-6$) (Byers, 1989), with far less time involved for analysis. In a driving situation, Park & Cha (1998) found that the RTLX scale was the more sensitive to mental demand and difficulty in driving than the TLX.

Subjective Workload Assessment Technique (SWAT)

The Subjective Workload Assessment Technique uses three levels – low, medium, and high – for each of the three dimensions of time load, mental load, and physiological stress load to assess workload (Hill et al., 1992). The SWAT technique scales the measurement scores to produce a single rating scale with interval properties (Hill et al., 1992). This multidimensional test uses three steps to complete and analyze workload. Hill et al. (1992) outlines the test in the following step method. The first step is scale development, which combines all the possible combinations of the three dimensions in 27 cards. The person sorts the cards into a ranking that reflects his or her perception of increasing workload. The rankings are used to develop a scale with interval properties. The second step is rating the workload. The third step is to convert the scores into a 0 to 100 scale using the scale developed in step one. The theory behind the SWAT technique is that it "(gains) insight into the mechanism of human information processing resources, together with the notion that it is possible to derive a model, by some rational procedure, that has greater validity than that of an arbitrarily chosen model" (Hendy et al., 1993).

Rating Scale Mental Effort (RSME)

The Rating Scale Mental Effort (RSME) scale is a unidimensional scale. "Ratings of invested effort are indicated by a cross on a continuous line. The line runs from 0 to 150 mm, and every 10 mm is

indicated" (De Waard, 1996). This scale rates invested effort of the task, not explicitly mental effort. De Waard (1996) found the RSME could distinguish between the "task-load situation and baseline." This does not seem to be a mainstream test because no other st*udies could be found that use the RSME to measure mental workload.
The Activation scale is comparable to the RSME. "The scale has a range from 0 to 270 and is scored by measuring the distance from the origin to the mark in millimeters" (De Waard, 1996). The reference points are based on general tasks like "I am reading the newspaper" (De Waard, 1996). People mark their estimated workload, comparing it to the general tasks. The sensitivity and diagnosticity of this test is not documented.

Driver Activity Load Index (DALI)

The Driver Activity Load Index (DALI) (Pauzié, A. (2008) is related to the NASA-TLX. The Driving Load Activity Index (DALI) is a tool that enables the gathering of informative data about the mental workload for the driver. The procedure to set up DALI was to ask various experts involved in the driving tasks studies to define which were, in their opion, the main factors inducing metal workload for people driving a vehicle equipped with an on-board system (car phone, driving aid systesm, aradio, etc.). This investiateion led to the following definitions for teh6 workload dimensions dor the DALI: Effort of attention, Visual demand, Auditory demand, Temporal demand, Intereference and Situational stress. Evaluation occurs on a 5-point rating scale (1:Low to 5:High). Subjective measurement of workload is good for determining how much workload a person "feels." In the past, multi-dimensional measures were considered the best form of subjective measurement of workload. Recently, however, there is some evidence that unidimensional ratings of workload could be just as good as the multidimensional scales. For simple tasks, or while performing a task, a unidimensional rating scale is very good because it is fast, easy, and not distracting. The overall workload scale has been shown to be a good unidimensional rating scale. At the end of the test, it may be beneficial to use a multidimensional scale to gain a more exact estimate of workload.

4.1.3 Stress/ anxiety

4.1.3.1 In-vehicle systems/ sensors/algorithms

For this section, only range anxiety systems are presented and not for those related to driver's stress monitoring in general. The systems and respective measures have been discussed in depth in the respective literature section (many of the studies focusses on systems).

Product name - ReVive range calculator (UC B)

Mahindra Rive Ltd has developed an application to reduce 'range anxiety' for the users of electric vehicles. The driver can activate an invisible fuel tank via phone (sending a text message) and then access to small charge is granted (i.e. a 15 km range is granted from a hidden reserve0. This has been used as a strategy to address range anxiety.

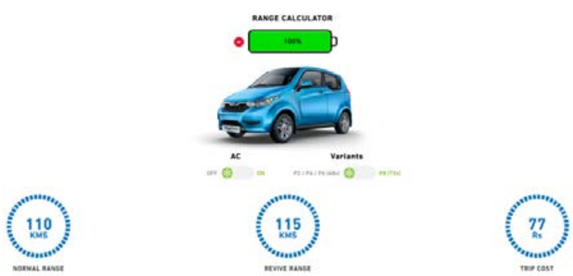


Figure 33: *In car range calculator*

Figure 34: *Phone activation of small charge*

Product name - Range assurance

Producer/ Manufacturer

Tesla Motors.

Contact information / Website (URL)

Sales

Toll free: (888) 51-TESLA or (888) 518-3752

Local: (650) 681-5100

Fax: (650) 681-5101

NASales@tesla.com

PowerwallOrders@tesla.com

Tech Support & Roadside Assistance

Toll free: (877) 79-TESLA or (877) 798-3752 Local Service Center: (844) 248-3752

Phone numbers for other countries

ServiceHelpNA@tesla.com

Safety recall information

URLs:

https://www.tesla.com/blog/model-s-has-you-covered

http://www.autoevolution.com/news/tesla-updates-model-s-with-range-assurance-and-trip-planner-auto-steering-will-follow-93477.html#

https://www.youtube.com/watch?v=mOYXaBHArP0

https://www.tesla.com

Short description

The Range Assurance application is running in the background even when navigation is not in use. In realtime, it communicates with the network of Tesla Superchargers and destination chargers, discarding any that are in heavy use or inactive and warns you before you drive out of range.

The navigation system then shows a map of the most convenient charging locations and guides you to the closest one. Moreover, it factors in height changes, like having to climb over a mountain pass, and looks up weather and windspeed from the Internet to determine range with accuracy.

Images

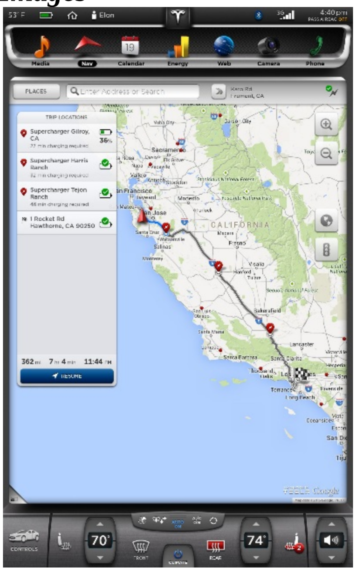


Figure 35: *Tesla range assistance*

Technical specifications / requirements

- System runs in the background (even when navigation is switched off);
- Communicates with charging stations;
- Warns the driver if battery is running low;
- Elevation and driving style are incorportaed in range estimation.

ADAS&ME relevance (aspects covered):
Relevant to UC B;
Constantly monitors range status and closest charging opportunities;
The driver is warned and informed about closest charging opportunities.
ADAS&ME irrelevance (aspects not covered):
The technology is manufacturer specific
It addresses charging stress but the car does not take control (i.e. no automated function)
Price: Vehicle implemented. No stand alone price.

Product name - Range assurance

Producer/ Manufacturer
BMW

Contact information / Website (URL)
http://www.bmw.com/com/en/insights/corporation/bmwi/connecteddrive.html

Short description
Within the centrepiece of BMW rests i Navigation is the Range Assistant with dynamic range map, which takes into account all factors that are important for route navigation: battery charge level, driving style, traffic conditions and topographic nature of the route. Using BMW ConnectedDrive Real Time Traffic Information, the ECO ROUTE is optimised on BMW servers. The calculation incorporates a traffic prediction, and the most efficient route is estimated in real time. The nearest available charging station is displayed at all times. BMW i Navigation also takes into account public transport connections via the Intermodal Routing service, displays up-to-date timetables, and guides you to a free parking space near the stop in question.
The BMW i Remote App for iOS and Android shows detailed information on the current status of BMW i – e.g. car location, range, and battery charge level, service messages, and information on whether the doors are locked and the lights are off. The charging process can be initiated remotely, using the weekly timer. The dynamic range map is also integrated into the BMW i Remote App. Destinations (points of interest, PoIs) and locations of charging stations can be sent easily from the application directly to the car. The BMW i Remote App also measures the efficiency of each journey in a BMW i model and gives helpful tips on how to drive the car more efficiently and extend the range. The efficiency value of each journey can be anonymously shared with others and compared.
Images

Figure 36: *Range assistance (BMW)*

Technical specifications / requirements

- Implemented in the navigation system
- Closest charging station is displayed at all times

- Incorporates relevant info on battery charge level, driving style, traffic conditions and topographic nature of the route
- ECO ROUTE included which displays most efficient route
- ECO PRO function
- ECO driving advice

ADAS&ME relevance (aspects covered: Relevance to UCB; Constantly monitors range status and closest charging opportunities; The driver is warned and informed about closest charging opportunities. **ADAS&ME irrelevance (aspects not covered):** No automated function **Price:** Vehicle implemented technology, no stand alone price.

4.1.4 Emotions

4.1.4.1 In-vehicle systems/ sensors/algorithms

This section includes systems that are not detecting or monitoring fatigue, sleepiness, distraction and range anxiety. These aspects are covered in the driver monitoring systems' section, as they are systems that have been commercialised for many years. Emotions are the psychological experiences of an individual's state of mind influencing the person's concentration by interacting with internal and external influences (e.g. joy, angry, fear, sadness, aware, accepted, rejected, surprised). Emotion recognition nowadays largely depends on facial recognition system, speech patterns, galvanic skin response (GSR) measurements, temperature and heart rate variability. The systems discussed in this section are mostly based on existing literature and prototypes that do not actually represent mature products in the market yet. They are added in this section to demonstrate the future concepts and implementation prospects.

Product name - Project Mobii

Producer/ Manufacturer

Joint project of Ford and Intel

Contact information / Website (URL)

www.corporate.ford.com.
conflictfree.intel.com.

Short description

Joint research between Ford and Intel explores new applications for interior cameras, using data from existing vehicle sensors to enhance the in-vehicle experience for drivers and passengers.

As vehicles become an integral part of the Internet of Things, Ford and Intel are researching new opportunities for the connected car, including giving drivers the ability to remotely peer into their car using a smartphone, or a vehicle that could identify its owner using facial recognition software.

The joint research project, called Mobile Interior Imaging, or Project Mobii, explores how interior-facing cameras could be integrated with sensor technology and data already generated within and around the vehicle, to create a more personalized and seamless interaction between driver and vehicle, that transforms the driving experience.

Upon entering the vehicle, the driver is authenticated by Project Mobii through a front-facing camera, using facial software recognition. The in-car experience is then personalized, to display information specific to that driver, such as calendar, music and contacts.

If Project Mobii does not recognize the driver, a photo is sent to the primary vehicle owner's smartphone. That owner can then set permissions and specify features that should be enabled or disabled. If the driver is the child of the vehicle owner, for example, restrictions could be automatically set to require safety belt use and to limit speed, audio volume or mobile phone use while driving.

A combination of natural gestures and simple voice commands is used in such tasks as turning the heat up and down, or opening and closing a sunroof while driving.

Just like smart keys, this recognition software will adjust the car's settings to whoever is driving. It can automatically adjust the music volume, driver's seat position, vehicle speed, and so on. Drivers will also be able to adjust climate, sunroof, and other options by using voice commands, allowing the driver to pay more attention to the road.

Images

Figure 37: *Driver authentication via facial recognition (Project Mobii)*

(Source: http://laurenfix.com/article/facial-recognition-vehicle/)

Figure 38: *Facial recognition camera (left) and Mobii system informs owner that does not recognise driver (right)*

(Source: https://media.ford.com/content/fordmedia/fna/us/en/news/2014/06/25/ford-and-intel-research-demonstrates-the-future-of-in-car-person.html)

Technical specifications / requirements

- Mobile Interior Imaging, also known as Project Mobii, uses facial recognition software to offer enhanced privacy controls, and a more secure and personalized in-vehicle experience
- A mobile phone app enables a driver to remotely access the vehicle, allowing for a quick check of belongings left inside or authorizing/declining other drivers to operate the vehicle
- Uses exterior vehicle cameras for driver-assist features, such as lane-keeping assist and lane departure warning.

ADAS&ME relevance (aspects covered):

Relevant to UC A (and generally to authentication of professional drivers and the handover of automated functions).

Facial recognition can be extended from driver status and identification to identifying the affective state of the driver and it might be one of the most promising types of technologies for identifying more complex emotions (e.g. surprise, anger, combinations of emotional states).

Incorporates external driving assist technologies (i.e. lane assist).
Secondary gesture recognition and interaction might be interested for personalized complex (or combinations) of affective states (e.g. anger in a driver can be identified with combination of facial feature recognition and gestures).
This system in progress has been considered here for its future potential for affective state recognition and monitoring.
ADAS&ME irrelevance (aspects not covered):
Not an existing commercial product, thus, cannot be used in the project. Focus is solely on driver identification.
No automation is involved or automated functions, only driver assistance.
Price: The use of interior imaging is purely research at this point; however, the insights to be gained will turn into vehicle implemented technologies in the future.

Product name – Toyota FV2 concept

Producer/ Manufacturer
Toyota Motor
Contact information / Website (URL)
https://www.toyota-europe.com/world-of-toyota/concept-cars/fv2
Short description
Using both voice and image recognition to determine the driver's mood, the car will accumulate driving history to suggest driving routes and even determine the driver's skill level to assist in driving technique. In doing so, the FV2 will develop a bond with the driver and grow in knowledge with them over time.

Images

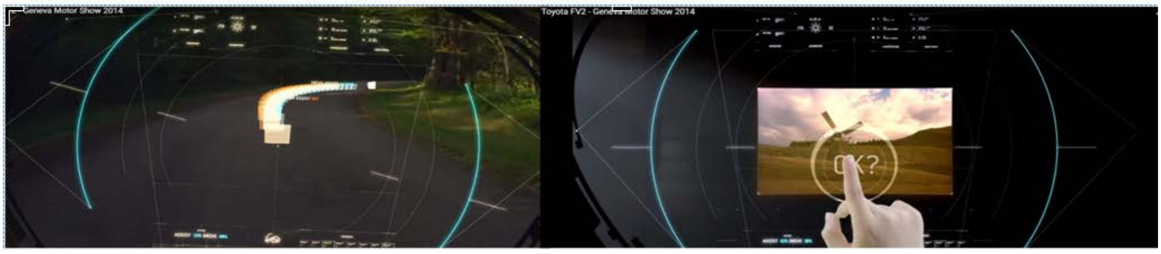


Figure 39: *The FY2 will connect with other vehicles and the infrastructure (left) and emotionally bond with the driver (right)* (source: https://www.toyota-europe.com/world-of-toyota/concept-cars/fv2#/youtube/JLGuUyzyteQ)

Technical specifications / requirements
Not available yet.

ADAS&ME relevance (aspects covered):
Relevant to UCs A, C, D.
Emotion recognition through combination of systems and variables (e.g. facial, speech, gesture, past experiences);
Communication with infrastructure (relevant for specific Use Cases).
ADAS&ME irrelevance (aspects not covered):
Not clear if automation will be involved;
A holistic approach in driver/vehicle communication;
Still a concept; does not constitute benchmark material but the ideas behind the concept are interesting.
Price: Not yet relevant/ it will be a whole vehicle; integrated system, not a stand alone.

Product name - EmoVu

Producer/ Manufacturer
Eyeris Technologies
Contact information / Website (URL)

530 Lytton Ave,
Palo Alto, CA 94301
Phone: 650-262-7900
Email: info [at] eyeristech.com / *URL: http://emovu.com/e/*

Short description

A facial expression recognition methodology imitates human vision and allows an algorithm to learn prototypic expressions directly from the face instead of relying on decomposed action units.
The methodology computes both shape and texture information, which results in accuracy under variant uncontrolled environments.

Images

Figure 40: *Emotion recognition system specification and parameters* (source: Eyeris Technologies)

Technical specifications / requirements

A tiny camera mounted in a dashboard and connected to the company's EmoVu software continually scans the driver's face, monitoring facial expressions, head position, and how open the driver's eyes are. It can also detect signs of exhaustion, such as eyes rolling downward or backward, according to Alaoui. The EmoVu software was created using a deep learning algorithm to train a convolutional neural network (CNN) to measure joy, surprise, sadness, disgust, fear, and anger. It is currently being tested by OEM's.

ADAS&ME relevance (aspects covered):
Emotion recognition (relevant to UCs A, C, and D);
System is not bound to certain car manufacturing company.
ADAS&ME irrelevance (aspects not covered):
No automation involved/ no automated functions;
Not yet available in market;
Price: Not available yet. Will be released in 2017.

Product name - EQ-Radio: Emotion Recognition using Wireless Signals

Producer/ Manufacturer

Computer Science & Artificial Intelligence Laboratory
Massachusetts Institute of Technology (MIT)

Contact information / Website (URL)

Mingmin Zhao *Fadel Adib* *Dina Katabi*
URL: http://eqradio.csail.mit.edu/

Short description

EQ-Radio is a new technology, that can infer a person's emotions using wireless signals. It transmits an RF signal and analyzes its reflections off a person's body to recognize his/her emotional state (happy, sad, etc.). The key enabler underlying EQ-Radio is a new algorithm for extracting the individual heartbeats from the wireless signal at an accuracy comparable to on-body ECG monitors.

Images

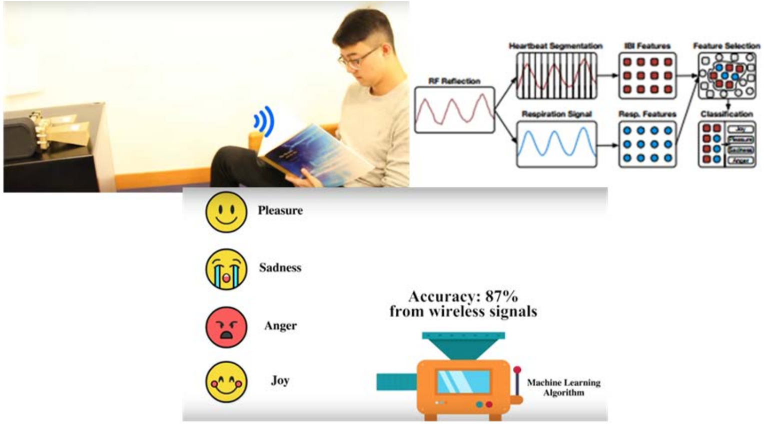


Figure 41: *EQ-radio system* (source: http://eqradio.csail.mit.edu/)

ADAS&ME relevance (aspects covered): Easy to implement and potentially non-obtrusive for driver to detect and identify emotions; Related to UCs A, C, D; Is not bound to a certain type of vehicle. **ADAS&ME irrelevance (aspects not covered):** Not commercial available yet (not clear if and when it will be); Not related to any automated function; No HMI for interaction; Not related to automotive industry. **Price:** Not known yet.

Product name – Empatica Emprace watch (user) and E4 wristband (researcher)

Producer/ Manufacturer

Empatica is an affective computing company, focused on human data analytics. They develop wearable devices with medical quality sensing.

Contact information / Website (URL)

Via Stendhal, 36 Milano, MI 20144, Italy

URL: https://www.empatica.com/

Short description

An Embrace watch was designed, in order to detect and prevent seizures, but has many more applications. It monitors sleep, physical activity, autonomic stress and arousal (stress monitoring coming soon). The device tells time and keeps tabs on metrics, like physical activity and sleep. But the Embrace goes one step further, measuring its wearer's stress levels by tracking something called electrodermal activity (EDA). EDA is essentially a measurement of the skin's conductance; as humans get excited or stressed, the amount of sweat on their skin fluctuates. The Embrace's sensors are able to track little changes in skin conductance and communicate via vibrations when the wearer is experiencing higher than normal levels of stress.

Images

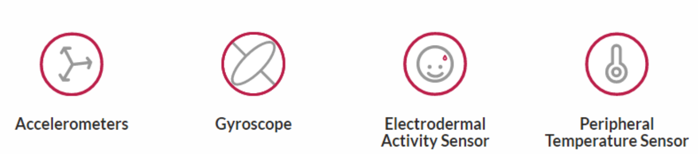


Figure 42: *Embrace for user – sensors* (source: https://www.empatica.com/product-embrace)

Technical specifications / requirements

Embrace for user

Activity Monitoring -The Embrace collects your physiological data not only during exercise, but also at work, during your commute, during the night.

Data Analysis - Your data is analyzed in real-time to give you feedback.

Data Clustering - The Empatica system analyzes historical data and interactions with your Embrace. In the future this will help you to discover patterns in your daily habits and behavior.
Personalized Insight - Visualize summarized data with various granularity to better understand your day.

E4 embrace for researcher

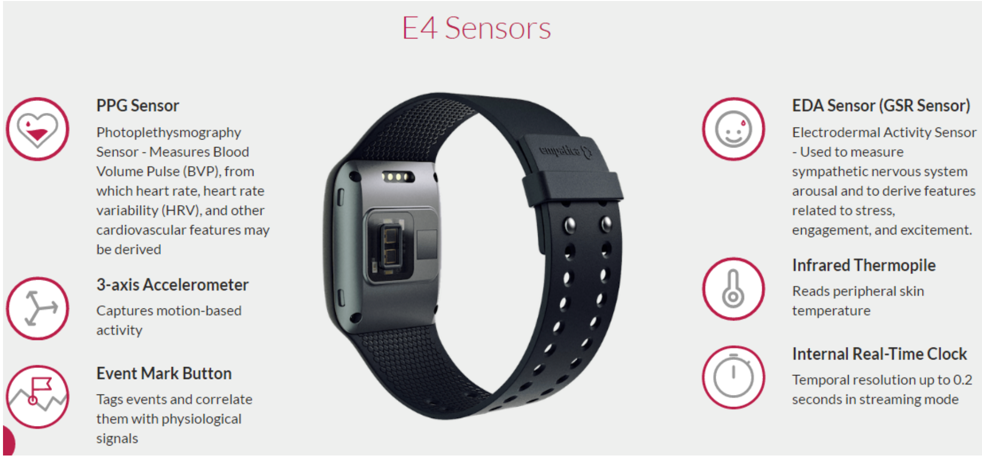


Figure 43: *E4 Emprace sensors with real-time monitoring of physiological signs* (source: https://www.empatica.com/e4-wristband)

ADAS&ME relevance (aspects covered):
Monitoring of activity, stress, and other physiological parameters useful for the investigation of other considered affective states (i.e. relevant to all UCs);
Non-obtrusive technology (especially for riders);
Existing commercial product;
Real-time data monitoring (especially useful for trials);
Developer's API and accompanying software.
ADAS&ME irrelevance (aspects not covered):
No automation involved;
No vehicle related;
Price: Embrace watch: 240 Euros, E4: 1,660 Euros

4.1.4.2 Algorithms and APIs

Lately there has been a movement on emotional intelligence and emotional recognition. There's a lot of API-accessible software online that parallels the human ability to discern emotive gestures. These algorithms driven APIs use **facial detection** and **semantic analysis** to interpret mood from photos, videos, text, and speech. Today exist over 20 **Facial Detection APIs that Recognize Mood.**

These computer vision APIs use facial detection, eye tracking, and specific facial position cues to determine a subject's **mood**. There are many APIs that scan an image or video to detect faces, but these go the extra mile to spit back an **emotive state**. This is often a combination of **weight** assigned to 7 basic emotions, and **valence** — the subject's overall sentiment. These tools reviewed in this section are relevant to Use Cases A, C, and D.

Emotient

Emotient aims to track attention, engagement, and sentiment from viewers. The RESTful Emotient Web API can be integrated into apps, or used to help power AB testing. In addition to the API, there's an account analytics panel.

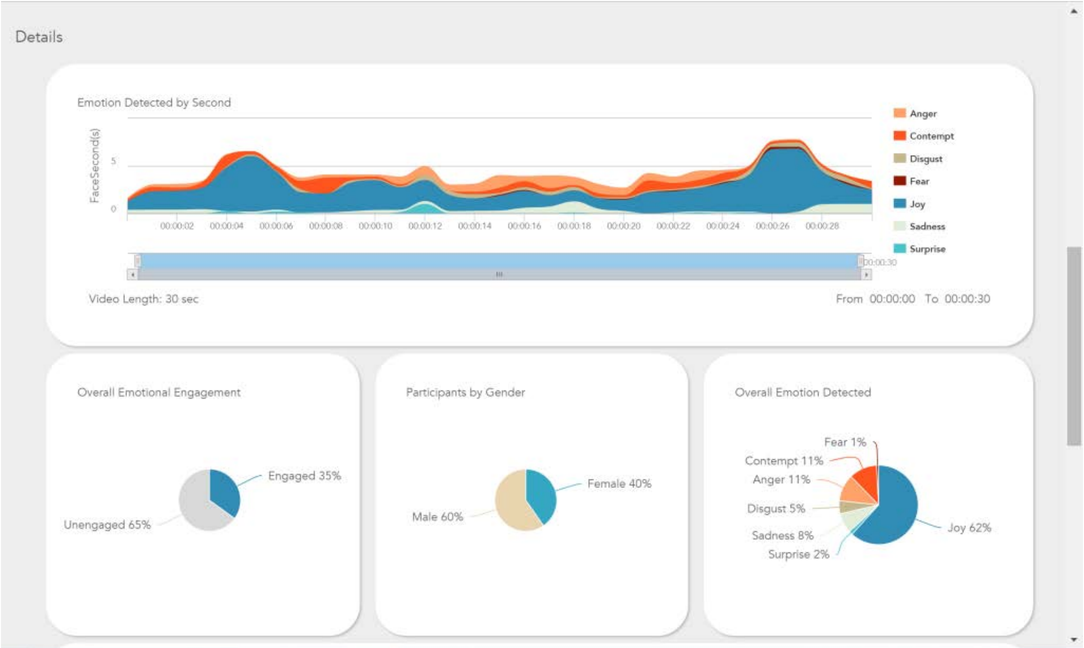


Figure 44: *Emotient interface*

Affectiva

With 3,289,274 faces analyzed to date, Affectiva is a solution for massive scale engagement detection. They offer SDKs and APIs for mobile developers, and provide visual analytics to track expressions over time.

EmoVu

Produced by Eyeris, EmoVu facial detection products incorporates machine learning and micro expression detection that allow an agency to "accurately measure their content's emotional engagement and effectiveness on their target audience." With a Desktop SDK, Mobile SDK, and an API for fine grained control, EmoVu offers wide platform support, including many tracking features, like head position, tilt, eye tracking, eye open/close, and more. They offer a free demo with account creation. It is also mentioned earlier in this section; here the API is presented.

Nviso

Switzerland-based Nviso specializes in emotion video analytics, using 3D facial imaging tech to monitor many different facial data points to produce likelihoods for 7 main emotions. Though no free demo is offered, Nviso claims to provide a real-time imaging API. They have a reputation, awarded for smarter computing in 2013 by IBM.

Figure 45: *Graphical representation of expressed emotions* (EmoVu)

Kairos

The Emotion Analysis API by Kairos is a more SaaS-y startup in the facial detection arena. Scalable and on-demand, you send them video, and they send back coordinates that detect smiles, surprise, anger, dislike and drowsiness. They offer a Free Demo (no account setup required), that will analyze and graph your facial responses to a few commercial ads. It supports with documentation for its Face Recognition API , Crowd Analytics SDK, and Reporting API. The Emotion Analysis API just recently went live.

Project Oxford by Microsoft

Microsoft's Project Oxford is a catalogue of artificial intelligence APIs focused on computer vision, speech, and language analysis.

Figure 46: *Nordic APIs founders Travis Spencer and Andreas Krohn – 99% happy*

The API only works with photos. It detects faces, and responds in JSON with specific percentages for each face using the **core 7 emotions**, and Neutral. Without the decimals this could be a very simple and to the point API.

Face Reader by Noldus

Used in the academic sphere, the Face Reader API by Noldus is based on machine learning, tapping into a database of 10,000 facial expression images. The API uses 500 key facial points to analyze 6 basic facial expressions as well as neutral and contempt. Face Reader also detects gaze direction and head orientation. Noldus seems to have a solid amount of research backing its software.

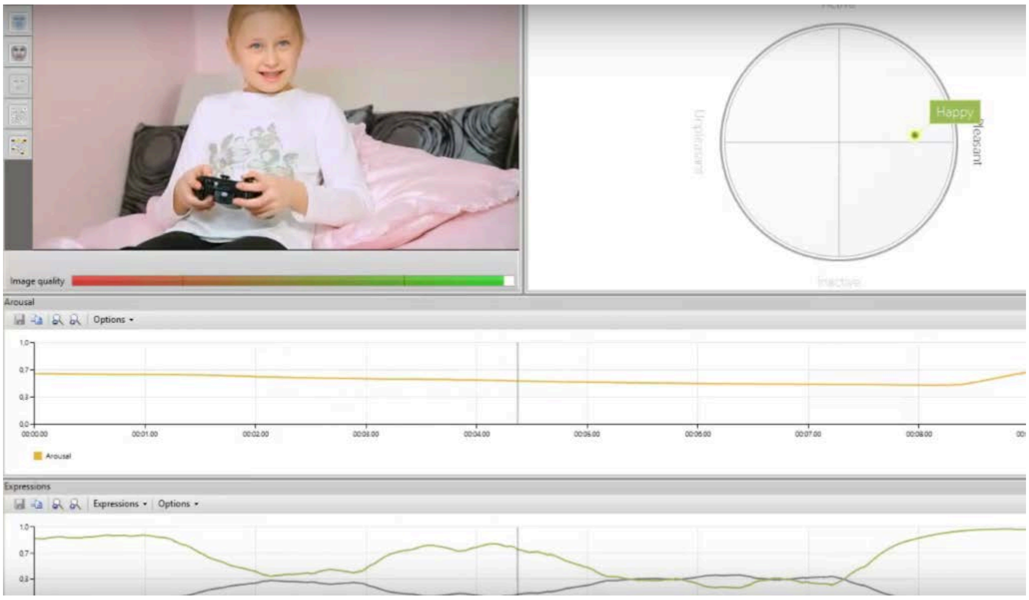


Figure 47: *Face expression software interface and expression images processing*

Sightcorp

Sightcorp is another facial recognition provider. Their Insight SDK offers wide platform support, and tracks hundreds of facial points, eye gaze, and has been used in creative projects, museum showcases, and at TEDX Amsterdam. Sightcorp's F.A.C.E. API (still in beta) is an cloud analysis engine for automated emotional expression detection.

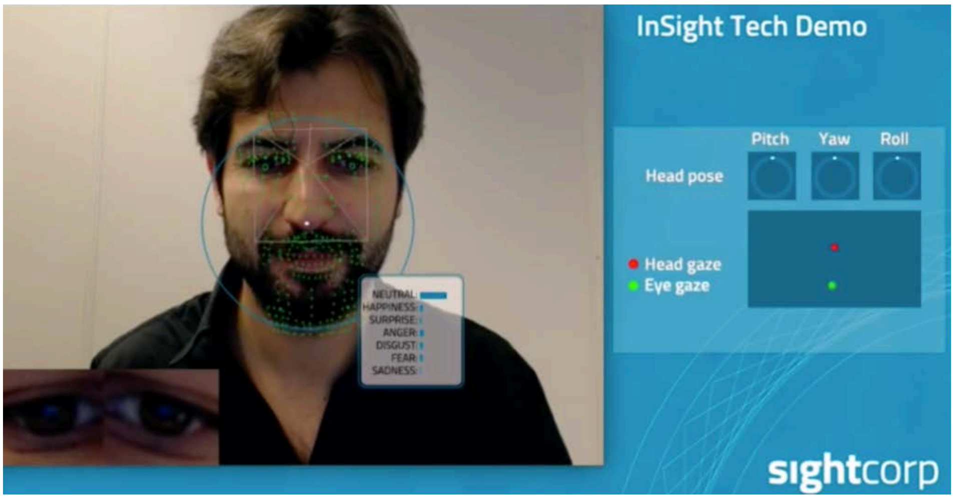


Figure 48: *Sighcorp demonstration if face recognition based on cloud analysis of facial expressions*

SkyBiometry

SkyBiometry is cloud-based face detection and recognition tool, which allows you detect emotion in photos. Upload a file, and SkyBiometry detects faces, and senses the mood between happy, sad, angry, surprised, disgusted, scared, and neutral, with a percentage rate for each point. It accurately determines if a person is smiling or not. Skybiometry is a spin off of a successful biometric company.

Face++

Face++ is more of a face recognition tool that compares faces with stored faces — intended mainly for name tagging photos in social networks. It makes our list because it does determine if a subject is smiling or not. Face++ has a wide set of developer SDKs in various languages, and an online demo.

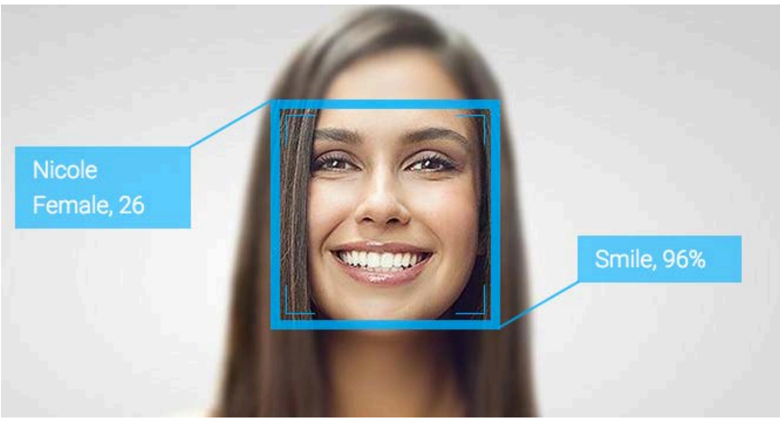


Figure 49: *Smile recognition with Face++*

Imotions

Imotions is a biometrics research platform that provides software and hardware for monitoring many types of bodily cues. Imotions syncs with Emotient's facial expression technology, and adds extra layers to detect confusion and frustration. The Imotions API can monitor video live feeds to extract valence, or can aggregate previously recorded videos to analyze for emotions. Imotion software has been used by Harvard, Procter & Gamble, Yale, the US Air Force, and was even used in a Mythbusters episode.

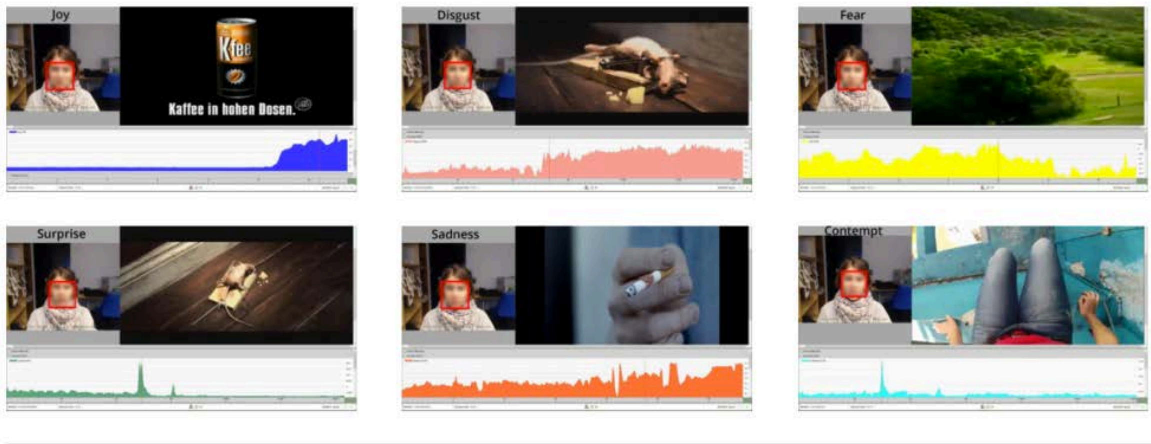


Figure 50: *Imotions detects different types of bodily cues based on layers*

CrowdEmotion

CrowdEmotion offers an API that uses facial recognition to detect the time series of the six universal emotions, as defined by Psychologist Paul Ekman (happiness, surprise, anger, disgust, fear and sadness). Their online demo will analyze facial points in real-time video, and respond with detailed visualizations. They offer an API sandbox, along with free monthly usage for live testing.

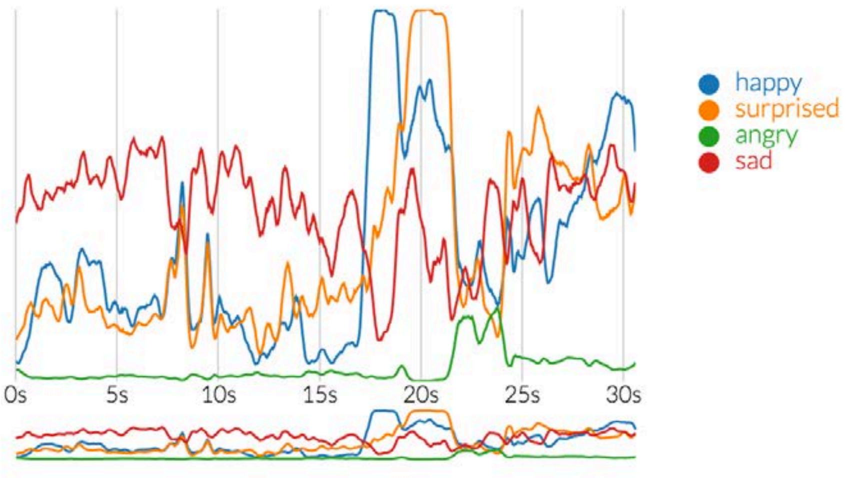


Figure 51: *Analysis of face points in real-time video (Crowdemotion)*

FacioMetrics

Founded at Carnegie Mellon University (CMU), FacioMetrics is a company that provides SDKs for incorporating face tracking, pose and gaze tracking, and expression analysis into apps. Their demo video outlines some creative use cases in virtual reality scenarios. The software can be tested using the Intraface iOS app.

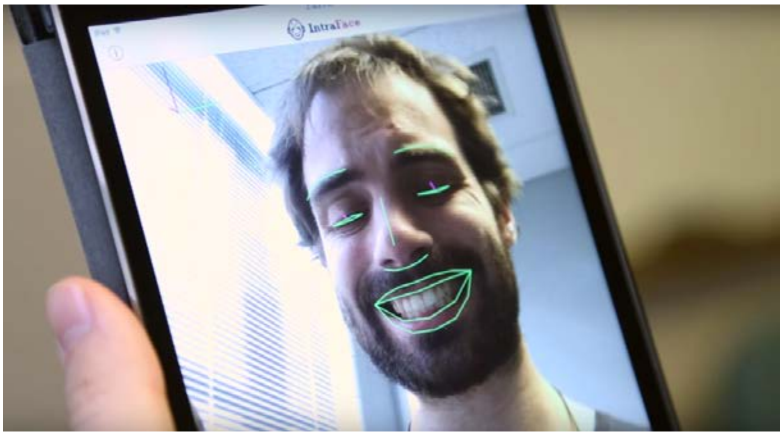


Figure 52: *Faciometrics expression analysis*

4.1.4.3 Speech to Emotion Software

Lastly, humans also interact with machines via speech. There are plenty of speech recognition APIs on the market, whose results could be processed by other sentiment analysis APIs listed above. Perhaps this is why an easy-to-consume web API, that instantly recognizes emotion from recorded voice, is rare.

Good Vibrations

The Good Vibrations API senses mood from recorded voice. The API and SDK use universal biological signals to perform a real time analysis of the user's emotion to sense stress, pleasure, or disorder. They're not really web APIs, but EMOSpeech is an enterprise software application that allows call centers to analyze emotion, and Audeering software detects emotion, tone, and gender in recorded voice.

Vokaturi

Vokaturi software purportedly can "understand the emotion in a speaker's voice in the same way a human can." With the Open Vokaturi SDK, developers can integrate Vokaturi into their apps. Given a database of speech recordings, the Vokaturi software will compute percent likelihoods for 5 emotive states: neutrality, happiness, sadness, anger, and fear. They provide code samples for working in C and Python.

4.2 Rider monitoring systems

The search of products for finding products that can detect/ predict the impaired rider state because of fainting, hypothermia, dehydration was not so successful. Relevant research is added to the Deliverable but products are not there yet.

4.2.1 Rider monitoring systems and accessories

This section is dedicated explicitly to systems developed only for riders.

Product name - "Math Behind The Morecambe Missile"

This is not an actual product but rather an experiment.

Producer/ Manufacturer

Dell EMC

Contact information / Website (URL)

http://uk.emc.com/microsites/morecambe-missile/index-alt.htm

Short description

Michael Foley, the Director of Marketing Science Lab in EMC stated that this is the first time in motorcycle history anyone has gathered data from man, machine and the environment—and in the harshest of conditions—to uncover the secret behind what makes one unique rider the fastest man on two wheels. It’s proven to be a big data challenge.

Images

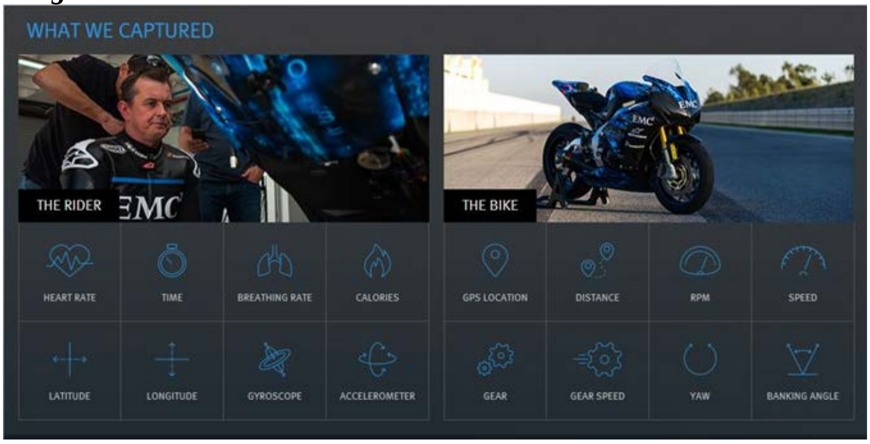


Figure 53: *Rider (left) and bike (right) variables collected*

Technical specifications / requirements

All variables shown in Figure 53 are collected. In particular, the variables collected are:

Human: Heart rate, time/ duration, breathing rate, calories consumption.

Human-machine: Latitude, longitude, gyroscope, accelerometer.

Machine (bike): GPS location, distance, RPM, speed, gear, gear speed,, yaw, banking angle.

No information on measuring units / system was found.

ADAS&ME relevance (aspects covered):
Relevant UCs are E, F and G.
One of the first experiment regarding the recording and correlation of physical behaviour of the rider with the performance of the rider.
ADAS&ME irrelevance (aspects not covered):
Physical behaviour: only heart rate/breathing rate;
Psychological behaviour: No
Price: -

Product name – WIKO

IMU is a device that monitors physical activity, providing a constant-flow of data in real time about how the athlete performs the physical activity and in return, improving his/her performance through a smart analysis of the information at individual and collective level.

Some existing application areas are shown in Figure 54 below:

Figure 54: *WIKO application areas*

Producer/ Manufacturer
RealTrack System
Contact information / Website (URL)
http://www.realtracksystems.com/index.php?lang=en
Short description
Wimu is a smart device, designed to give control over workouts. It has a user "push and record" technology and it also collects data from external devices. Monitors physical activity; providing a constant-flow of data in real time about how the athlete performs the physical activity and in return, improving his/her performance, through a smart analysis of the information at individual and collective level. Cinematic variables such as acceleration, speed, crossed distance or physiological ones such as heart rate, impacts, among others; and tactical variables, are collected by Wimu sensors and then displayed by Qüiko and Wisee, the software provided with the device. There is a potential to be transferred/used in the case of a motorcycle rider.
Images

Figure 55: *Wise product*

Technical specifications / requirements
Qüiko is a horizontal tool that offers the possibility to process and analyze the different sensors from several Wimus device and any other sensors you could connect (using ANT+ technology);

• Stored data playback;
• Data export: XML, EXCEL, HTML, TXT, etc.

ADAS&ME relevance (aspects covered):
Relevant UCs are E, F and G;
Provides a constant-flow of data in real time about how the rider performs the physical activity and in return, improving his/her performance through a smart analysis of the information at individual and collective level.
ADAS&ME irrelevance (aspects not covered):
Physical behaviour: only heart rate;
Psychological behaviour: No.
Price: 1,633 €

Product name - NO PRODUCT NAME, it was an experiment
Producer/ Manufacturer
DAINESE / MEDIASET
Contact information / Website (URL)
http://www.sportmediaset.mediaset.it/video/superbike/biaggi-il-battito-onboard_69679-2015.shtml
Short description
Recording the heart rate of the rider (MAX BIAGGI) during Misano SBK race in 2015. Mediaset collect the date from different side (Rider HR, motorbike dinamics, and position of the motorbike in circuit), showing all the information during TV broadcast of the race.
Images


Figure 56: *Rider heart rate measures during the race*

ADAS&ME relevance (aspects covered):
Physical behaviour: only heart rate
ADAS&ME irrelevance (aspects not covered):
Physical behaviour: only heart rate
Psychological behaviour: No
Price: -

Product name - One: Performance Tracking System for Motorcyclists
Producer/ Manufacturer
BRAIN
Contact information / Website (URL)
http://brainsomeness.com/
Short description
BRAIN One is a portable, stand-alone smart telemetry device for motorsports. It tracks rider's performance, provides feedback in real-time and stores motorcycle performance data. It is standalone device that attaches to the motorcycle without cables or wires and begins a recording session that feeds directly to the mobile phone with the push of a button or, if you don't have the smartphone with you, stores information into the internal memory until it's ready to be synced.
Images

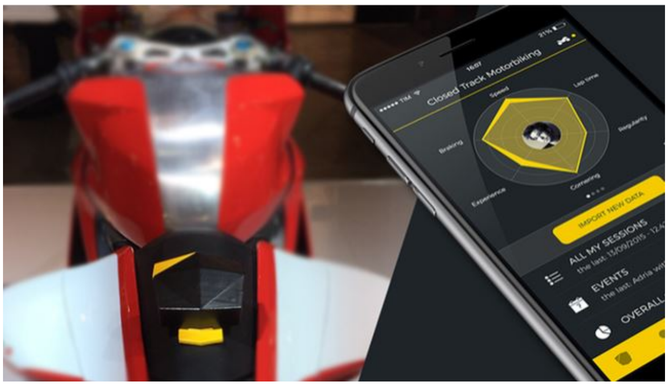


Figure 57: *Brain telemetry device for motorsports*

Technical specifications / requirements

Figure 58: *Indicators and sensors used to collect these data (Brain)*

ADAS&ME relevance (aspects covered): Physical behaviour: NO **ADAS&ME irrelevance (aspects not covered):** ONLY telemetry device **Price:** 300€ - 500€

Product name - D|AIR RACING

Producer/ Manufacturer

DAINESE / MEDIASET

Contact information / Website (URL)

http://www.dainese.com/it_it/d-air/racing

Short description

D-air® Racing is the intelligent protective air-bag based system for motorbike riders on the track.

The range of products which use this air-bag system includes D-air® Racing Mugello, the top of the range made-to-measure suit in kangaroo leather and D-air® Racing Misano, the entry level suit in cowhide made in standard sizes.

For World Championship riders only, Dainese have also created D-air® Armor, the open platform air-bag based on D-air® technology.

D-air® Racing was designed to be used exclusively on the track and is not for road use.

Images

Figure 59: *Dair Racing suit*

Technical specifications / requirements
Realizing that the Dainese D-Air Racing suit had three accelerometers, three gyroscopes and a GPS.

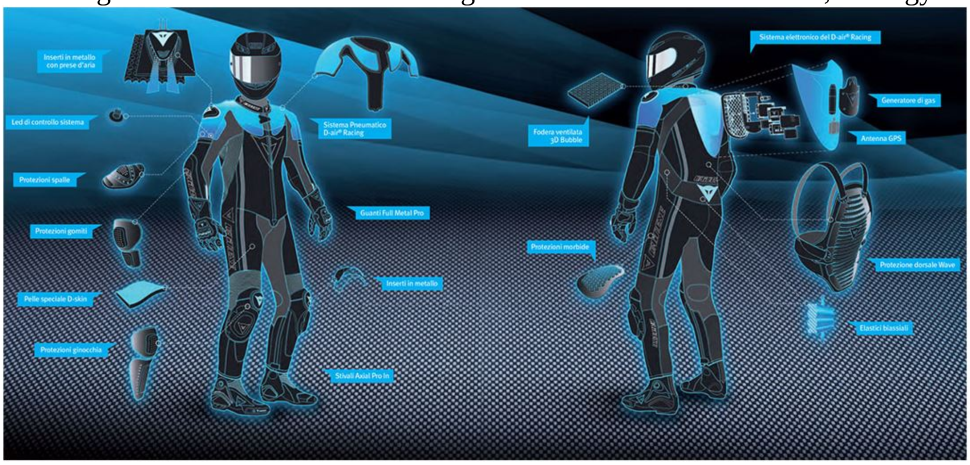


Figure 60: *Dainese D-Air Racing suit parts and sensors*

ADAS&ME relevance (aspects covered):
Relevant UCs are E, F and G.
ADAS&ME irrelevance (aspects not covered):
Physical behaviour: NO;
ONLY telemetry device;
In addition to deploying an airbag that protects a rider's neck, chest, and shoulders, the Dainese D-Air system also provides a telemetry package that track riders can use in lieu of a basic motorcycle data acquisition system.
Price: 2000€

Product name - LVL Hydration Monitor (Dehydration)
Producer/ Manufacturer
LVL
BSxinsight
Contact information / Website (URL)
http://www.onelvl.com/
Short description
The new LVL Hydration Monitor keeps tabs on your internal water levels and lets you know when it's time to imbibe. Mostly intended for athletes monitoring but it could be used also by riders. For everyone else, it's a simple reminder that we probably all need to drink more water throughout the day to perform better mentally and emotionally, and it's as simple as wearing a fitness tracker and measures activity, also. It measures hydration levels in real time, including sweat rates to show what

you’re losing. It then combines that data with heart rate from the built in sensors, activity level and calculated caloric expenditure during both rest and activity, to make hydration and refueling recommendations. It adds in mood, sleep and performance analytics, suggesting how much you need to drink to optimize all three.

Images

Figure 61: *LVL wristband*

Figure 62: *Wristband features to communicate mood, hydration levels, heart rate*

Technical specifications / requirements

The bonus is that they also measure your heart rate at a claimed 8x to 10x. The device and its prototypes were tested on more than 250 people and is reported to be as accurate as urine, body weight and blood tests, meeting or exceeding the requirements for first responders and the military. Heart rate measurement claims to be within 2.7bpm of actual, compared to a claimed +/-14bpm with other devices.

Figure 63: *LVL measures*

ADAS&ME relevance (aspects covered):

Relevant to UCs E and F (and C, D because it recognizes the person's mood);
Measures dehydration and mood, is wearable, and cheap.Will be able to buy soon.
ADAS&ME irrelevance (aspects not covered): Not adjustable or open to change and re-programming.
Price: Approx. 96 Euros.

Product name - The Perspiration Detective.

Producer/ Manufacturer

University of Cincinnati with industrial partner.

Short description

A Wearable, Smart-Phone-Enabled Patch: This is a small patch – similar in size to nicotine patches – that monitors sweat to determine hydration status. The patch, which was developed by researchers at the University of Cincinnati, measures sodium and chloride levels in sweat and small iconic solutes that are released when we're dehydrated. The patch can then transmit all that information to a mobile device.

Images

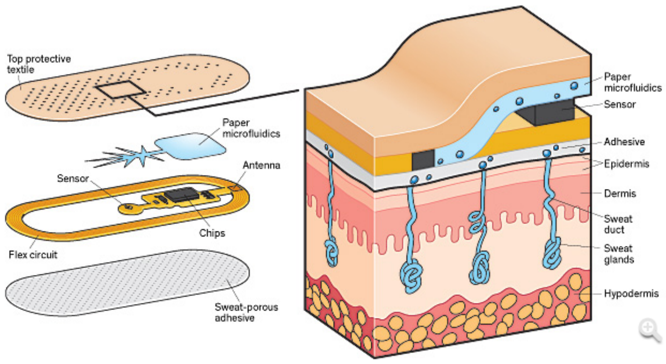


Illustration: James Provost

Perspiration Detective: This patch, developed at the University of Cincinnati, uses paper microfluidics to wick sweat from the skin through a membrane that selects for a specific ion, such as sodium. Onboard circuitry calculates the ion concentration and sends the data to a smartphone. The electronics within the patch are externally powered, as in an RFID chip.

Figure 64: *How the perspiration detective will work*

(Source:http://spectrum.ieee.org/biomedical/diagnostics/sweat-sensors-will-change-how-wearables-track-your-health)

Technical specifications / requirements

In the patch, the paper wicks sweat in a tree-root pattern, maximizing the collection area while minimizing the volume of paper. To keep the sweat pumping along after it passes through the sensors, these microfluidic channels direct the sweat to a superabsorbent hydrogel, such as the filler used in diapers, which pulls the sweat out of the paper and stores it. The patch can pull sweat along for several hours with the hydrogel swelling only 2 to 3 millimeters, enlarging it to hundreds of times its original volume. They built a sodium sensor, the voltage meter, a communications antenna, the microfluidics, and a controller chip onto a patch that's externally powered (like an RFID chip) by a smartphone. They printed it onto a flexible substrate and, with the help of researchers at the 3M Co., coated it with a sweat-porous adhesive so that it could stick to the skin. In tests, this patch performed as well as the benchtop electrolyte-sensing systems used by doctors to test for cystic fibrosis. Right now their industry partners are preparing to use standard flexible-electronic manufacturing processes to produce several hundred patches for more extensive human trials, which are expected to start before the end of the year. They are also adding about a half dozen other sensors that will detect additional ions besides sodium and chloride and use them to predict things like exertion level and muscle injury or damage. The initial results look promising, and if the upcoming human trials go well, it's not a far stretch to imagine using the patch in conjunction with the RFID-reading mats that already record marathoners' split times to also identify runners at risk of a dangerous electrolyte imbalance.

ADAS&ME relevance (aspects covered):
Relevant Use Cases: E and F;
Detects and warns about dehydration**.** Can share results through mobile (i.e. with others).
ADAS&ME irrelevance (aspects not covered): Just a wristband, not in vehicle or motorcycle tested**.** Not a product yet.
Price: N/A yet.

Product name – Frostbite detector and alarm

Producer/ Manufacturer

[Caleb Hanneman](#)

Contact information / Website (URL)

https://hackaday.io/project/11841-frostbite-detector-and-alarm

Short description

A small pocketable or wearable device that can warn the user of prolonged exposure to cold conditions.This device is meant to reduce the number of injuries and deaths due to frostbite. The device is meant to notify the user that they have been exposed to cold temperatures for too long of a period of time. Frostbite can occur within 5 minutes, particularly at low temperatures.

Images

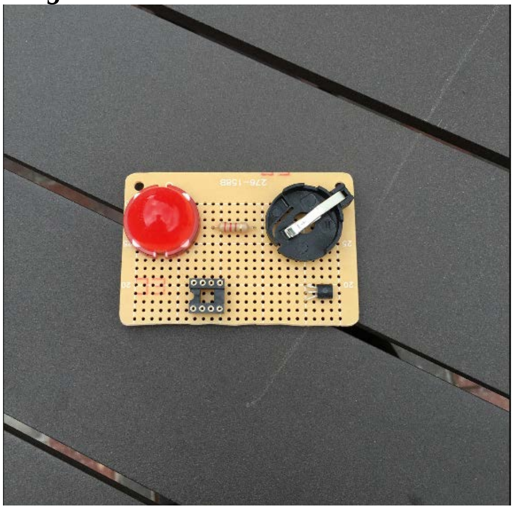


Figure 65: *The frostbite detector and alarm prototype*

Technical specifications / requirements

The device is small, pocketable, and battery powered, with future units possible featuring rechargeable lithium batteries. The device is meant to reduce rates of frostbite by notifying the user of conditions where frostbite is imminent with a solid LED, and when to take shelter with a flashing LED.

ADAS&ME relevance (aspects covered):
Relevant to UCs E and F;
Small and easy to carry;
Warns user of potential frostbite.
ADAS&ME irrelevance (aspects not covered):
Simple, aimed to be used by children;
Under development;
Not yet there and not standardised; it is a prototype.
Price: Not relevant (yet).

Product name - A Sensor System Integrated Into The Steering Wheel That Can Monitor The Driver's State Of Health While Driving

Producer/ Manufacturer

Jakob Neuhäuser / Technische Universitaet Muenchen

Short description

Scientists at the Technische Universitaet Muenchen have developed a sensor system, integrated into the steering wheel, that can monitor the driver's state of health while driving. When a stress situation is detected, phone calls can be blocked, for instance, or the volume of the radio turned down automatically. With more serious problems the system could turn on the hazard warning lights, reduce the speed or even induce automated emergency braking.

The driver can use his/her time behind the wheel for a minor health check. At the same time the device might be used to recognize the onset of fainting spells or heart attacks. Together with researchers from the BMW Group, scientists at the TU Muenchen Chair of Micro Technology and Medical Device Technology (MiMed) directed by Professor Tim C. Lueth, have developed a system that monitors vital signs, such as heart rate, skin conductance and oxygen saturation in the blood via simple sensors in the steering wheel.

Images

Figure 66: *Health check up through the steering wheel (detects fainting spells)*

Technical specifications / requirements

A series of systems for monitoring vital signs while driving have already been developed in the context of studies to measure stress levels while driving, among other things. By integrating appropriate sensors into the steering wheel, the scientists managed to circumvent the laborious wiring of the driver. The data collected is radioed to a microcontroller, which in turn can show the measurement results on the vehicle information system display.

A driver's skin conductance, for instance, reveals whether he or she is under severe stress, or whether his or her blood pressure exceeds a critical value. The only requirement is that the driver's hands are in contact with the sensors integrated into the steering wheel. Initial tests with people in cooperation with the Munich Senior Citizens Advisory Council were reported as promising. The sensors integrated into the steering wheel provided data during four fifths of the driving time. More than half of the test persons felt incited by the system to conduct repeated check-ups.

Two commercially available sensors are key elements of the integrated vital signs measurement system. One of them shines infrared light into the fingers and measures the heart rate and oxygen saturation via reflected light; the second measures the electric conductance of the skin at contact.

The scientists at MiMed have also developed a micro-controller application that processes the data and transfers them back to the vehicle. In order to extend the data pool and make as many reliable assertions as possible on the state of a driver's health, a radio connection can be established to additional external devices, e.g. a blood pressure monitor.

ADAS&ME relevance (aspects covered):

Detection of faint;

Relevant to driver and rider UCs – though right now developed for drivers.

ADAS&ME irrelevance (aspects not covered):

It is not yet a product;

It is not related to automated functions, though it could for cars; not known its transferability value to motorcycles.
Price: N/A
These results ensued from the research project Fit4Age in the "Assistance Systems for an Aging Society" group and were funded with grants from the Bavarian Research Foundation (BFS). Cooperation partners at the BMW Group did the technical installation of components into the vehicle.

Product name - BEMPU Hypothermia Alert Bracelet

Producer/ Manufacturer
Siemens Stiftung

Contact information / Website (URL)
Address:
Kaiserstraße 16
80801 München

Email:
empowering-people-award@siemens-stiftung.org

URL: Siemens-Stiftung.org
URL:https://www.empowering-people-network.siemens-stiftung.org/en/solutions/projects/the-bempu-hypothermia-alert-bracelet/

Short description
BEMPU is a temperature monitoring wristband for newborn babies. The wristband intuitively alerts a parent if the baby’s temperature drops and the baby becomes hypothermic. Compared to current standards of care, the device reliably prevents hypothermia and its complications, and it promotes kangaroo mother care (skin-to-skin care) in low-resource clinics and homes.
Once an infant starts becoming hypothermic, the body conserves heat by restricting the blood flow to the arms and legs. This causes the limbs to become significantly colder which BEMPU uses as an early detection sign of hypothermia. The intuitive device alerts the mother so she can swaddle the baby or perform kangaroo care, which in itself would prevent further hypothermia. Multiple alarms signal that the infant is unable to stay warm.

Images

Figure 67: *Bembu hypothermia alert wristband*

Technical specifications / requirements
- No external power supply or smartphone required;
- Some level of training required.

ADAS&ME relevance (aspects covered):
Relevant to UCs E and F;
Hypothermia detection with a wearable device;
Easy to wear and to be used by riders;
Existing product.

ADAS&ME irrelevance (aspects not covered):
No further information if it works with adults, as not correlated to transportation applications;
Adult bodies work different from newborns;
No other info available.
Price: Not known.

4.2.1.1 Wearables, Helmets &Accessories

These wearables are not only for riders but also for athletes and people involved in extreme sports; however smart clothing is a very related and interesting area of research for riders and these are items that have just been out to the market or are about to.

Hexoskin

The Hexoskin is a popular health related smartshirt and wearable. The Hexoskin can measure heart rate, breathing rate, and can also tell how much sleep a person is getting and how intense their workouts are. Some of the other features that come with the Hexoskin are a battery with 14 hours of life, Bluetooth capability and compatible with iPhone, iPad, and Android, and independently verified data. This smartshirt is made of a special fabric and is machine washable. The Hexoskin has a compatible app which will store all information and will to keep track of workout targets.

Manufacturer MSRP: 160-550 Euros
Where to Buy: Hexoskin
Product Page: Hexoskin

Cityzen Sciences

Cityzen Sciences is a French based company that has been in the smartclothes business since 2008. They are noted for their D-Shirt, which is short for Digital Shirt. Microsensors are embedded all throughout the shirt and they are able to keep track of information, such as temperature, heart beat and heart rate, and the speed and intensity of workouts. Cityzen Sciences can also customize smartclothes for clients. This company can be contacted at their website at www.cityzensciences.fr.

Manufacturer MSRP: N/A
Where to Buy: Cityzen Sciences
Product Page: Cityzen Sciences

OMsignal

The biometric smartwear from OMsignal has fitness tracking abilities and can track heartbeat and breathing. It has the compatible app in order to track health and fitness information. The shirt is not very bulky and is able to keep the biometric information by using a small black box woven into the shirt. The OMsignal has moisture control, odor control, and is also machine washable. It also has the compression feature which helps with circulation and muscle recovery.

Manufacturer MSRP: $249
Where to Buy: OMsignal
Product Page: OMsignal

Clothing+

Clothing+ is a new and emerging company who specializes in wearable sensors that are embedded in clothing. The company started developing the first heart beat and rate sensor for a shirt back in 1998 and then they came out with a sensor strap in 2002. The company is based in Finland and Hong Kong. Clothing+ can be contracted about their biometric smartclothes and the logistics about their product at www.clothingplus.fi.

Manufacturer MSRP: N/A
Where to Buy: Clothing Plus
Product Page: Clothing Plus

Xsensio

Xsensio develop monitors and sensors that are woven into this smartgarment that give ECG readings, core body temperature, and can also alert a runner if they are becoming dehyrated. Xsensio is partnered with the Swiss Instiitute of Technology Lausanne and they have a strong force of engineers. Product release and shipping information can be found at www.xsensio.com.

Manufacturer MSRP: N/A
Where to Buy: Xsensio
Product Page: Xsensio

R-shirt

R-shirt is a French based company that uses a small waterproof chip that is sewn into the clothes. Depending on the needs and wants of the customer, R-shirt is able to customize R-shirt's iBeacon chip is compatible with both iOS and Android processing systems.

Manufacturer MSRP: N/A
Where to Buy: R-shirt
Product Page: R-shirt

Skully

The AR-1's features include rear-view camera and a transparent, Infinite Focus HUD that's projected against the visor. Turn by turn directions are sourced through mobile phone; the helmet lets the rider keep it in his/her pocket with hands-free calling.

Figure 68: *Skully AR-1 helmet*

Forcite Alpine Helmet

The Forcite Alpine is equipped with GPS tracking, an altimeter, motion and impact sensors, Wi-Fi, Bluetooth, fog lights, HD video, and integrated speakers.

Figure 69: *Forcite alpine helmet*

LiveMap helmet

LiveMap is a motorcycle helmet that uses augmented reality for navigation. Street names, speed, and turn-by-turn directions are displayed directly over the world around you, negating the need to shift focus from the road. Slow to a stop, and you can pop up your map. The LiveMap smart helmet also includes a microphone and earphones for voice control.

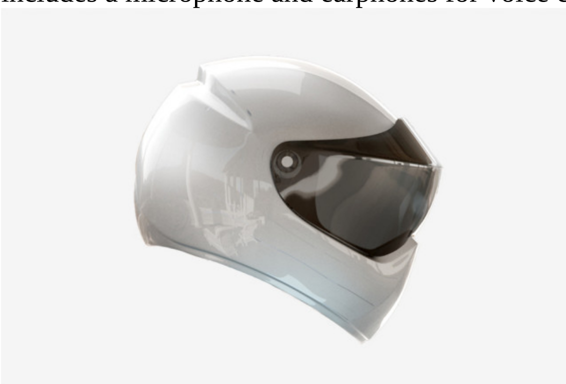


Figure 70: *LiveMap helmet*

NandLogic Encephalon

Apart from increasingly standard GPS, accelerometer, and gyroscope, it is equipped with other features: ambient light sensors, headlights, turn signals, brake lights, collision warnings, and a fan for summer.

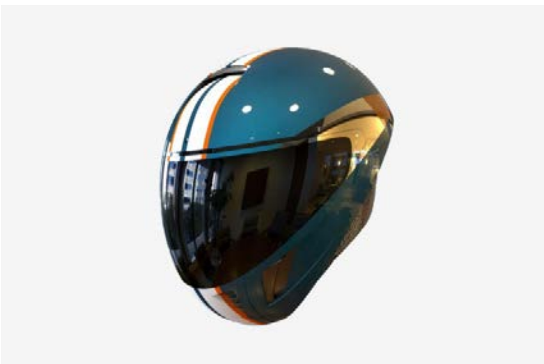


Figure 71: *NandLogic Encephalon helmet*

Mohawk

The Mohawk is a camera, tracker, and emergency alert system all rolled into one. It automatically records the last two minutes of audio and video, like an airplane's black box. The waterproof housing and mount are made to fit on any kind of helmet, and the handlebar controls make it easy to keep hands on the bars, as do the optional wrist-based mounts.

Figure 72: *The Mohawk system mounted on a helmet*

Beartek Gloves

Beartek gloves have the capability to use Bluetooth to sync to your phone, or Wifi to sync to your GoPro Action Sports Camera. Once synced, you don't need to take your hand off the handlebars to control your gadgets. For example, touching your thumb to your index finger will turn on your camera.Price: 240 Euros (Amazon).

4.2.1.2 Subjective measure

A subjective measure that has been developed within the framework of the SAFERIDER EU Project is the RALI, an adaptation of DALI instrument.

RALI (Riding Activity Load Index)

The procedure to set up DALI was to ask various experts involved in the driving tasks studies to define which were, in their opion, the main factors inducing metal workload for people driving a vehicle equipped with an on-board system (car phone, driving aid systes, a radio, etc.). This investiateion led to the following definitions for the workload dimensions of the DALI: Effort of attention, Visual demand, Auditory demand, Temporal demand, Intereference and Situational stress. Evaluation occurs on a 5-point rating scale (1: Low to 5: High). The RALI version has the following factors: Visual demand, auditory demand, Temporal demand, system interference, effort of attention, situation own coping, situational stress, emotions handling vehicles and was developed by the IFSTTAR team (Lot et al., 2009).

4.2.1.3 Automation strategies and patterns for motorcycles

In this section, certain automation strategies that could be applicable to ADAS&ME rider systems and relevant patterns are included that do not necessarily fall under the literature review or benchmarking of existing systems.

The following table presents the main publications as presented in previous chapters. The only missing column is the connection with UCs, because this review refers to the UCs for motorycles in general.

In addition, more literature summaries can be found in Annex 2; here only the most interesting studies for stabilisation of motorycles are presented. Table 16 does not include all the results, only the ones that propose strategies or functions relevant to stabilisation of motorcycles to be uptaken within the project.

Table 16: *Summary of literature review- Automation strategies for motorcycles*

Publication	**Objective**	**Measured**	**Results**	**Relevance to ADAS&ME**	**Key**
Key:	✓ - Must have	x - Not needed	■ - Good to have	◆ - Highly recommended	
Kanjanawanishkul et al. (2015)	LQR and MPC controller design and comparison for a stationary self-balancing bicycle robot with a reaction wheel	Simulation tests conducted for three control strategies: linear quadratic regulator (LQR), linear model predictive control (LMPC), and nonlinear model predictive control (NMPC).	Little, almost only numeric simulation	The stabilization performed using a reaction wheel is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). LQR and MPC to be kept in consideration.	■
~~Savino et al. (2015)~~ Savino et al. (2016)	~~Autonomous emergency braking for cornering motorcycle~~ Considerations on the acceptability of unexpected automatic decelerations	~~Riders seem to accept better non invasive systems, with increased usability. Warning on lack of confidence of the rider in cornering braking or panic reaction if the deceleration is too big.~~ 16 riders were involved in the tests and were exposed to random and unexpected brake activations along a rectilinear path at a nominal speed of 40 km/h	~~Results are good but very limited (only computer simulation). Need for further and deeper investigations.~~ Riders seem to accept and manage unexpected decelerations (-0.15g), with minor to moderate effort. However this is a really first test and the scenario is very limited	~~Based on simulation. More sophisticated control in ADAS&ME, acting on EMS.~~ The information about the reaction to unexpected decelerations is good for the implementation of the recovery mode. The deceleration could be obtained with a more sophisticated control	■
Yetkin (2013)	Stabilization of	Equations of motion of	Very little, the test was	The stabilization	

Publication	**Objective**	**Measured**	**Results**	**Relevance to ADAS&ME**	**Key**
	Autonomous Bicycle	a bicycle with a wheel mounted on its bottom are derived and a first order sliding mode controller is designed to achieve the goal of stabilization	performed with a limited range of speeds and not on open roads	performed using a gyro is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). Make a motorcycle curving only with lean control (no steering control) could be interesting.	
Kaplan (2010)	Design of an Active-Assistance Balancing Mechanism for a Bicycle	inclinometer or gyro+accelerometer	Almost zero: testing only possible in controlled environment. The study remained a simple university project.	The stabilization of a bicycle is much easier (lighter with less inertia). - It is not considered the presence of the rider with all the disturbances he can make (e.g. actions on steer). - The solution with these mechanical arms is not good for market, there are already on market similar solutions for paraplegic riders	
~~Sharp (2007)~~	~~Motorcycle steering control by road preview~~	~~This necessary preview is found to be in accord with conventional wisdom of motorcycle riding and rider training. Optimal path tracking preview controls are shown to~~	~~It is concluded that a motorcycle rider model representing a useful combination of steering control capability and computational economy has been~~	~~The rider has two ways to control motorcycle directions (3 with the throttle control):~~ ~~- modify the steer angle~~ ~~- modify his lean angle (moving from the original position on the seat).~~	

Publication	Objective	Measured	Results	Relevance to ADAS&ME	Key
		~~represent the inverse dynamics of the motorcycle (numerical simulation based on theoretical model)~~	~~established. The model yields new insights into rider and motorcycle behavior~~	~~Steer torque and lean torque both applied on the steer.~~ ~~One of the research results is that the effect of the first parameter is bigger than the second one.~~	
Beznos et al. (1998)	Control of Autonomous Motion of Two- Wheel Bicycle with Gyroscopic Stabilisation	Simulation tests to develop a stabilization system using gyroscopic stabilization. Then a mini-bycicle was built and first tested were made in lab	Results were very limited, the prototype was tested only in lab and the stabilization performances were rather poor	Stabilisation using a copule of gyros is interesting and should be considered. Of course stabilizing a mini-bycicle is much easier.	

4.3 Transfer of knowledge from aviation, rail and maritime

This section is focusses on knowledge transfer from other transportation areas. A complete review of literature can be found in Annex 3. The following table summarises key knowledge that can be transferred from each transportation area to ADAS&ME.

Table 17: *Knowledge transfer from other transport areas*

Transportation area (publication)	Knowledge transfer	ADAS&ME relevance
Aviation (Roveda et al. 2016)	A combination of several data categories (i.e., HR, RR, R-R intervals, and HRV) may provide an indicator for the quality of sleep and thus may be a way to track sleep-stress-emotion changes in pilots and astronauts in particular, and the public in general.	The platform described incorporates many of the sensors that are to be tested for ADAS&ME.
Aviation (Bias et al. 2016)	Proposed approach proved to be highly effective when dealing with contaminated and noisy data. Due to insufficient number of participants no general hypothesis can be drawn from performed analysis.	The utilization of the power of frequency bands as fatigue indicators will be part of the ADAS&ME approach.
Aviation (Cakir et al., 2016)	An LDA based classification system for mental workload was developed based on features extracted from fNIR data. The results seem to be affected by the presence of noise during the recording	The proposed sensoring method with the current technology can only be used (for practical applications) by riders.
Aviation (Borghini et al. 2015)	The present study suggested as cognitive neurometrics could provide more objective and quantitative information with respect to the subjective methodologies, in order to test and compare different avionic technologies in terms of requested mental workload.	The use of EEG measures to quantify mental workload which is related to fatigue/stress can be used for monitoring driver's state. The results could also be exploited during the HMI design.
Aviation (Oh et al. 2015)	Boosting, stacking, and voting showed very reliable performance as expected. In particular, stacking and voting could be easily extensible through a hierarchical structure particularly when any new feature set is included in the future to produce more reliable results.	Ensemble learning is a valid candidate for state classification.
Aviation (Wei et al. 2014)	The dynamic flight simulation experiments show that four indexes, i.e., flight operation accuracy, reaction time, SDNN and NASA_TLX scale, are significantly sensitive to the change of flight task-related mental workload.	SDNN can be used as indicator of mental workload.
Aviation (Aricò et al. 2014)	By combining information coming from different biosignals (e.g. EEG and HR), it is possible to have more reliable and faster information about the mental states of the user. It has been also demonstrated that i) the system is able to significantly differentiate three workload levels related	This study is only concerned with the mental workload. The idea is to be used as part of a system that "could intervene in real-time before the operator becomes overloaded while performing safety-critical tasks". The extracted indicators can

Transportation area (publication)	**Knowledge transfer**	**ADAS&ME relevance**
	to the three difficulty level tasks employed with a high reliability; ii) the subjective features used for the evaluation of the mental workload remain stable over one week.	be tested within ADAS&ME.
Aviation (Borgini et al. 2014)	Review of the literature suggests that exists a coherent sequence of changes for EEG, EOG and HR variables during the transition from normal drive, high mental workload and eventually mental fatigue and drowsiness. In particular, increased EEG power in theta band and a decrease in alpha band occurred in high mental workload. Successively, increased EEG power in theta as well as delta and alpha bands characterise the transition between mental workload and mental fatigue. Drowsiness is also characterised by increased blink rate and decreased HR values.	This paper does not only address pilots but drivers as well. Therefore it is directly related to the scopes of ADAS&ME.
Aviation (Sauvet et al. 2014)	The best concordance between automatic detection and visual scoring was observed within the O1-M2 channel, using the ratio of energies in frequency bands.	This study is only concerned with one state condition. No Assistant System and a relative mechanism is considered. The approach is actually one that has been already been tested in drivers.
Aviation (Luig & Sontacchi 2014)	There is no 'universal descriptor' for changes in stress level, but different events lead to changes in different parameters.	Speech is one of the targeted measurements of ADAS&ME. The database is available on request (Access is subject to approval and limited to academic institutions only.) for non-commercial research purposes.
Aviation (Gentili et al. 2014)	This study confirms and extends previous research by identifying multiple biomarkers to assess cognitive workload and attentional reserve during progressive simulated piloting task demands. EEG power and HRV were used to assess cognitive workload while the ERPs assessed attentional reserve. Cognitive workload and attentional reserve were negatively related.	The extracted biomarkers could be used as part of the ADAS&ME system.
Aviation (Lehrer at al. 2010)	Technical solutions are available only in exceptional cases in especially transport modes aviation and sea. The available solutions are rather old, don't use state-of-the-art technology and less innovative compared to what has been developed for car and truck industry. There is reason to believe that rail is the transport mode were you most easily can use less innovative solutions like "dead man's switch" and activation monitoring.	The report contains a thorough investigation of available countermeasures of fatigue. Some of them could be part of ADAS&ME. The leading partner is also involved in ADAS&ME.

Transportation area (publication)	**Knowledge transfer**	**ADAS&ME relevance**
Maritime **(**Varoneckas et al., 2015)	According to the authors "The study results demonstrated that sea farer's functional status mostly depends on the physical and mental fatigue during operational activity. The functional status is also influenced by gender, age, physical fitness, pain, boredom and emotions."	ADAS&ME will also have a data repository where, however, the most crucial information will come from sensors instead of questionnaires.
Maritime (Arima et al., 2013)	The index of the sympathetic nervous system (SNS) can be a useful index to detect subject's psychological condition. The facial monitoring system can detect and follow subject's face even though he/she walks around in a navigation bridge.	The sympathetic and parasympathetic indices can be part of the indicators used by ADAS&MEADAS&ME. Multiple cameras could also be part of the monitoring system. The proposed method however has not been properly validated.
Maritime (Barnett et al., 2012)	Sleepiness and neurobehavioral performance, as measured by the EEG electrodes, are particularly affected towards the end of the 0000-0600 watch. Sleepiness and fatigue are enhanced and brain performance reduced. In addition, there is a gradual increase of fatigue during the work periods as the week progresses.	It is nor clearly described how the EEG recordings were utilized.
Rail (Sinha et al., 2016)	A prototype in its very early stage was presented.	No verified results presented for the effectiveness of the methods.
Rail **(**Macii etal., 2015)	The full design process of a novel dead-man's vigilance device (DMVD) was presented.	The vigilance detector is well suited for trains but might not be adequate for drivers/riders since the rules that trick the detector might not be realistic outside the locomotive setting. On the other hand the methodological approach might be of interest if an FPGA implementation it pursuit.
Rail (Rahman et al., 2013)	The results reveal that the mean alpha power values are higher during rainy night condition, which indicate that the train drivers experience reduced levels of vigilance. The EEG measurements taken at the PZ locations (i.e. points that contribute to the primary visual perception of humans) show a decrease in mental workload towards the end of the driving period for rainy night condition, which clearly indicates an increased level of sleepiness..	Standard frequent band indicator. Can be used at ADAS&MEADAS&ME.
Rail (Jap etal., 2011)	Simultaneous decreases in beta and increases in theta activity have been shown as the train drivers entered the repetitive phase of transition from the alert state to a fatigued state. Greater amplitude of	The proposed indicators could be part of ADAS&ME ADAS&ME"indicator's bank".

Transportation area (publication)	Knowledge transfer	ADAS&ME relevance
	difference between the alert and fatigued state was found when using the computation based on (theta+alpha)/beta. The results of the current study indicate that the outcome of using the equation (theta+alpha)/beta, combined with detecting decreases in beta and increases in theta activity, can be utilised as an indicator of fatigue and for implementation of EEG based countermeasures.	
Rail (Lal et al., 2011)	An overview of technologies that can affect driver's status was presented.	This paper is a bit old. However the main findings suggestions are in agreement with the ADAS&ME ADAS&MEapproach "There is an ongoing need to advance existing know-how and technology to further improve the safety in the railway transportation sector".
Rail (Dorrian et al., 2008)	The results indicated that the EDA indicator was not sensitive to increased sleepiness and fatigue at the levels produced in the present study.	**:** Even though this system is meant to be used in trains, the experiments were conducted using a car-driving simulator. Therefore the results can be exploited by ADAS&ME.
Rail (Ridwan et al., 2008)	A prototype was delivered which "has to be miniaturized in the future work in order to fit into a headband or a cap".	Wireless sensors will be part of the ADAS&MEADAS&ME. The presented technology is outdated. Off the shelf solutions exist.
Rail (Jap et al., 2007)	The result of the current study showed a significant change in the brain activity during a fatigue instigating driving session, and several sites that showed significant changes during fatigue could potentially be used to detect fatigue.	Frequency band indicators as well as the identified sites demonstrating the higher sensitivity to fatigue manifestation could be use in ADAS&MEADAS&ME.
All transport areas (Anund et al., 2015)	Technical solutions are available only in exceptional cases in especially transport modes aviation and sea. The available solutions are rather old, don’t use state-of-the-art technology and less innovative compared to what has been developed for car and truck industry. There is reason to believe that rail is the transport mode were you most easily can use less innovative solutions like “dead man’s switch” and activation monitoring.	The report contains a thorough investigation of available countermeasures of fatigue. Some of them could be part of ADAS&ME. The leading partner is also involved in ADAS&ME.

5 Alignment of results

5.1 Alignment with ACEM priorities

ACEM (http://www.acem.eu/), the European Association of Motorcycle Manufacturers, is the trade association that represents manufacturers of powered-two and three-wheelers as well as quadricycles

(L-category vehicles) in Europe. ACEM members include 15 manufacturing companies and 17 national industry associations in 14 different European countries. About 156,300 jobs depend on the motorcycle, moped, tricycle and quadricycle industry in Europe. ACEM works closely with the EU institutions, as well as with a wide range of stakeholders, in different policy-areas. These include type-approval of L-category vehicles, environmental legislation, road safety and transport policies, international trade negotiations, etc.

5.1.1 Objective

The effort to align the ADAS&ME Use Cases E "Long-range attentive touring with motorbike"& F "Rider Faint" with ACEM's Safety Strategy was identified as a necessary process, in order to both provide strong basis to ADAS&ME and identify possible synergies with other initiatives regarding riders' safety. The approach followed started by the identification of ACEM's priorities, followed by the in-depth analysis on priorities diretly relevant to ADAS&ME and resulted to the interpretation of the potential synergies and disagreements with the ADAS&ME objectives.

5.1.2 ACEM priorities

ACEM safety strategy, entitled **"The Safe Ride to the Future"** was launched on 24th September 2014 (www.acem.eu/publications/item/333-the-safe-ride-to-the-future-acem-road-safety-strategy). It is a working document which is continuously revised and its updates are presented in a dedicated annual meeting.

The approach of the association to the topic is typically holistic, therefore there are actions oriented to:

1. **Public institutions**: to enhance the in-force legislations, to keep PTWs (Powered-Two-Wheelers) at the centre of transport strategies and policies, to foster the innovative design and the proper maintenance of road infrastructure;
2. **End users**: to improve their riding skills (e.g. through post license training), to promote the usage of adequate PPE (Personal Protective Equipment) and to enhance the other road users' awareness towards riders;
3. **Research and development** of new safety devices, both active and passive. This is addressed by OEMs individually or by joining forces with other partners (research centres, other OEMs, Tier-1 suppliers,…) in specific national or European projects.

The third action point is directly relevant to ADAS&ME and is further analysed hereafter. Currently, ACEM actions are mainly focusing on two technological pillars: eCall and Cooperative ITS (C-ITS) systems.

3.1 For what concerns **eCall**, ACEM is an associate member of the i-HeERO project for the harmonised eCall European development. i-HeERO (where "i" stands for infrastructure) is aimed at the preparation of the PSAP (Public Safety Answering Points) in Member States for the deployment of eCall based on the pan-European '112' emergency number. A specific section is dedicated to prepare the deployment of eCall systems for powered two-wheeled vehicles. The goal is to set the basis for a reliable and economically feasible eCall system using PSAP.

The project started in January 2015, lasts 36 months and is partially financed by the EU under the Connected Europe Fund Annual Program (more information is available at: http://iheero.eu/).

3.2 With regard to **C-ITS** systems, all ACEM members have signed a MoU (Memorandum of Understanding) in 2014, where they commit to have at least one of their models available for sale equipped with C-ITS technology by 2020, either as standard equipment or as optional equipment. Goals of the MoU are to embrace and become involved in C-ITS deployment movement in the transport area and to draw attention to and maximise benefit of C-ITS technology to protect PTWs as vulnerable road users.

The next step of this MoU was the creation of the CMC (Connected Motorcycle Consortium), where ACEM is involved as associate partner. The CMC objectives are to integrate PTWs into global future ITS strategies, to join forces of the PTW industry towards the creation of a common approach for ITS technologies and to achieve a successful implementation and deployment of ITS functions on PTWs (for further info please refer to: www.cmc-info.net).

Regarding **road vehicle automation**, ACEM has made the following statement, which although it is not included in its roadmap yet, it forms its official position in the topic when it was specifically asked. For the purpose of this document we will consider this statement as Priority 4:

"*Practically all automotive manufacturers are involved in research, development and demonstration of different levels of vehicle automation. Compared to cars (and trucks), full automation/autonomy is not relevant/feasible for PTWs because of technical complexity and the vehicle's characteristics. Contrary to cars, PTWs have 3D dynamics, leaning and complex behaviour; the rider forms an integral active part of the vehicle and has a physical influence on the vehicle dynamics.*

The PTW industry is nevertheless looking at various levels of driver support/assistance functions such as for example cruise control, adaptive cruise control, and particular PTW rider assistance systems. ACEM expects that, together with other VRUs (Vulnerable Road Users), PTWs will continue to be "recognized" by other road vehicles, depending on the level of automation either by the driver or by the automated vehicle/system.

As a matter of fact, automated vehicles can offer benefits for cooperative safety: unambiguous behaviour (e.g. no unexpected manoeuvres, zero traffic rules violations, …) and self-path prediction are two key items able to provide important information to PTW riders about what the intentions of automated vehicles.

Note: A possible future risk is that automated vehicles will gradually "displace" non/less-automated vehicles such as motorcycles from the main road infrastructure. ACEM should continue to demand that PTWs should be allowed to circulate freely together with other road vehicles. Automated vehicles should be separated from traffic of non-automated vehicles if recognition of other road vehicles/users is not / cannot be guaranteed. However, current road capacity should not be reduced to accommodate separate roads/space for automated vehicles."

5.1.3 Results

Alignment to Priority 1

Going in-depth Priority 1, one of the main factors, which leads riders not to wear adequate protective gear, is thermal discomfort during the summer (see as a partial bibliography (LizdeRome et al, 2016) and (deRome et al, 2011). To develop an innovative protective gear, which assists the rider, monitoring his thermal state and dehydration and provide instant advice such as suggested rests, may highly contribute to spread the usage of adequate personal protective equipment.

A possible future evolution, beyond ADAS&ME, could be to develop innovative garments able to automatically balance rider's temperature (e.g. opening or closing vents on the jacket or even enabling a cooling system).

Alignment to Priority 2

With regard to the eCall technology, the system to be developed in ADAS&ME will be able to monitor the rider's psycho-physical state, information that, in case of sudden illness or crash could be sent to the PSAPs. This information could be extremely worthy for first-aiders. Speaking of which it has to be highlighted that Activity 3.5 of the i-HeERO project is focusing on developing a system capable to measure injuries severity (for further information: https://dl.dropboxusercontent.com/content_link/CupxZASrJBIevSsso8DYaIVat52mB16ia826rA77Ap30X3MIHysYxWuTJsK7I75d/file). Furthermore, vital parameters could be added in the eCall triggering algorithm, in order to reduce false positives.

The timing is also good: the i-HeERO project is expected to end in December 2017, however it is not planning to develop a working system to be put into market, but rather set the basis of the system specifications to be developed in the next phase. It is therefore unlikely that a pan-European system will be ready before 2020-2021, thus a possible integration of ADAS&ME with a PTW eCall system is foreseen as an excellent opportunity for deployment.

Alignment to Priority 3

ADAS&ME develops functionalities which provide information about the riding environment such as type of road, weather, etc. which are in line with ACEM's MoU for adopting C-ITS features by 2020. Another possible integration includes the communication to the surrounding vehicles, through a V2V

system, with information such as the sudden illness of the rider and, even that the motorcycle has activated a safety system (e.g. a system that modifies the motorcycle speed or even tries to stop it autonomously and safely). The communication with the surrounding traffic will enhance the safety of all road participants, by increasing drivers' attention and reducing crash risk in case of rider critical state.
Here the timing is good as well: ACEM's MoU requests to OEMs to equip one of their bikes with at least one C-ITS feature by 2020, while ADAS&ME i ending March 2020.

Alignment to Priority 4

About automation, ACEM is aware that OEMs (and Tier 1 suppliers) are investigating such systems and does not obstruct them. Their position expresses general statements about motorcycles peculiarities, which limit the maximum automation level achievable, and highlight that the other vehicles will have to continue detecting PTWs. Therefore it is not possible to state that the automation features included in UC E and UC F are in line with the association's priorities or not, however they can be considered as an alignment gap.

5.1.4 Conclusion

Table 18: *Overview of alignment results to ACEM priorities*

	Priority	Agreement /Possible Synergies	Disagreement	Gaps
Organization	Protective gear	Improve assistance (thermal comfort) to spread the use of PPE		
	eCall	Add psycho-physical state to the information sent to PSAP to improve the aid. Use vital parameters to improve crash detection and reduce false positives.		
	C-ITS	Weather info; Communicate rider states to other vehicles and relevant PTW automation manoeuvres to avoid critical situations		
	Automation systems			Automation targeted in ADAS&ME (recovery mode, active capsize control system)

5.2 Alignment with ERTRAC prorities

ERTRAC is the European Road Transport Research Advisory Council. According to the ERTRAC webpage (ertrac.org), it is the European technology platform which brings together road transport stakeholders to develop a common vision for road transport research in Europe. The mission of ERTRAC is *"to provide a framework to focus on the coordinated efforts of public and private resources on the necessary research activities"* (ertrac.org/mission). ERTRAC is recognized and supported by the European Commission.

5.2.1 Objective

The objective of this alignment is to identify to what extent the results from A.1.1 are in line with the goals and priorities given by ERTRAC in the ERTRAC Automated Driving Roadmap. The outcome should be an understanding whether the performed activity covers given priorities, or if there are existing gaps that need to be further addressed.

5.2.2 *ERTRAC'S priorities*

The ERTRAC priorities and goals elaborated in this document are summarized from the ERTRAC Automated Driving Roadmap (ERTRAC Automation Roadmap). Key societal needs identified in the Strategic Research Agenda of ERTRAC are: **safety, energy efficiency, reliability of schedules, and urban accessibility**. More specifically, the given priorities have an impact on:

- **Safety**: reduce accidents caused by human errors.
- **Efficiency and environmental objectives**: increase transport system efficiency and reduce time in congested traffic. Smoother traffic will help to decrease the energy consumption and emissions of the vehicles.
- **Accessibility**: facilitate access to city centers.

Automated driving is considered an opportunity to support all these challenges. These priorities in relation to automation research are illustrated in Figure 73 below.

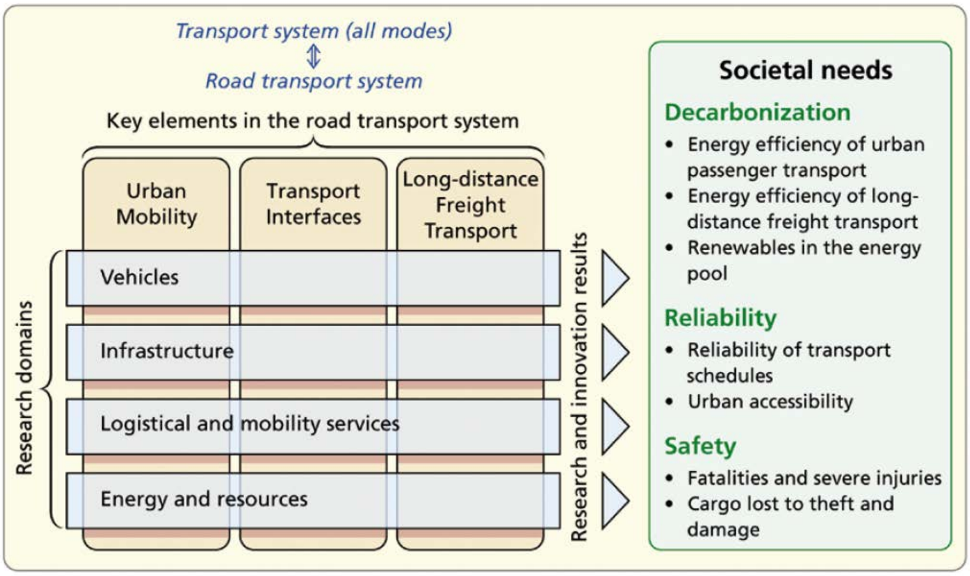


Figure 73: *ERTRAC Strategic Research Agenda, System approach to Road Transport Societal Challenges*

Further, automation is considered to support **comfort** (enable user's freedom for other activities when automated driving is activated) and **social inclusion** (ensure mobility for all, including elderly and impaired users).

In order to enable automated driving, the vehicles need to *perceive the environment* with very high precision and reliability. Efforts should focus on e.g. integration of sensors and to manage different data sources, V2X. Vehicle communication will have a great impact on reliability and safety and is a prerequisite to enable automated driving functions. Trust and safety are issues concerned by professional drivers that have an impact on social and user acceptance. *Human factors and HMI* becomes important, and highly automated vehicles should enable a safe interaction and usage. Technological functions and driver monitoring should support interaction between all involved automated components and functions – and manage miss usage, e.g. falling asleep or not taking back control. Specific challenges are mentioned in the ERTRAC Automated Driving Roadmap (ERTRAC Automation Roadmap), relevant to ADAS&ME: (1) driver's situation assessment, inattention and distraction are some main causes for road accidents, and (2) environment perception capabilities of sensor systems, functional safety, HMI and monitoring strategies.

5.2.3 *Alignment*

The focus is on creating connections between the goals and priorities identified within the ERTRAC roadmap, and the Use Cases (A-G) elaborated within ADAS&ME. The alignment connects affective states and driver monitoring systems explored in A1.1 with each Use Case and ERTRAC priorities. The connections give information about how the results from A1.1 support the developed Use Cases and further ERTRAC goals.

5.2.3.1 Alignment methodology

The alignment is performed based on the ERTRAC goals and priorities, to which the Use Cases (A-G) and results from A1.1 are related. Each Use Case support different ERTRAC priorities and each priority is related to the Use Case(s) and affective states or monitoring systems that best aligns with the given priority. Five affective states are included in the alignment, based on the project scope (ADAS&ME - Part B, Annex 1 to the Grant Agreement, 2016) and results from the literature review performed in A1.1: fatigue, stress, emotions, inattention, rider impairment. Specific efforts are focused on how to detect driver rest. The results from the benchmarking (A1.1) are related to these affective states, to ensure that all states are covered by the investigated monitoring systems.

5.2.4 Results

5.2.4.1 Alignment to Safety

The priority can be related to all Use Cases that aim to prevent accidents on road or reduce accident risk. Increased safety is in focus in all the investigated Use Cases (A-G), based on the predefined Use Case descriptions (ADAS&ME - Annex 1 to the Grant Agreement, 2016). Several efforts to increase safety are made within the project. Existing high risk driving situations are reduced through alerting drivers that enter an inappropriate state for driving, e.g. drowsiness in Use Case A. In several Use Cases (A-D, G) safety is enhanced through enabling safe transitions between driver and vehicle.

A number of driver and mental and psychological states are in the project description (ADAS&ME - Annex 1 to the Grant Agreement, 2016) defined to be related high rate crashes, such as stress, sub-optimal emotions, inattention or drowsiness.

Sleepiness/drowsiness/fatigue is frequently addressed in the results of A1.1 and a variety of solutions and indicators of the state is proposed, e.g. EEG, ANOVA, PERCLOS and KSS. Some monitoring systems to use for investigation of fatigue are eye tracking (e.g. SmartEye or FaceLab) and detection of heart rate (e.g. Real Track System). These results are well aligned with the ERTRAC priority safety and can be used to manage safety challenges mentioned in the ERTRAC Automation Roadmap, such as miss-usage, e.g. falling asleep or not taking back control. I.e. monitoring and development of HMI systems that addresses the investigated states should (1) enable detection and prevention of dangerous driving situations and (2) enable driver rest – supporting the ERTRAC priority of increased safety.

5.2.4.2 Alignment to Efficiency and Environmental Objectives

This ERTRAC priority has some alignment to the Use Cases but limited alignment to the results of A1.1. HMI systems developed for all Use Cases (A-G) are dependent on environmental sensing. Environmental sensing is well aligned to ERTAC priorities, considering vehicles' need to perceive the environment (ERTRAC Automation Roadmap). Further, several Use Cases (E, F, D) support enhancement of V2V and V2X communication that is well aligned to the ERTAC priority considering increased efficiency in congested traffic (ERTRAC Automation Roadmap). I.e. efficiency can be enhanced by environmental sensing, which is performed in the project but not benchmarked in A1.1.

Detection of rest is related to the affective state fatigue and is investigated in e.g. Use Case A and reflected in the results of A1.1. The possibility to rest can be related to work efficiency – if a driver can rest during automated drive, the total driving period can be extended. Identification of benefits related to automation, of which rest is one, is a part of the ERTRAC strategy towards increased social acceptance towards automation. This can be also lined with ADAS&ME UC B which targets the better management of the driving range with efficient drive – supporting the ERTAC priority efficiency.

Reduced fuel or power consumption can be interpreted as an environmental objective of ERTRAC. This is in focus in Use Case B, which aims to increase the willingness to use electric vehicles. Overall reduced consumption is not focus in the project research but should be achieved through application of a higher level of automated driving.

5.2.4.3 Alignment to Accessibility

Increased accessibility might be achieved through the implementation of Use Case G, in which the bus driver is allowed the appropriate time to monitor passengers' embarkation/ disembarkation, enhancing the mobility of all travelers. HMI solutions that enable automation (and thereby accessibility) have been also investigated in A1.1, fostering the enhanced interaction of the driver both with the automated system and the passengers.

5.2.4.4 Alignment to Comfort

Increased comfort and released time for driver to focus on other work tasks is achieved in several Use Cases (A, C, G, E), in which the driver e.g. can use secondary devices or help passengers to board and disembark. The willingness to perform secondary tasks might be achieved by building trust in the technology, through appropriate and personalised HMI development and communication with the driver. HMI solutions are addressed in the results of A1.1, and are further dependent on the investigated affective states (fatigue, stress, inattention, etc.).

Furthermore, rest is enabled in the majority of the Use Cases, supporting the ERTRAC priority of increased driver comfort.

5.2.4.5 Alignment to Social Inclusion

Use Case G enables mobility for elderly and impaired users, since the proposed automation allows the bus driver to help passengers to embark and disembark. As stated in the ERTRAC priority comfort, the possibility to release time for these activities depends on the offere4d HMI solutions and further supported by the investigated affective states.

5.2.5 Conclusion

Table 19: *Overview of alignment results to ERTRAC's priorities*

	Priority	Agreement	Disagreement	Gaps
ERTRAC	*Safety*	Fulfilled in ADAS&ME through investigation of all affective states (driver fatigue, inattention, etc.). Seek to reduce accidents caused by human error – achieved through different driver monitoring systems: heart rate, EEG, activity data, eye-tracking, etc. Priority is addressed in all Use Cases (A-G)	No disagreements are found between the results from A1.1. and ERTRAC priorities. The priorities in ERTRAC are broadly described while the results from A1.1. are detailed descriptions of states and monitoring systems – i.e. it is not always clear how well these align.	
	Energy efficiency and Environmental Objectives	Enable increased efficiency due to detection of rest, investigated in UCA. Enable environmental objectives and decreased power consumption is achieved through UCB.	---	Environmental sensors are not investigated in A1.1., but in other work packages.
	Accessibility	Some fulfillment through enabling the driver to help older passengers in UCG. Detection of states and HMI design should support bus driver to focus on other work.	---	Low focus on accessibility within ADAS&ME
	Comfort	Fulfilled through enabling user's freedom for other activities and rest during automated driving, investigated in some Use Cases (A, C, G, E). Aligned with monitoring	---	Identification of what other activities users are able to do during automated drive

T R	Priority	Agreement	Disagreement	Gaps
		systems that detect rest, e.g. eye-tracking and heart rate. HMI design should support driver to do other work (includes all investigated affective states)		
	Social inclusion	Limited fulfillment through enabling driver to help older passengers in UCG. Poor alignment with results from A1.1 – detection of states and HMI design should support bus driver to focus on other work.	---	Low focus on enabling mobility for all users in ADAS&ME

5.3 Alignment with Trilateral Working Group on Automation (EU-US-Japan) – CARTRE project

Automated Road Transport (ART) is seen as one of the key technologies and major technological advancements influencing and shaping our future mobility and quality of life. The ART technology encompasses passenger cars, public transport vehicles, and urban and interurban freight transport and also extends to the road, IT and telecommunication infrastructure needed to guarantee safe and efficient operations of the vehicles.

The European Commission places a high priority on the deployment of automated road transport. It has set up two projects that will work together with a broad range of international stakeholders to ensure that these technologies are deployed in a coordinated and harmonised manner, which will accelerate the implementation of safe and connected automated driving in Europe.

CARTRE and SCOUT projects are offering a joint networking platform towards the alignment of road vehicle automation activities in Europe (http://connectedautomateddriving.eu).

SCOUT brings together the automotive, telecommunications and ICT industries to conceive use cases and business models to leverage the investments into technology development. It targets to promote a common roadmap of the automotive and the telecommunication and digital sectors for the development and accelerated implementation of safe and connected and high-degree automated driving in Europe.

CARTRE brings together more than sixty organisations with view to consolidate the current industry and policy fragmentation surrounding the development of automation in road transport. CARTRE will run for two years and aims to establish a joint stakeholders forum in order to coordinate and harmonise automated road transport approaches at European (e.g. strategic alignment of national action plans for automated driving) and international level (in particular with the US and Japan).

5.3.1 CARTRE's priorities

CARTRE Coordination Action addresses the following priorities:

- **Accelerate development and deployment of automated road transport** by increasing market and policy certainties.
- **Support the development of clearer and more consistent policies** for EU Member States in collaboration with industry players, ensuring that automated road transport systems and services are compatible at EU level and are deployed in a coherent way.
- **Create a solid knowledgebase of all European activities**, to support current activities and structure research outcomes by enablers and thematic areas.
- **Setup a platform for sharing and re-using data** and experiences from different automated road transport systems.
- **Actively support Field Operational Tests** (FOTs) **and pilots** carried out at National and European levels.
- **Work on future visions, potential impacts and research gaps** in the deployment of automated road transport.

5.3.2 *Methodology*

CARTRE is a project that has started near the fall of the VRA project, during which the Trilateral Working Group EU-US-Japan on road vehicle automation was established. Within CARTRE several ADAS&ME partners are involved (CERTH, IDIADA, VALEO, TOMTOM, CONTI, DLR, IFSTTAR), therefore offering a great networking opportunity to communicate the ADAS&ME solutions and innovation. A first step is to connect the actions and results of A1.1 with the CARTRE project objectives, which are the following:

- **OBJ-01** Establish European leadership through public-private collaboration for development and deployment of ART
- **OBJ-02** Support international cooperation activities in the area of road automation at global level, in particular with the US and Japan
- **OBJ-03** Support Strategic alignment of national action plans for automated driving
- **OBJ-04** Ensure that stakeholders are well informed of past, current
- **OBJ-05** Actively support ART pilots and test beds
- **OBJ-06** Report on progress of ART projects on enablers and thematic areas
- **OBJ-07** Facilitate exchange of data, experience and knowledge for comparing and deploying results from pilots
- **OBJ-08** Foster a common evaluation framework across ART projects
- **OBJ-09** Describe possible deployment alternatives and evaluate their impacts
- **OBJ-10** Reach out to stakeholders, decision makers and wider public
- **OBJ-11** Establish annual international conferences, and workshops in Europe

Table 20: *Overview of alignment results to ACEM priorities*

	Priority	Agreement /Possible Synergies	Disagreement	Gaps
CARTRE	Objectives 1, 3, 4, 6, 10, 11	Improve knowledge transfer across domains to better understand measuring complex states such as faint and rest, not covered in literature	Not known yet if there will be any	Measuring complex states such as faint and rest, not covered in literature
	Objectives 2, 5, 7, 8, 9	Learn from countries already implemented and deployed automation	Cultural, policy, legislative and transportation and infrastructure variations and differences need to be considered in order communication to be effective. Disruptive technologies do not adhere the same in different countries.	Automated vehicles' technologies are not the same as automated functions. Therefore, the technology and know-how gap might exist and transferability might not solve them.

5.4 Alignment with Euro NCAP priorities

During this study duration, we couldn't identify a clear alignment of ADAS&ME with Euro NCAP priorities. However, Euro NCAP is currently under discussions to define the new roadmap 2020 to 2025 and the common ADAS&ME partners have the opportunity to address the technologies and

solutions developed in the project. In a next step, ADAS&ME could establish a MoU with Euro NCAP (to safeguard potential confidentiality) and support the exchange of information especially in key safety areas of the forthcoming 2025 roadmap.
First communication steps have already been established and will be further boosted the next few months. The goal is to achieve triggering Euro NCAP to adapt driver monitoring as a key safety priority for its future vision.

6 Conclusion

It is easily inferred that we are moving towards hybrid monitoring systems for the driver and such a rationale probably should be adopted within the project. In other words, we may use the same systems to detect different affective states and collaboration amongst systems will be necessary in order to satisfy the detection and monitoring of an affective state (e.g. faint is very difficult to define state with multiple reasons, the person might faint from stress when their hydration levels are not problematic). In the following table (Table 21), an overview of the benchmarking results are presented.

Table 21: *Benchmarking overview*

UC (Partner)	Affective state	Vehicle / user	Considered/ included systems	MS2 contribution
UCA (SCANIA/ DENSO)	- Drowsiness / sleepiness - Inattention/ distraction - Worload/stress - State of rest (resting yes/no) - Emotion state/valence	Truck – professional drivers	- Smart Eye: Eye tracking and emotion tracking - Autoliv Steering Wheel: GSR, HR - “Fitwatch”: HR, accelerometer - Cognitive Model (DLR) - Stockholm University: Sleep/rest detection - 1 channel EEG (potentially)	- Drive monitoring systems, mainly existing in vehicle - Rest will be addressed in literature search - Emotions Need to address more truck drivers in literature.
UCB (VEDECOM/ VALEO)	- Range Anxiety - Driving style	Electric car / passenger car drivers	Anxiety monitoring Driving style monitoring	Range anxiety addressed with a few products. Further in literature search. Driving style was not addressed by products, only literature. Decide on driving style (which are we interested in-have to be relevant to UC).
UC C (DLR, DENSO, TomTom, FORD)	- Drowsiness / sleepiness - Inattention/ Distraction - Workload/stress - Impairment / fainting	Passenger car/ passenger car driver	Apart from affective states’ related monitoring, additionally: - Environmental sensing - Maps and guidance	Fainting and rest will be addressed in literature search. Non-existing products. Some products under production.

UC (Partner)	Affective state	Vehicle / user	Considered/ included systems	MS2 contribution
	- Rest			
UC D (DLR, DENSO, TomTom, FORD)	- Workload/ stress - Impairment / fainting - Rest	Passenger car/ passenger car driver	Apart from affective states' related monitoring, additionally: - Environmental sensing - Maps and guidance (navigation) - V2X communication (for emergency maneuvers) - HMI designs for automation (taking over, control, emergency)	Same as previous
UC E (DUCATI/ DAINESE)	- Drowsiness - Fatigue - Inattention - Stress - Dehydration - Frostbite - Hypothermia	Touring motorcycle/ rider	The PTW will be equipped with the following sensors: • Satellite navigator • IMU • ABS • BBS • BT • ~~DSB~~ • ~~D|AIR~~ The PTW will be equipped with the following HMI: • visual feedback • haptic feedback (if necessary) The wearable system will be equipped with the following sensors: • body temperature • ECG sensor • Galvanic Skin Response • GPS • D|AIR platform (accelerometer, gyrometer and magnetometer) The wearable system will be equipped with the following HMI: • visual feedback • haptic feedback	Same as previous

UC (Partner)	Affective state	Vehicle / user	Considered/ included systems	MS2 contribution
			DAINESE Intelligent Helmet The helmet will be equipped with the following sensors: • head tracking system • eye tracking system The helmet will be equipped with the following HMI: • visual feedback	
UC F (DUCATI/ DAINESE)	- Faint	Touring motorcycle/ rider	Same as above	Same as previous
UC G (SCANIA/ VTI)	- Stress - Fatigue - states	Bus/ bus driver	Driver monitoring systems Map/ stop monitoring and control Wristband reminder	Stress for bus drivers will be addressed in literature search (more relevant) as well as fatigue.

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Annex. 1 Compedium of literature review

Annex 1.1 Affective state: Sleepiness

Jackson, M. L., Kennedy, G. A., Clarke, C., Gullo, M., Swann, P., Downey, L. A., & Howard, M. E. (2016). The utility of automated measures of ocular metrics for detecting driver drowsiness during extended wakefulness. Accident Analysis & Prevention, 87, 127-133. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

The study aims at the comparison of two drowsiness monitors. Driving simulator performance, KSS and PVT are used as sleepiness indicators. A within-subject design was applied using extended wake to invoke sleepiness. Drivers undertake a 20min night-time motorway drive after 24h sleep deprivation. Used two sleepiness monitors: Copilot (Carnegie Mellon Research Institute) and Optalert (Optalert). Copilot use PERCLOS, Optalert use a composite measure of eyelid velocity, blink duration etc. Copilot (PERCLOS) is really not very good. Optalert metrics increased significanlty with KSS and driving performance deterioration.

Advantages: -
Disadvantages: Optalert showed significant differences between alert and after 24 sleep deprivation, but it is not known how it performs in the transition between these states. Optalert requires a special pair of glasses with cameras and IR illumination.
Outcomes: Since the optalert systems outperforms PERCLOS, it may be possible to boost the performance of remote camera systems by using the same sleepiness metric (JDS) as optalert does.
Comparison to ADAS&ME: Composite measures, consisting of several (eye) parameters, should be used in ADAS&ME. PERCLOS alone does not seem to be a good choice**.**

Selvakumar, K., Jerome, J., Rajamani, K., & Shankar, N. (2016). Real-time vision based driver drowsiness detection using partial least squares analysis. Journal of Signal Processing Systems, 85(2), 263-274. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

A new partial least squares based algorithm for classifying open/closed eyes is presented. Eye/face detection was based on Viola-Jones folllowed by partial least squares to separate open eyes from closed eyes. Comparison of open/closed eyes of 50 participants was performed. The data were collected during day/night with/without glasses, but the design is only used for data collection, not to invoke sleepiness. PERCLOS is used as a direct measure of sleepiness. Eye detector has a true positive rate of 96%, out of these, between 90-100% accuracy is acheived. Worst performance in darkness with glasses due to reflections (about 90%).

Advantages: Works roughly in real-time (3 fps).
Disadvantages: No comparison to other techniques. Difficult to know how good the results are.
Outcomes: A closed-eyes detector has been developed. It is not really revealed how well it operates in realistic conditions.
Comparison to ADAS&ME: The algorithm is based on PERCLOS which may not be an ideal measure of sleepiness. If it really is a robust closed-eyes detector then it can at least be used as a late-stage sleepiness or actual sleep detector.

Schömig, N., Hargutt, V., Neukum, A., Petermann-Stock, I., & Othersen, I. (2015). The interaction between highly automated driving and the development of drowsiness. Procedia Manufacturing, 3, 6652-6659.

The authors compared 12 motorists with high BEV driving experience (M= 60.500 km) with 12 motorists, who had never driven a BEV before. The test drive was designed to lead to a critical range situation (remaining range <trip length). Investigated the effects of highly automated driving on driver drowsiness while doing nothing compared to while performing a non-driving related additional task. Three experimental conditions:
−driving with a highly automated system (HA)
−driving with a HA system and additionally performing a Quiz Task (HA+QT)
−driving manually during the test phase (MAN)

After a certain drowsiness level during manual drive, a test phase of 15 minutes was initiated ending with a take-over scenario. Drowsiness was highest when drivers drove manually and highly automated
−While performing a secondary task drowsiness level stayed on a relatively low level.
−Interesting and motivating tasks for highly automated drive has the potential to raise driver's alertness to an extent that a massive increase in drowsiness during the activity can be prevented. Drowsiness was highest when drivers drove manually and highly automated. While performing a secondary task drowsiness level stayed on a relatively low level. Interesting and motivating tasks for highly automated drive has the potential to raise driver's alertness to an extent that a massive increase in drowsiness during the activity can be prevented.

Advantages: Address drowsiness in BEV and consideration for driving experience and automation and comparison to manual driving.
Disadvantages: Only certain type of vehicle (BEV) and a simulator study.
Outcomes: Interesting and motivating tasks can prevent increase of drowsiness.
Comparison to ADAS&ME: performing secondary tasks can have a positive effect on avoiding drowsiness.

Åkerstedt, T., Anund, A., Axelsson, J., & Kecklund, G. (2014). Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. Journal of sleep research, 23(3), 242-254. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

Review article comparing KSS ratings with physiological and behavioural measures in different settings, including car driving. It is actually a descriptive summary of multiple studies. There is an exponential relationship between KSS and (lane departures, slow eye movements, EEG alpha power) and also with subjective ratings on eye symptoms (heavy eye lids, gravel-eyed, difficulties keeping eyes open). Subjective ratings of sleepiness are put forward as a sensitive and valid indicator of sleepiness, which is easy to use and just as valid as other sleepiness measures.

Advantages: Easy to use.
Disadvantages: Not possible to measure with a sensor. It is subjective in its very nature.
Comparison to ADAS&Me: KSS should be used as a reference measure of sleepiness in the ADAS&ME evaluations.

Neubauer, C., Matthews, G., & Saxby, D. (2014, September). Fatigue in the Automated Vehicle: Do Games and Conversation Distract or Energize the Driver?. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 58, No. 1, pp. 2053-2057). Sage CA: Los Angeles, CA: SAGE Publications.

The study investigated whether secondary media (control, trivia games or cell phone) devices impacted subjective responses and driver performance, during fatigue drives. Subjective state response, vehcile control and reaction time to a sudden event were recorded. The media devices helped improve concurrent driver performance, minimize the loss of task engagement and elevated distress produced by vehicle automation. Media usage was not associated with faster response time. Participants completed a 45-minute simulator drive, randomly assigned to (1) non/partial/total automation and (2) control, trivia or cell phone condition. Participants in the TR and CP conditions were required to engage in a game of "trivia" or hands-free cell phone conversation during two, 10-minutes periods throughout the drive. The STISIM Model 400 simulator, equipped with a 38" NEC XM3760 monitor. Monitors to record SDLP and reaction time. Secondary devices (cell phone, trivia game). Measures reaction time & SDLP to determine fatigue state. Subjective stress and fatigue states were assessed with the DSSQ: addressing task induced stress, task engagement, distress and worry. Meanwhile the simulator logged variability of lateral position. Response time to an emergency event was tested towards the end of the drive. Subjective stress and fatigue states were assessed pre- and post-drive, with the Dundee Stress State Questionnaire (Matthews, et al., 2002). The DSSQ yields three higher order factors of task engagement, distress and worry. All groups showed relative increases in distress and relative decreases in task engagement. ANOVA run resulted in $F(2,171)=18.60$, $p<.001$ and $F(2,171)=5.91$, $p<.01$. Engagement was lowest in the control group and highest among drivers in the trivia and cell phone groups, while distress was highest in the control and trivia groups and lowest in cell phone group. Automation did not influence stress state response. A significant difference in SDLP was noted between cell phone and control and trivia and control groups, $p<.05$, but not between the trivia and cell phone groups, $p>.05$.

Advantages: The study showed that usage of secondary media devices may improve vehicle control and reduce driver fatigue.
Disadvantages: Beneficial effects of media use may be confined to low-workload driving. Study is performed in a limited simulator and the results may differ from a real life drive.
Outcomes: Secondary media devices may help counteract some effects of fatigue while driving. Media conditions elevated task engagement, but did not counteract the slowed braking to an emergency event produced by automation. Cell phone use was effective in reducing distress, trivia game was not. Both automated and control drives produced large magnitude declines in task engagement.
Comparison to ADAS&ME: HMI design that support secondary task in low-workload driving can reduce driver fatigue and increase task engagement. Though media usage is not associated with faster response time or lasting driver alertness.

Hallvig, D., Anund, A., Fors, C., Kecklund, G., & Åkerstedt, T. (2014). Real driving at night–Predicting lane departures from physiological and subjective sleepiness. Biological psychology, 101, 18-23. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

Objective is to relate unintentional lane departures to various sleepiness measures (KSS, blink duration, KDS). A within-participant design was applied using extended wake to invoke sleepiness. Drivers drive three times from 90min on a real rural road. The processing unit was based on extract blink duration from EOG, Karolinska drowsiness score from EEG and EOG, and unintentional lane departures based on video analysis. All analyses performed offline and the models applied were Baysian multi-level models (lane departure ~ KSS + blink duration + KDS + session (day/night) + exposure).

Advantages: The driver is quite capable of knowing when he/she is sleepy.
Disadvantages: KSS can not be monitored by any system.
Outcomes: KSS is the best indicator of lane departures. Blink duration can also be used when customized to an individual. KDS (EEG+EOG-based) is not successful in predicting lane departures.
Comparison to ADAS&ME: Measures of sleepiness should be individualized.

Jung, S. J., Shin, H. S., & Chung, W. Y. (2014). Driver fatigue and drowsiness monitoring system with embedded electrocardiogram sensor on steering wheel. IET Intelligent Transport Systems, 8(1), 43-50. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

Measuring ECG with fabric electrodes positioned at the steering wheel. HRV parameters are related to subjective ratings of fatigue and drowsiness. The scenario included 2h driving in the real world with tasks related fatigue (not sleepiness). The technologies used involved Measures ECG via conductive fabric electrodes. Results were only descriptive.

Advantages: Interesting sensor.
Disadvantages: No proper validation.
Outcomes: Not sure, the sensor is not properly tested so it is not possible to say much.
Comparison to ADAS&ME: Similar to the steering wheels provided by Autoliv. Other studies, using medical ECG equipment, have had trouble providing reproducible results.

McDonald, A. D., Lee, J. D., Schwarz, C., & Brown, T. L. (2014). Steering in a Random Forest Ensemble Learning for Detecting Drowsiness-Related Lane Departures. Human Factors: The Journal of the Human Factors and Ergonomics Society, 56(5), 986-998.

Evaluation of whether more advanced steering wheel angle measures can be used to predict drowsy lane departures. 162 drowsy lane departures (ORD>37) are compared to 416 matched alert cases without lane departures (verified by PVT and subjective sleepiness). Several classification algorithms are compared and the winner (random forest) is compared to PERCLOS. This was a simulator study. Lane departures are used as an indicator of sleepiness. Each lane departure was rated using the ORD scale (Wierwille 1994) and only lane departures with ORD>37 are used. A matched set of alert non-departures are used. Time series of unprocessed 54-seconds SWA time series data leading up to lane departures (-60s to -6s before departure) are detected via a random forest classifier. The article benchmarks different classifiers: decision tree, neural network, kNN, naive Bayes, SVM, boosted tree and random forest. Performance is comparable, but random forest is the best in terms of AUC. Accuracy of the algorithm was 79% (PERCLOS 55%) and positive predictive value was 80% (PERCLOS 88%).

Advantages: The algorithm use SWA which is readily available in all vehicles. The algorithm performs better than PERCLOS, which is supposed to be a valid drowsiness measure.
Disadvantages: The parameters of the random forest probably have to be retrained for each vehicle.
Outcomes: The steering wheel angle alone, without taking road geometry into account, provides a decent estimate of driver sleepiness. However, the results also indicate that a lack of steering is the key feature used to predict sleepiness. This appears to be a poor indicator on long monotonous motorways (where little steering is needed and where sleepiness is a large problem).
Comparison to ADAS&ME: Vehicle measures should not be ruled out for drowsiness detection, but despite what the authors claim, it is probably wise to take road geometry into account.

Jin, L., Niu, Q., Jiang, Y., Xian, H., Qin, Y., & Xu, M. (2013). Driver sleepiness detection system based on eye movements variables. Advances in Mechanical Engineering. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

Classify alert vs. sleep restricted conditions with SVM. Within-subject design (Sleep restriction vs baseline) using restricted sleep and afternoon dip to induce sleepiness. Driving session consisted of 2h low traffic motorway driving. SmartEye Pro system was used to measure PERCLOS, blink rate, fixation time and gaze direction. Gaze direction was calculated as percentage of time that the driver looked in the "normal fixation region", which is an undefined square area. SVM is used to classify eye features to a binary sleepiness decision. The applied model SVM is using PERCLOS, gaze direction, blink rate and fixation time as features. Individual models were used and the accuracy of the general model was 72%. Individualized models showed 85% accuracy.

Advantages: Individualized models.
Disadvantages: It would have been nice to complement the target class with something more than sleep restriction, for example KSS. It would also have been interesting to see how the developed sleepiness indicator performs over time, not just using an entire 2h drive as input.
Outcomes: Individual models were used and the accuracy of the general model was 72%. Individualized models showed 85% accuracy.
Comparison to ADAS&ME: The lesson to be learned from this paper is that we can gain a lot by individualized models. Performance drops when a general (group-level) model is applied to an individual driver.

Marina, M., Torrado, P., Busquets, A., Ríos, J. G., & Angulo-Barroso, R. (2013). Comparison of an intermittent and continuous forearm muscles fatigue protocol with motorcycle riders and control group. Journal of electromyography and kinesiology, 23(1), 84-93.

Motorcycle races' long duration justify the study of forearm muscles fatigue, especially knowing the frequently associated forearm discomfort pathology. Moreover, while continuous fatigue protocols yield unequivocal results, EMG outcomes from an intermittent protocol are quite controversial.
This study examined the forearm muscle fatigue patterns produced during these two protocols, comparing riders with a control group, and relating maximal voluntary contraction with EMG parameters (amplitude – NRMS and median frequency – NMF) of both protocols to the forearm discomfort among motorcycle riders. Twenty riders and 39 controls performed in separate days both protocols simulating the braking gesture and posture of a rider. EMG of flexor digitorum superficialis (FS) and carpi radialis (CR) were monitored. CR revealed more differences among protocols and groups compared to FS. To monitor rider's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause).The greater CR activation in riders could be interpreted as a neuromotor strategy to improve braking precision. When FS fatigue increased, the control group progressively shifts toward a bigger CR

activation, adopting an intermuscular activation pattern closer to riders. Despite the absence of NMF decrement throughout the intermittent protocol, which suggest that we should have shorten the recovery times from the actual 1 min, the superior number of rounds performed by the riders proved that this protocol discriminates better riders against controls and is more related to forearm discomfort. The performance related parameters of the intermittent protocol not only discriminate better the riders from the control group but have also a strong relationship with the level of forearm discomfort within the riders. These results should encourage improving and optimizing specific intermittent fatigue protocols. Both Protocols induce different EMG results, confirming a stronger fatigue round effect in the continuous protocol. The CR was the muscle group that revealed more differences among groups and protocols. Because braking requires fine tuning and precision when racing, the riders possibly are more habituated to coactivate the CR and FS. Moreover, when FS fatigue increased, it seems that the control group progressively shifted toward a larger CR coactivation, adopting an intermuscular activation pattern closer to the one of the riders. The absence of a significant NMF decrement throughout the intermittent protocol, suggests that we should modify recovery times after each MVC shorter than 1 min.

Advantages: EMG used as a measure of both fatigues and inattention.
Disadvantages: Professional riders have skills not necessarily found in every day or leisure riders (e.g. braking behaviour, speed adjustments). Body position can vary between subjects because the relative position between segments cannot be exactly the same among all participants due to their stature and segment lengths differences.
Outcomes: Forearm discomfort might affect inattention.
Comparison to ADAS&ME: To monitor rider's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause).

Craig, A., Tran, Y., Wijesuriya, N., & Nguyen, H. (2012). Regional brain wave activity changes associated with fatigue. Psychophysiology, 49(4), 574-582.{keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

Slow wave activity in the alpha and theta bands increase over the entire cortex when fatigued. Also beta increases in frontal regions. ICA-based artifact removal, spectral analyses to investigate brain wave activity in delta, theta, alpha, beta bands. All analyses performed offline. Different measures: long blink durations >400ms (EOG), expert rating of "fatigue related facial behaviours", and deviating off the road for more than 15s. Driving simulator experiment where the drivers (N=30) drove until fatigued (passive task related fatigue). Comparison between alert and fatigued conditions. The changes between alert and fatigued are highly significant, but the size of the change is rather small (typical example: 29.5 -> 30.4 dB).

Advantages: The paper reviews 17 papers related to EEG changes and the results of this paper confirms previous results.
Disadvantages: There are no results showing the time-evolution between the alert and the highly fatigued states. If only the highly fatigued state can be distinguished from the alert state then it is too late for a detection system.
Outcomes: Changes in EEG can be used to detect severe fatigue, but the actual difference is small between alert and fatigued, and the paper says nothing about the transition phase from alert to fatigued.
Comparison to ADAS&ME: Even with EEG it is difficult to design a sleepiness detection system.

Dong, Y., Hu, Z., Uchimura, K., & Murayama, N. (2011). Driver inattention monitoring system for intelligent vehicles: A review. IEEE transactions on intelligent transportation systems, 12(2), 596-614.

The paper review SoA technologies for driver inattention monitoring, classified into (1) distraction and (2) fatigue. Five approaches are addressed: 1. subjective report measures, 2. driver biological measures, 3. driver physical measures, 4. driving performance measures, 5. hybrid measures. Subjective (1) and biological (2) measures are not considered suitable under real driving conditions, but can be rough ground truth indicators. Hybrid measures combining driver physical measures and performance measures are believed to give more reliable solutions.

Advantages: The paper reviews various DSMSs and relates suitability for real driving conditions. Hybrid measures are supported since they minimize the number of false alarms and maintain a high recognition rate, which promote the acceptance of the system.
Disadvantages: The monitoring systems are not related to automated driving.
Outcomes: Hybrid measures (esp. physical and performance measures) for driver state monitoring are expected to give more reliable measures than single measures. Subjective and biological measures are not considered suitable under real driving conditions, since they can be intrusive and cause interference.
Comparison to ADAS&ME: Recommended to use hybrid measures in driver monitoring. Physical and performance measures are supported, since they are considered to affect the driver less than subjective and biological measures.

Senaratne, R., Jap, B., Lal, S., Hsu, A., Halgamuge, S., & Fischer, P. (2011). Comparing two video-based techniques for driver fatigue detection: classification versus optical flow approach. Machine Vision and Applications, 22(4), 597-618.

Comparison of classification approaches versus optical flow to estimate eye state (open/closed). The result is used to estimate PERCLOS, which is assumed to be a good sleepiness indicator. Evaluation is done based on the FERET database and on the 9 participants. Comparison of open/closed eyes of 9 participants (5 from behind a desk, 1 from real driving, 4 from simulator). For most comparisons, data acquired from 5 subjects sitting behind a desk and mimicking fatigue are used. Face detection with LMM (Viola-Jones not good enough). Eye detection via adaptive thresholding (find iris near approximate eye location from LMM). The developed system isn't really evaluated in terms of sleepiness, mainly on open/closed eyes with/without glasses (320x240 camera).
Classification: Eye pixels or wavelet coefficients are classifed as open/closed using MoCC, kNN, SVM, NBC.
Optical flow: Lucas-Kanade calculates the velocity of the upper eyelid in relation to the eye brows.

- Using Gabor wavelet coefficients (jets) as features is preferable to raw pixel intensites.
- Mean of Class classifier (MoCC) provided best results.
- Optical flow techniques are preferable when there is not enough training material available.

Advantages: -
Disadvantages: Despite the many graphs and tables in the paper, the developed algorithms have not been sufficiently evaluated (both in terms of sleepiness and in terms of generalizability on new test subjects).
Outcomes: The classification approach is more accurate but requires large amounts of training data. If such data are unavailable, the optical flow approach is preferable.
Comparison to ADAS&Me: The algorithm is based on PERCLOS which may not be an ideal measure of sleepiness. If it really is a robust closed-eyes detector then it can at least be used as a late-stage sleepiness or actual sleep detector.

Golz, M., Sommer, D., Trutschel, U., Sirois, B., & Edwards, D. (2010). Evaluation of fatigue monitoring technologies. Somnologie-Schlafforschung und Schlafmedizin, 14(3), 187-199.

The aim of the paper is to propose how electrophysiological signals can be used to validate video-based fatigue monitoring systems. The video-based systems use PERCLOS to monitor fatigue. KSS, SDLP (standard deviation of lateral position), and a combined measure of EEG and EOG. Correlation analysis between PERCLOS and KSS/SDLP, and nonlinear discriminant analysis (target values obtained by thresholding according to KSS=7). Many different systems. Appendix 3 here contain a summary of each system, including links to companies and costs (when available): http://www.slideshare.net/willred/cat-fatigue-technology-report-2008. PERCLOS correlates with KSS and lane deviations (r>0.9) on a group level when using long analyzing windows (>30min). On an individual level and with shorter time windows, PERCLOS fails to estimate KSS and lane deviations. PERCLOS is also considerably worse at detecting high levels of fatigue/sleepiness compare to

EEG/EOG.

Advantages: Correlation levels between PERCLOS, KSS and Lane deviations obtained for a whole 30 minutes' measurements.
Disadvantages PERCLOS is not related to KSS and lane deviations in a useful manner.
Outcomes: PERCLOS in itself is practically not very usfeul for fatigue monitoring.
Comparison to ADAS&ME: The authors recommend complementing PERCLOS with other eye/face measures that can also be extracted from the camera, such as pupil diameter and eye movements. Off-the-shelf products are not good enough for sleepiness detection.

Liu, C. C., Hosking, S. G., & Lenné, M. G. (2009). Predicting driver drowsiness using vehicle measures: Recent insights and future challenges. Journal of safety research, 40(4), 239-245.{keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

This is a review article aimed to assess whether it is possible to predict driver sleepiness using vehicle measures. The reviewed articles use Stanford or Karolinska Slepiness Scale, blink rate and EEG activity as ground truths. It was found that simple functions such as SDLP and SWM are too rudimentary to predict sleepiness. Individualized composite measures are probably needed. This article aimed to assess whether it is possible to predict driver sleepiness using vehicle measures.

Advantages: -
Disadvantages: Most papers report results averaged across groups only. It is usually not known how the predictor functions on an individual level. Studies that do investigate performance on an individual level show large differences between participants.
Outcomes: Composite vehicle measure has to be explored further. The time window used for deriving the sleepiness estimate was high-lighter. Is it possible to shorten the time windows to get a timely warning without introducing to much noise?
Comparison to ADAS&Me: Individualization is brought up (again). It is very beneficial to adapt driver monitoring systems to individual drivers.

May, J. F., & Baldwin, C. L. (2009). Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. Transportation Research Part F: Traffic Psychology and Behaviour, 12(3), 218-224. {keywords: driver AND (sleepiness OR drowsiness OR fatigue) AND (detection OR monitoring OR predicting)}

There are different types of fatigue. Sleepiness related fatigue caused by circadian rhythms, sleep deprivation and sleep restriction. Task related fatigue caused by the driving task and the driving environment, can be Active due to overload or Passive due to underload. The paper is theoretical and is an overview of countermeasures and technological aids for driver fatigue: PERCLOS, head-nodding, deadman switch, rumble strips, lane departure and collision avoidance systems. Sleepiness related fatigue is resistant to interventions techniques (only a nap, caffeine or similar will do). Task related fatigue can be countered by alerting the driver with an alarm etc.

Advantages: PERCLOS and lane departure/collision avoidance systems are useful to counter multiple driver impairments such as task related fatigue and inattention. Automation at levels 0-3 may counter active task related fatigue.
Disadvantages: Head-nodding and deadman switches are only able to detect sleepy drivers after sleep has set in. Automation at levels 0-3 may cause passive task related fatigue.
Outcomes: Several systems available to detect and counter fatigue.
Comparison to ADAS&ME: An effective countermeasure technology has to take the cause and type of fatigue into account.

Annex 1.2 Affective cluster: Stress

Giannakakris, G., Pediaditis, M., Manousos, D., Kazantzaki, E., Chiarugi, F., Simos, P.G., Marias, K., Tsiknakis, M. (2017). Stress and anxiety detection using facial cues from videos. Biomedical Signal Processing and Control, 31 (89), 101. {search keywords: Stress AND Driving}

The aim of the study was to develop an automated identification of a set of facial parameters (semi and non-voluntary). An experimental approach was used for data collection and 23 (16 males - 7 females) participated n the study. This was done in different phases looking at social exposure, emotion recall, stressful images/mental task and stressful videos. The study was conducted in laboratory environment with a camera with a distance of 50 cm with its Field of View (FOV) and application of machine learning techniques. The data pre-processing involved histogram equalization for contract enhancement face detection, and region of interest (ROI) determination. The classification methods that were used and tested are: K-nearest neighbors (K-nn), Generalized Likelihood Ratio, Support Vector Machines (SVM), Naïve Bayes classifier and AdaBoost classifier.
In each case, the classifier was trained using 9folds (90% of data) and tested on the remaining data (10% of data). The results in terms of classification accuracy varied between 80-90 % taking into account the most effective classifier.

Advantages: The phases for data collection to manipulate stress/Anxiety are interesting. The use of Active Apperance model för stress recognision. Input to mouth motion estimation from an optical flow approach. Information of photoplethysmography is applied to estimate HR.
Disadvantages: Done in laboratory. Not on real driving.
Outcomes: This systematic review provides evidence that adverse psychosocial work conditions are negatively associated with ANS function as indexed by HRV.
Comparison to ADAS&ME: The use of different classification across various contents but not contexts. Real driving requires increased sensitivity and accuracy and no evidence exists; only potential for transferability.

Rodrigues, J. G., Kaiseler, M., Aguiar, A., Cunha, J. P. S., & Barros, J. (2015). A mobile sensing approach to stress detection and memory activation for public bus drivers. IEEE Transactions on Intelligent Transportation Systems, 16(6), 3294-3303. {search keywords: Stress AND Driving}
A mobile sensing approach was designed to detect georeferenced stress responses and facilitate memory recall of the stressful situations. Data were collected among public bus drivers in the city of Porto, Portugal (145 h, 36 bus drivers, +2300 km), and results supported the validation of their approach among this population and allowed them determine specific stressor categories within certain areas of the city. Furthermore, data collected throughout the city allowed them to produce a citywide "stress map" that can be used for spotting areas in need of local authority intervention. Participants were wearing t-shirts with ECG sensors (Vital acket + Physionet), GPS and button for self-reporting stress event and were driving every day a daily route. The time window for measurements was 100 s. The metrics included the average normal-to-normal (NN) Intervals, the standard deviation of these NN intervals, their low frequency spectral power (LF) between 0.04 Hz and 0.15 Hz, the high frequency power (HF) , between 0.15 Hz and 0.4 Hz, and the ratio LF/HF. The findings suggest that the system can be a promising tool to support applied occupational health interventions for public bus drivers and guide authorities' interventions to improve these aspects in "future" cities. The system show promising results combining HRV and GPS information with stress button.

Advantages: It involves real driving with a simple system using t-shirt for HR detection.
Disadvantages: The reference value is self-reporting.
Outcomes: The sensor and the approach to connect stress to the geo-graphics, the memory and the speed is interesting.
Comparison to ADAS&ME: Good for bus drivers understanding. Highlighting the most stressful contributors as: Other drivers or pedestrians behaviors were the most commonly reported source of stress, reported for 35% of the recalled or tagged events and mentioned at least once by 62% of the 29 bus drivers. Difficulty driving due to urban planning was the second most reported source of stress, reported for 22% of the events recalled or tagged, and mentioned by 41% of the drivers (12/29). Also, events that impact time schedule was a frequently reported source of stress, accounting for 19% of the events and mentioned by 41% of the drivers.

Wickens, C. M., Wiesenthal, D. L., & Roseborough, J. E. (2015). In Situ Methodology for Studying

State Driver Stress: A Between Subjects Design Replication. Journal of Applied Biobehavioral Research, 20(1), 37-51 {search keywords: Stress AND Driving}

Previous studies of driver stress have utilized in-vehicle in situ questionnaires to measure driver stress during the actual commute. These studies demonstrated several important findings, but all adopted a repeated-measures research design where each participant was exposed to counterbalanced high and low congestion conditions. This approach reduced between-subjects variability but increased the possibility of demand characteristics. The current study replicated the findings of the in situ methodology using a between-subjects research design. State stress was greater in heavy traffic. Time urgency, lack of perceived control, and trait susceptibility to perceiving driving as stressful contributed to higher levels of state driver stress. No gender differences in state driver stress were found. Implications of the results and future research directions are discussed. Everyday hassles such as getting to work/school on time likely heighten the frustration and negative affect in the driving environment. Likewise, consistent with the second hypothesis, drivers experiencing a lack of perceived control over the driving situation also reported higher levels of state driver stress. Consistent with the third hypothesis, heavy traffic congestion was associated with reports of greater state driver stress. Traffic congestion blocks the attainment of goals, such as driving at a certain speed, and is therefore interpreted as a negative and frustrating event. Consistent with the fourth hypothesis, drivers with a trait susceptibility to driver stress reported higher levels of in-vehicle state stress. Results of the current study have several important implications for the societal response to driver stress, not the least of which is acknowledging the contribution that traffic congestion and time urgency make to driver stress, and recognizing them as a public health concern. As such, a multifaceted approach to reducing driver stress should be implemented, including organizational changes to reduce traffic congestion (e.g., telecommuting, flextime hours) and promotional campaigns encouraging motorists to remain calm behind the wheel.

Advantages: Solid and validated approach.
Disadvantages: Not in real life and subjective driven stress reporting. Focus on traffic congestion.
Outcomes: Driving style and loci of control are of key importance.
Comparison to ADAS&ME: The main outcomes (e.g. lack of perceived control, trait susceptibility) can be used to build up the current driving style as part of the driver's behaviour that can directly or indirectly affect the affective state the driver experiences.

Rigas, G., Goletsis, Y., Bougia, P., & Fotiadis, D. I. (2011). Towards driver's state recognition on real driving conditions. International Journal of Vehicular Technology, 2011. {search keywords: Stress AND Driving}

In this work a methodology for detecting drivers' stress and fatigue and predicting driving performance is presented. The proposed methodology exploits a set of features obtained from three different sources: (i) physiological signals from the driver (ECG, EDA, and respiration), (ii) video recordings from the driver's face, and (iii) environmental information. The extracted features are examined in terms of their contribution to the classification of the states under investigation. The most significant indicators are selected and used for classification using various classifiers. The approach has been validated on an annotated dataset collected during real-world driving. The results obtained from the combination of physiological signals, video features and driving environment parameters indicate high classification accuracy (88% using three fatigue scales and 86% using two stress scales). A series of experiments on a simulation environment confirms the association of fatigue states with driving performance.

Advantages: Combinations of metrics that can be used in order to identify both stress and fatigue with high accuracy. In addition, consideration is made for environmental information.
Disadvantages: Results based only one driver; reliability is not sufficient.
Outcomes: Association of fatigue states with driving performance.
Comparison to ADAS&ME: Classification of states based on extracted features is extremely relevant to the FER that the project has uptake. The approach is validated and thus within the project we may replicate or replicate parts of it.

Benoit, A., Bonnaud, L., Caplier, A., Ngo, P., Lawson, L., Trevisan, D. G., & Chanel, G. (2009). Multimodal focus attention and stress detection and feedback in an augmented driver simulator. Personal and Ubiquitous Computing, 13(1), 33-41. {search keywords: Stress AND Driving}

This paper presents a driver simulator, which takes into account the information about the user's state of mind (level of attention, fatigue state, stress state). The user's state of mind analysis is based on video data and biological signals. Facial movements such as eyes blinking, yawning, head rotations, etc., are detected on video data: they are used in order to evaluate the fatigue and the attention level of the driver. The user's electrocardiogram and galvanic skin response are recorded and analyzed in order to evaluate the stress level of the driver. Driver simulator software is modified so that the system is able to appropriately react to these critical situations of fatigue and stress: some audio and visual messages are sent to the driver, wheel vibrations are generated and the driver is supposed to react to the alert messages. A multi-threaded system is proposed to support multi-messages sent by the different modalities. Strategies for data fusion and fission are also provided. Some of these components are integrated within the first prototype of OpenInterface: the multimodal similar platform. Video data and biological signals are collected.

Advantages: The simulator-based approach is interesting and the combination of video and physiological (especially which data types have been chosen) in relation to feedback output.
Disadvantages: testing is not described.
Outcomes: Not described.
Comparison to ADAS&ME: Difficult to define the relationship with this project as processes and outcomes are not clearly discussed. However, the choice for measuring stress and its relation to multimodal attention is interesting not only for identifying the driving impairment per se because of stress but also the effect it can have in designing the respective HMIs within the project (i.e. multimodality in information/ warning and stress).

Range Anxiety

Franke, T., Rauh, N., Günther, M., Trantow, M., & Krems, J. F. (2016). Which Factors Can Protect Against Range Stress in Everyday Usage of Battery Electric Vehicles? Toward Enhancing Sustainability of Electric Mobility Systems. Human factors, 58(1), 13-26.

The authors examined range anxiety in the form of everyday range stress (ERS) in a field study setting. Seventy-two customers leased a BEV for 3 months. The field study was specifically designed to enable examination of factors that can contribute to lower ERS. In particular, study design and sample recruitment were targeted at generating vehicle usage profiles that would lead to relatively frequent experience of situations requiring active management of range resources and thereby potentially leading to experienced range stress. Less frequent encounter with critical range situations, higher practical experience, subjective range competence, tolerance of low range, and experienced trustworthiness of the range estimation system were related to lower ERS. Moreover, range stress was found to be related to range satisfaction and BEV acceptance.

Advantages: concrete HMI concepts were tested.
Disadvantages: low number of participants.
Outcomes: Less frequent encounter with critical range situations, higher practical experience, subjective range competence, tolerance of low range, and experienced trustworthiness of the range estimation system were related to lower ERS. Moreover, range stress was found to be related to range satisfaction and BEV acceptance.
Comparison to ADAS&ME: Variables are of interest to be considered.

Günther, M., Trantow, M., & Krems, J. F. (2015). Which factors can protect against range stress in everyday usage of battery electric vehicles? Towards enhancing sustainability of electric mobility systems. Human Factors: The Journal of the Human Factors and Ergonomics Society, 0018720815614702.

A longitudinal field study with 40 participants was conducted to examine which eco-driving strategies users know before and after driving a BEV for 3 months. Furthermore, participant's knowledge regarding eco-driving strategies with BEVs versus internal combustion engine vehicles (ICEVs) was compared. After 3 months of BEV usage, a driving test was applied in order to investigate the strategies drivers apply to drive energy efficiently and to estimate the effectiveness of these strategies. Results reveal that reported eco-driving strategies for BEVs and ICEVs differ significantly. Users reported significantly more BEV eco-driving strategies after experiencing the BEV for 3 months than before. Furthermore, drivers were able to significantly reduce energy consumption by applying eco-driving strategies in the driving test. Reported eco-driving strategies proofed to be effective.

Advantages: driving test on eco-driving skills.
Disadvantages: relatively short test drive (4 km).
Outcomes: The results imply that eco-driving strategies for ICEVs have to be adapted for BEV eco-driving and that drivers gain a deeper understanding of factors that influence energy consumption by experiencing the BEV for a longer period of time. Based on the results, support of the driver through training or assistance systems is recommended.
Comparison to ADAS&ME: The strategies are more important for training EV drivers rather than measuring range anxiety.

Khan, T., Williams, M. A., Robertson, D., & Binersley, J. (2012). Designing the human machine interface to address range anxiety. In 26th Electric Vehicle Symposium 2012 (Vol. 1, pp. 216-225).
Users' feedback that estimated range of the vehicle is one of the most critical pieces of information for a driver. Combining this with battery state of charge information can provide the driver with a better understanding of the current range of their EV. However accuracy is a key factor to gain trust in range information. EV drivers need dynamic information on factors that influence available range. There is also a requirement for information that will enable drivers to drive economically.

Advantages: articles links range anxiety to HMI design.
Disadvantages: methodology of the user study / questionnaires is disputable, statistical analysis is lacking.
Outcomes: importance of adequate HMI design is emphasized.
Comparison to ADAS&ME: However accuracy is a key factor to gain trust in range information. EV drivers need dynamic information on factors that influence available range.

Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, J. F. (2012). Experiencing range in an electric vehicle: Understanding psychological barriers. Applied Psychology, 61(3), 368-391.
The authors examined the nature of how range is experienced in an EV and whether variables from other adaptation contexts, notably stress, have explanatory power for inter-individual differences in what we term comfortable range. Forty EVs were leased to a sample of users for a 6-month field study. Qualitative and quantitative analyses of range experiences were performed, including regression analyses to examine the role of stress-buffering personality traits and coping skills in comfortable range.

Advantages: scientific conceptualization of range experience.
Disadvantages: field study approach.
Outcomes: providing drivers with a reliable usable range may be more important than enhancing maximal range in an electric mobility system.
Comparison to ADAS&ME: Measures are interesting to take into consideration for Use Case B.

Annex 1.3 Affective cluster: Emotions

Koo, J., Kwac, J., Ju, W., Steinert, M., Leifer, L., & Nass, C. (2015). Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust, and performance. International Journal on Interactive Design and Manufacturing (IJIDeM), 9(4), 269-275.
This study explores, in the context of semi-autonomous driving, how the content of the verbalized

message accompanying the car's autonomous action affects the driver's attitude and safety performance. Using a driving simulator with an auto-braking function, we tested different messages that provided advance explanation of the car's imminent autonomous action. Messages providing only "how" information describing actions (e.g. "The car is braking") led to poor driving performance, whereas "why" information describing reasoning for actions (e.g., "Obstacle ahead") was preferred by drivers and led to better driving performance. Providing both "how and why" resulted in the safest driving performance but increased negative feelings in drivers. These results suggest that, to increase overall safety, car makers need to attend not only to the design of autonomous actions but also to the right way to explain these actions to the drivers.

Advantages: Explores the interaction between the driver and semi-autonomous driving actions
Disadvantages: Simulator study
Outcomes: These results suggest that, to increase overall safety, car makers need to attend not only to the design of autonomous actions but also to the right way to explain these actions to the drivers.
Comparison with ADAS&ME: Reasons for an action is as important as the action in order drivers to trust and continue to use function, i.e.need to establish connection. i.e. affective design.

Mesken, J., Hagenzieker, M. P., Rothengatter, T., & de Waard, D. (2007). Frequency, determinants, and consequences of different drivers' emotions: An on-the-road study using self-reports,(observed) behaviour, and physiology. Transportation research part F: traffic psychology and behaviour, 10(6), 458-475.

In the present study, the frequency, determinants and consequences of three relevant emotions in traffic were investigated. Based on appraisal theory, it was predicted that the combination of three appraisal components (goal congruence, blame and threat) affects the occurrence of anger, anxiety and happiness. Participants (*n* = 44) filled in a questionnaire containing background and personality variables, and performed a test drive in an instrumented car. During the drive, speed and heart rate were registered and the traffic environment was recorded on video. Participants verbally reported scores for emotions and perceived risk. The most frequently occurring emotion was anxiety, followed by anger and happiness. Emotions while driving were related to emotional traits. Emotions while driving were also related to traffic events: anger and anxiety were both associated with goal incongruent events, and happiness with goal congruent events. Anger was mostly associated with other-blame and anxiety with situation-blame. Anger was mostly associated with events affecting impeded progress, and anxiety with events affecting safety. Anxiety, but not anger or happiness, was associated with increased perceived risk and with increased heart rate. Participants who reported anger drove faster and exceeded the speed limit more often on a 100 km/road section than participants who did not report anger. These and other results are discussed in terms of appraisal theory and state-trait differences in emotion.

Advantages: The study includes the collection of various types of measures (e.g. background/ personality variables through questionnaire completion and video recordings).
Disadvantages: Anxiety is an affective state that is considered to be related range anxiety in ADAS&ME which is not actually generally related to anxiety but specifically only to electric cars.
Outcomes: Anxiety is the most frequent state very much related to emotional traits, goal congruent events resulting to increased perceived risk and increased heart rate.
Comparison with ADAS&ME: The study does not consider assistive or support systems but guides us towards theories and state-trait differences in emotions that we might consider in defining the emotions and selecting the appropriate indicators.

Vaa, T. (2007). Modelling driver behaviour on basis of emotions and feelings: intelligent transport systems and behavioural adaptations. In Modelling driver behaviour in automotive environments (pp. 208-232). Springer London. {keywords: emotions, driving, automated functions}

In this paper, we present a methodology and a wearable system for the evaluation of the emotional states of car-racing drivers. The proposed approach performs an assessment of the emotional states using facial electromyograms, electrocardiogram, respiration, and electrodermal activity. The system consists of the following: 1) the multisensorial wearable module; 2) the centralized computing module;

and 3) the system's interface. The system has been preliminary validated by using data obtained from ten subjects in simulated racing conditions. The emotional classes identified are high stress, low stress, disappointment, and euphoria. Support vector machines (SVMs) and adaptive neuro-fuzzy inference system (ANFIS) have been used for the classification. The overall classification rates achieved by using tenfold cross validation are 79.3% and 76.7% for the SVM and the ANFIS, respectively.

Advantages: Wearable system and approach that is of interest and relevance to ADAS&ME project and pilots for most vehicle types (i.e. even riders in controlled simulated environment).
Disadvantages: Race car drivers differ significantly from rest of drivers with regards to skills as well as self-control under extreme or risky situations (i.e. personality traits).
Outcomes: Classification worked using SVMs and ANFIS with adequate rates.
Comparison with ADAS&ME: Testing set up is interesting, the system and sensor selected, the approach and the classification models applied. However, the clusters selected: high/ low stress, disappointment and euphoria may be very relevant for race car drivers but it is still to be decided if this clustering will work for everyday drivers, professional drivers and leisure riders.

Jonsson, I., & Harris, H. (2005). Emotions, driving and in-car speech based information systems. The Role of Emotion in Human-Computer Interaction.

To investigate the impact of car voices and emotions on driving, they setup driving simulator experiments. For these experiments, they did not rely on participants being in a certain mood or exhibit a certain emotion so they used inducement techniques, audio, video, computer tasks, visualization tasks to ensure certain emotions. They also manipulate both the driving scenario and the in-car voices for emotional effect and content. Voice prompts are designed to vary both in linguistic and paralinguistic features such as 1) emotional colouring 2) familiar/unfamiliar voice 3) prompts that provide warnings and information on road conditions and 4) prompts that provide a conversational partner. The data from these studies are evaluated both for driving performance, are the voice systems helpful, and attitude, are the voice system well liked and will hence stay turned on.

Advantages: Investigate emotion recognition through speech based systems with real users taking into consideration both linguistic and paralinguistic features.
Disadvantages: Experiments are conducted in simulated but still driving environment.
Outcomes: The data from these studies are evaluated both for driving performance, are the voice systems helpful, and attitude, are the voice system well liked and will hence stay turned on.
Comparison with ADAS&ME: Testing set up is interesting and especially the categories of prompts can be used to categorize speech outputs and help design the HMI for certain driving instances.

Annex 1.4 Affective cluster: Inattention/distraction/workload

van der Meulen, H., Kun, A. L., & Janssen, C. P. (2016, October). Switching Back to Manual Driving: How Does it Compare to Simply Driving Away After Parking?. In Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 229-236). ACM. {keywords: Distraction monitoring, driver, gaze fixation, inattention, in-vehicle information systems IVIS, naturalistic simulator, percent road center}.

Method to monitor driver distraction based on a stereo camera to estimate the face pose and gaze of a driver in real time. A coarse eye direction is composed of face pose estimation to obtain the gaze and driver's fixation area in the scene, which is a parameter that gives much information about the distraction pattern of the driver. The system provides some consistent statistics, which help psychologists to assess the driver distraction patterns under influence of different in-vehicle information systems (IVISs). These statistics are objective, as the drivers are not required to report their own distraction states. The proposed gaze fixation system has been tested on a set of challenging driving experiments directed by a team of psychologists in a naturalistic driving simulator. This simulator mimics conditions present in real driving, including weather changes, manoeuvring, and distractions due to IVISs. Professional drivers participated in the tests. Several scenarios run in a truck driving simulator in order to test distraction induced by various contexts and evaluated using stereo camera. Data recording on face pose and eye fixation, registered incidents (crashes, near crashes and incidents) in the driving simulator, reaction time to events were collected. Several scenarios run in a truck driving simulator in order to test distraction induced by various contexts and evaluated using stereo camera. Reaction times and gaze focalisation behaviour patterns measured on a sample of professional drivers allow evaluating truck driver's distraction under a set of various situations.

Advantages: The system does not require any subject-specific calibration; it is robust to fast and wide head rotations and works under low-lighting conditions.
Disadvantages: The gaze fixation system has been tested in a driving simulator and not on real road conditions.
Outcomes: System evaluating distraction tested in a truck driving environment.
Comparison to ADAS&ME: System allowing evaluating truck drivers distraction.

Craye, C., & Karray, F. (2015). Driver distraction detection and recognition using RGB-D sensor. arXiv preprint arXiv:1502.00250. {keywords: Driver distraction, inattention recognition, computer vision, machine learning}.
Based on active sensor Kinect and computer vision tools, an efficient module for detecting driver distraction and recognizing the type of distraction has been developed. Based on colour and depth map data from the Kinect, our system is composed of four sub-modules. We call them eye behaviour (detecting gaze and blinking), arm position (is the right arm up, down, right of forward), head orientation, and facial expressions. Each module produces relevant information for assessing driver inattention. They are merged together later on using two different classification strategies: AdaBoost classifier and Hidden Markov Model. Evaluation is done using a driving simulator and 8 drivers of different gender, age and nationality for a total of more than 8 hours of recording. Development of a module to detect driver distraction based on active sensor Kinect and computer vision tools. Module includes: detection of gaze and blinking, detection of arm position (up, down, right of forward), detection of head orientation and facial expressions. Two modules were used, merged together using two different classification strategies: AdaBoost classifier and Hidden Markov Model. Evaluation aimed at driver's behaviour identification: data from arm position, face orientation, face expression and eye behaviour. Qualitative and quantitative results showed strong and accurate detection and recognition capacity (85% accuracy for the type of distraction and 90% for distraction detection).

Advantages: The system based upon Kinect sensor, computer vision and machine learning is suitable for context aware human-machine interaction.
Disadvantages: Tests have been conducted only on driving simulator and not on real road.
Outcomes: Qualitative and quantitative results showed accurate detection and recognition capacity (85% accuracy for the type of distraction and 90% for distraction detection).
Comparison to ADAS&ME: Each module developed to detect distraction is obtained independently and could be used for other types of inference, such as fatigue detection.

Gold, C., Berisha, I., & Bengler, K. (2015, September). Utilization of drivetime–performing non-driving related tasks while driving highly automated. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 59, No. 1, pp. 1666-1670). Sage CA: Los Angeles, CA: SAGE Publications.
The study investigated whether different tasks are impeding the drivers' capabilities of regarding control intake over situations. The tasks were chosen with different level of workload and high visual motoric engagement. A cognitive motoric task and laptop based fill in the blank text representing office work like writing emails were also included. The study took place on a driving simulator. The drivers were allowed to drive 45 minutes in a highly automated vehicle on the three lane highway and accomplishing 31 tasks in a permuted order. While performing the task 12 take-over positions were emerged and not every task came with take-over request. T-react time between TOR and first gaze directed away from the task. The T take-over is the time between TOR and conscious beginning of the manoeuvring. The take-over quality was measured by assessing minimum/ maximum longitudinal/lateral acceleration and minimum occurring time to collision (TTC). The driving simulator consists of full vehicle mock up BMW Series 6, equipped with different sensors for

monitoring driver behaviour and inputs, active steering wheel, seven projectors enabling a front view angle of about 180 degrees as well as mirrors and a freely programmable head up display. The workload and distraction was introduced using visual motoric SURT tasks and cognitive n-Back task. The impact of selected task on take-over performance was measured with 5 dependent variables. For visual distracting SURT and Text, the reaction time T react. For take over scenarios, T take over time. For measuring the quality of take-over, minimum and maximum, longitudinal and lateral acceleration (a long; a lat) and the minimum occurring time to collision (TTC) within each situation. The driving simulator consists of full vehicle mock up BMW Series 6, equipped with different sensors for monitoring driver behaviour and inputs, active steering wheel, seven projectors enabling a front view angle of about 180 degrees as well as mirrors and a freely programmable head up display. The workload and distraction was introduced using visual motoric SURT tasks and cognitive n-Back task. Mauchly-test on spherecity was used and Analysis of Variance (ANOVA) were used for the analysis react did not show any differences between SURT and TEXT in ny condition. Drivers reacted to the TOR on average after 535 ms. In situation left and right ,For depended variables ANOVA showed significant differences for the factor task (F(1.23)=10.106, p<0.001). Mean values and pairwise comparisons (Bonferroni) showed a significance (F(1,23)=5.196,p=.008) Subjective ratings scale, participants reported being highly motivated while engaging in the tasks (M=4.04,SD=0.95) and that of operation of those tasks awhile driving highly automated is rather dangerous (M=3.13,SD=1.19) impairing performance (M=3.29, SD=1.16) and capability of reaction (M=3.71;SD=1.12). On stressful take overs (M=2.23; SD=0.96).On how challenging the take-over (M=1.96; SD=0.92) on how demanding the tasks were (M=2.30; SD=1.13). The stressfulness of take-over showed significant differences between the tasks (F(1,23=9.777, p<0.001).

Advantages: The study provides a good understanding on how non driving tasks influence the driver behaviour during take over. The secondary tasks are quiet interesting and the method of evaluating the distraction is also very informative.

Disadvantages: The cluster sampling was from the university students. The results might vary for the real population.

Outcomes: The cognitive demanding tasks are impeding the take-over in cognitive demanding take-over situations and the influence of cognitive tasks is less easy in well-practiced take over conditions.

Comparison to ADAS&ME: The study investigated on method using cognitively demanding secondary tasks that influence the take-over performance during highly automated driving. This could useful to include highly demanding cognitive tasks in the ADAS experiments and investigate the performance of drivers' during such situations.

Lorenz, L., Kerschbaum, P., & Schumann, J. (2014, September). Designing take over scenarios for automated driving: How does augmented reality support the driver to get back into the loop?. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 58, No. 1, pp. 1681-1685). Sage CA: Los Angeles, CA: SAGE Publications.

The study investigated whether augmented reality information can positively influence the take-over process. Two different types of concept were evaluated AR red and AR green. The findings report that the type of augmented reality information does not influence the take-over times, but considerably affects reaction type. The participants were tested with a freeway with three lanes and they can switch on the automation with a button on steering wheel. The instrument cluster displayed the automation states ON and TAKE OVER REQUEST (TOR). The TOR was triggered as soon as the automation reached a system boundary such as an unknown obstacle or accident. The variables measured in this study includes gaze reaction, road fixation, hands on, Take over time, side mirror (time until the driver glances at the side mirror), Indicator (time until the driver uses the indicator). Data like steering angle, pedal positions, status of hands on detection as well as longitudinal and lateral accelerations were recorded with 10 ms cycle time. The gaze behaviour with 40 ms cycle time by the eye tracking system. he results showed that AR red caused the shortest average take over time of 2.86 seconds (SD=0.77 s).Take over time of AR green (M=2.91 s; SD=0.97 s) and control condition (M=3.03 s; SD=0.86 s) were longer. Kruskal- Wallis test revealed no significant difference (H(2)=7.6,p=.68). Drivers of both AR groups (AR red: M=3.09 s; SD=0.87 s;AR groups (AR red: M=3.09 s; SD=0.87 s;AR green (AR red: M=3.22 s; SD=0.54 s) looked at the side mirror later than the drivers of the control condition group. Regarding reaction type, chi square test '(x^2 (2)=13.20,p=0.1) showed a significant differences between the groups. Contrary to 56.3% of participants of AR red group steered and braked and 25% braked only. In AR green and control condition group 76.4% respectively and 66.6% of drivers' changes lanes without checking the corridor beside the car. The university of Leeds driving simulator was used. The vehicle cab for the simulator was based on Jaguar S- type Vehicle has driver controls within a 4 m diameter spherical projection dome. The road scenes encompass a horizontal field of view of 250 degree and three ear projectors display the scenes in the rear view and side mirrors. The simulator was equipped with eye tracker with camera mounted on the vehicle dashboard. The Lane keeping system (LKS) algorithm was developed by Sharp, Casanova and Symbols (2009), projecting a series of look- ahead points in front of the vehicle before calculating the error from the desired trajectory, weighted according to the proximity of look- ahead points. On activation of LKS, a small LCD panel with back lit displays ACC/LKS when the highly automated driving was active. Three dependent variables were evaluated, driver behaviour, driver fatigue and drivers secondary tasks. The metrics used for driver behaviour were lane keeping or speed choice (TETTC), driver drowsiness was assessed using PERCLOS and secondary tasks were assessed using PRC. TETTC- time exposed time to collision. PECLOS- Percentage eyes closed, PRC- percentage road centre.

Advantages: The study provides a good understanding on how the number and the maximum duration of off road glances seem to be suitable gaze parameters to assess and categorise the drivers monitoring behaviour in highly automated driving situation. The study also provides good understanding on the method that should be used to measure the gaze behaviour of visually distracted drivers.

Disadvantages: The findings reported here are based on the study conducted in the simulator. The complexity of the environment is minimal, increasing the complexity would have given better insights.

Outcomes: After a take-over request visually distracted drivers initially avert their gaze on secondary tasks to the road way and simultaneously establish motor readiness to intervene in the vehicle guidance. Drivers who distribute their visual attention appropriately between driving and the secondary task and regular monitoring the roadway should be able to acquire and maintain high situation awareness. Cognitive and not motor processes determine the take-over performance.

Comparison to ADAS&ME: The study investigated on method on how to use gaze behaviour as an indicator of driver readiness to take over control during automated driving. The study also showed that how specific gaze parameters are suitable to assess the adequacy of driver monitoring strategy. This could be useful in ADAS for investigating use case driver monitoring (driver distraction).

Mok, B., Johns, M., Lee, K. J., Miller, D., Sirkin, D., Ive, P., & Ju, W. (2015, September). Emergency, automation off: Unstructured transition timing for distracted drivers of automated vehicles. In Intelligent Transportation Systems (ITSC), 2015 IEEE 18th International Conference on (pp. 2458-2464). IEEE.

The study investigated driver monitoring capability from a highly distracted state. During this study the participants were allowed experience an highly automated driving using the simulator and the unstructured transition of control occurring in 2 seconds, 5 seconds or 8 seconds before participant encountered a road hazard. The study identified the minimum amount of time in which drivers can take over the control of vehicle safety and comfortably from the automated system in the advent of an impending road hazard. The study took place in a driving simulator. The drivers were tested on three experimental conditions where unstructured transitions of control occurred in 2 seconds, 5 seconds or 8 seconds. The occurrence of the unstructured transitions was indicated by an audible alert: Emergency, Automation Off. During the automated mode the participants were given passive distraction in the form of watching a video on iPad. The critical incident was encountered near to the climax of the video and participants were also prevented from pausing and scanning the through the video to see how they would naturally disengage with the task. The immersive simulator, the Stanford Driving Simulator composed of two parts: a Whole car and a visual display system. The first component is a Toyota Avalon interface for simulation. Both the steering wheel and pedals provide haptic feedback to drivers. The other component which surrounds the car is a 270 degree field of view screen. Utilizing five projectors, this 22- foot diameter cylindrical display together to create seamless simulated driving environment. Wide angle cameras GoPro cameras and microphones inside the Avlon's cabin. Drivers' emotional state captured using GoPros camera inside the cabin to provide additional video feed of the drivers face for automated emotion analysis. Emotion coding is performed using FACET algorithm (Attention tool software). Driving scenario is created using Internet Scene

Assembler Software. Sim creator is used to create simulation, providing the audio and video outputs. The driving performance measured by variation in road offset, steering wheel positions and post drive questionnaire.

Advantages: The study provides a good understanding on how the number and the maximum duration of off road glances seem to be suitable gaze parameters to assess and categorise the drivers monitoring behaviour in highly automated driving situation. The study also provides good understanding on the method that should be used to measure the gaze behaviour of visually distracted drivers.
Disadvantages: -
Outcomes: After a take-over request visually distracted drivers initially avert their gaze on secondary tasks to the road way and simultaneously establish motor readiness to intervene in the vehicle guidance. Drivers who distribute their visual attention appropriately between driving and the secondary task and regular monitoring the roadway should be able to acquire and maintain high situation awareness. Cognitive and not motor process determines the take-over performance.
Comparison to ADAS&ME: The study investigated on method on how to use gaze behaviour as an indicator of driver readiness to take over control during automated driving. The study also showed that how specific gaze parameters are suitable to assess the adequacy of driver monitoring strategy. This could be useful in ADAS for investigating use case driver monitoring (driver distraction).

Gonçalves, J., & Bengler, K. (2015). Driver state monitoring systems–Transferable knowledge manual driving to HAD. Procedia Manufacturing, 3, 3011-3016.

The main contribution of this paper is to provide an overview on DSM from a HAD point of view. The paper considers the following distraction categories: visual, auditory, mechanical, and mental; and fatigue metrics: eye based and behaviour based. Eye based metrics will remain an important DSMS. For distraction detection, monitoring of body posture and head rotation is a possible alternative. For fatigue detection, body posture or driver interaction (scratching face, covering mouth, rubbing eyes...) could be future metrics.
Reference metrics for distraction detection, obtained from eye-tracking: Glance pattern, mean glance duration and eyes-off-road duration (Visual); Pupil diameter, blink frequency (auditory), head direction (mechanical) and pupil diameter (cognitive). Metrics commonly used for detecting fatigue, obtained by eye-tracking systems: PERCLOS, EYEMEAS, MEANCLOS, AECS, Blink Frequency, Microsleep rate (Eye based). Image processing/cameras: Yawning, Nodding, Slouching, eyebrow rising (behaviour based). Eyes-Off-Road (EOF) measures to detect driver distraction: higher time indicates lower driver awareness. Areas of interest (AOI) allow measurement of glance's space and time dimensions (Glance Pattern): referring to a sequence of AOI fixated by the driver. Mean Glance Duration measures time spent on each AOI: used as an indicator of task engagement/distraction. Fatigue is often measured with eye-based-metrics: raw eyelid behaviour, blink frequency, gaze process. Behaviour-based fatigue measures are: postural adjustments, verbal exchange, ludic activities, self-centered.

Advantages: Advantages of reviewed monitoring systems: Eye metrics is valuable due to the ability to obtain relevant data associated with fatigue in a non-intrusive way, and has broad community acceptance. Behaviour based metrics is recognised as a promising source for detecting drowsiness - drivers' change behaviour to counter the fatigue progression.
Disadvantages: Disadvantages of reviewed monitoring systems: Eye-tracking drawbacks; data can be noisy. In blink based metrics a non-detected eye may be interpreted as an eyelid closure. Glasses' lens can hinder the pupil detection. Sunglasses or body postures not facing the camera nullify any eye-metric based system. Behaviour based metrics cannot be used alone, since behaviour activities are person dependent.
Outcomes: Eye based metrics will remain an important DSMS for fatigue detection. For distraction detection, monitoring body posture and head rotation is a possible alternative.
Comparison to ADAS&ME: Image processing/cameras for detecting body postures (fatigue detection) and eye tracking for monitoring fatigue and distraction. Behaviour based metrics is a promising information source for detecting drowsiness but should not be used alone, since these

activities are person dependent. Use generic algorithms for detecting driver behaviour.

Strayer, D. L., Turrill, J., Cooper, J. M., Coleman, J. R., Medeiros-Ward, N., & Biondi, F. (2015). Assessing cognitive distraction in the automobile. Human factors, 57(8), 1300-1324. {keywords: Cognitive workload, cognitive distraction, driving, EEG, visual scanning behaviour, divided attention, multitasking}

Establish a systematic framework for measuring and understanding cognitive distraction in the automobile, defining relationship between mental workload, cognitive distraction, and impaired driving. Across three studies, participants completed eight in-vehicle tasks commonly performed by the driver of an automobile. Primary, secondary, subjective, and physiological measures were collected and integrated into a cognitive distraction scale.

In-vehicle activities, such as listening to the radio or an audio book, were associated with a low level of cognitive workload; the conversation activities of talking to a passenger in the vehicle or conversing with a friend on a handheld or hands-free cell phone were associated with a moderate level of cognitive workload; and using a speech-to-text interfaced e-mail system involved a high level of cognitive workload. The following data were collected: Detection Response Task (DRT), Brake reaction time, following distance, glances at hazard locations, subjective workload rating (NASA-TLX), physiological measures (EEG). The cognitive distraction scale provides a comprehensive analysis of several of the cognitive sources of driver distraction. Evaluation of several in-vehicle tasks in context of laboratory control (experiment 1), driving simulator (experiment 2) and instrumented vehicle (experiment 3) with recording of several variables: reaction time, performance, physiological measures, glances. Setting up of a cognitive distraction scale, reflecting the standardized averages for each condition, equally weighting physical, secondary, subjective and physiological measures across the 3 experiments conducted in 3 different contexts.

Advantages: Provide a comprehensive analysis of several of the cognitive sources of driver distraction.

Disadvantages: Use the NASA-TLX (set up by the NASA for pilot context) rether than the DALI ("Driving Activity Load Index", which is the revised version of NASA-TLX to be adapted to the driving context) to evaluate the driver's workload.

Outcomes: Definition of a cognitive distraction scale.

Comparison to ADAS&ME: Framework to measure driver distraction associated with differentin-vehicle activities.

Wu, J., Chang, C. C., Boyle, L. N., & Jenness, J. (2015, September). Impact of In-vehicle Voice Control Systems on Driver Distraction: Insights from Contextual Interviews. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 59, No. 1, pp. 1583-1587). Sage CA: Los Angeles, CA: SAGE Publications.

Drivers use of voice interfaces within their own vehicles was explored using contextual interviews. The participants were asked to perform voice control tasks for communication, navigation, accessing information, and entertainment while driving. The interviews were video recorded and a researcher rode along and logged the responses and errors made during the voice interactions. Cognitive workload was assessed using the NASA TLX (Task Load Index). They held contextual interviews of drivers on planned route with 64 participants. Cognitive workload was measured by using the NASA TLX (Task Load Index), measuring the error performance in driving and conducting drivers interview. A visual interface was used. Errors made and cognitive workload has been analysed and showed variability according to the different voice tasks, indicating that varying levels of distraction can occur with voice interfaces.

Advantages: Voice communication with systems releases visual constraints and is preferred by the driver.

Disadvantages: High quality of voice communication is required in automotive context to avoid driver's workload.

Outcomes: Accuracy of speech interface can impact safety.

Comparison to ADAS&ME: Voice communication with systems is recommended but has to be robust with high quality.

Rashid, H., Omar, A. R., Jaafar, R., Abdullah, S. C., Ma'arof, M. I. N., Fauzi, W. M. S. W., & Ismail, M. A. M. (2015). Usage of Wireless Myon 320 Surface Electromyography (sEMG) System in Recording Motorcyclist Muscle Activities on Real Roads: A Case Study. Procedia Manufacturing, 3, 2566-2573.

This case study was conducted to determine signal transfer challenges and limitations that researchers tend to experience while using a wireless Myon 320 sEMG system during a real on-road motorcycle riding experiment. Eight muscle groups were evaluated bilaterally involving: upper trapezius (T), triceps brachii (TB), erector spinae (ES), latissimus dorsi (LD), extensor carpi radialis (ECR), sternocleidomastoid (S), gastrocnemius (G) and biceps formaris (BF) muscle groups. One healthy male volunteer participated in this case study riding a 135cc motorcycle which was followed and monitored by a group of researchers in a van. Inconsistent signals were recorded and signal connections were lost a few times. Inability of maintaining the same speed and distance between the motorcycle and the van due to road and traffic conditions were also dangerous for both parties. Suggestively, minimizing these inconsistencies shall give better sEMG data. However, any procedures and experimental setup to minimize these inconsistencies should be observed carefully for the safety of all parties and other road users. Performing wireless sEMGexperiment during real on-road motorcycle riding tend to cause inconsistent data to be recorded due to positioning issues between the motorcycle and the van(side by side positioning). By positioning the front of the van in series may minimize these inconsistencies but creates a dangerous maneuver for both parties. Meanwhile, real-time monitoring of the sEMGsignals transmitted should be practiced throughout the trial to detect any abnormalities, so that on-site remedies can be taken to sustain the data being recorded.However, the sEMG data recorded in this study does reflect the muscle activities characteristics of a motorcyclist during riding a motorcycle in spite of the inconsistencies. As a conclusion, this study provides an insight of what to expect during performing wireless sEMG experiments on real roads involving two moving vehicles. Finally, any procedures and experimental setups involved in such on-road experiment should be observed carefully for the safety of all parties and road users.

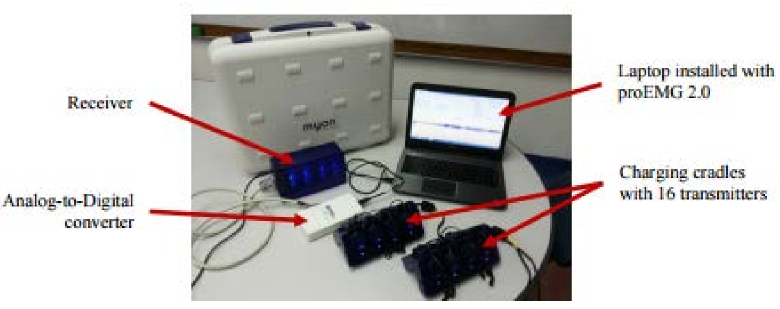

Fig. 1.Myon 320 surface electromyography (sEMG) system.

Figure 74: *Myon 320 surface electromyography (sEMG) system*

Advantages: Real-life and real-time sEMG measures and gathering of any related issues.
Disadvantages: Performing wireless sEMGexperiment during real on-road motorcycle riding tend to cause inconsistent data to be recorded due to positioning issues between the motorcycle and the van(side by side positioning)
Outcomes: As a conclusion, this study provides an insight of what to expect during performing wireless sEMG experiments on real roads involving two moving vehicles. Finally, any procedures and experimental setups involved in such on-road experiment should be observed carefully for the safety of all parties and road users.
Comparison to ADAS&ME: to monitor rider's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause).

Bucchianico, D. (2014). Advances in Human Aspects of Transportation. AHFE Conference.

Investigation of the effects of ADAS, specifically Lane Departure Warning (LDW), on driving performance while participants performed a secondary task (mental math) designed to simulate cognitive effort while driving. The experiment was conducted on a closed-course test track in an instrumented vehicle. Results suggest that cognitive engagement influenced driver control of the vehicle. Effects of cognitive engagement in a secondary task were not mitigated by the presence of LDW. Results were discussed in the framework of a continued need for active input and control from the human operator in vehicles with assistive technologies. Data collected were the following: recording CAN-Bus data from the vehicle: activation of ADAS, steering wheel angle, accelerator position, vehicle speed, engine RPM and brake activation. Video recording of the ground on side view mirror to record lane position and instances of lane departure and video recording of instrument cluster and view of the roadway, performance of secondary tasks did affect vehicle control, specifically variations in steering wheel angle and speed control. Results suggested that passive ADAS technologies such as LDW may not fully compensate for the effects of cognitive distractions on vehicle control. Effects of LDW would work as a reminder to maintain lateral control, rather than a more general reminder to attend to the vehicle's position.

Advantages: Test the capacity of ADAS such as LDW and ACC to potentially compensate loss of vehicle control linked to driver's distraction in real driving context; the results are not convincing but the approach is valuable.
Disadvantages: Patterns of results could have been different if the drivers had more time to gain familiarity and experience with ACC and LDW.
Outcomes: In real driving context but through a maybe too short appropriation experiment, ADAS technologies happened to be not successful in fully compensating impaired driving capacity linked to high cognitive workload.
Comparison to ADAS&ME: Importance of the phase of appropriation of ADAS technologies while running experiments to test the efficiency of these systems.

Othman, R., Zhang, Z., Akiduki, T., Suzuki, H., Imamura, T. and Miyake, T. (2014). Development of a driver inattention detection system using dynamic relational network. International Journal of Innovative Computing. Information, and Control., 10 (3), 1189-1205. {keywords: Driver inattention, dynamic relational network, sensor diagnosis, intentional driving}.
Development of a robust driver inattention detection system based on a driver model and dynamic relational network using sensor data such as the quantity of vehicle speed and pedal operation. The system is composed into 3 parts: the sensor diagnosis module, the driver model and the inattentive driving detection module. The sensor diagnosis module using the DRN allowed to analyse and to identify faulty sensors through its measurement data. This driver inattention detection system has been tested with actual data recorded on a highway and the system's diagnosis performance has been evaluated. A driver model and Dynamic relational network (DRN) using vehicle speed and pedal operation were applied. The evaluation methods were the following: recording synchronous data such as video, speech, driving control and physiological signals in real road context. Development of an inattentive driving detection system using a dynamic relational network (DRN) to improve driver model and to exclude faulty sensor's signal, avoiding then false alarm detection. Test of the robusteness of this system on real road context with a sample of drivers. Development of a robust driver inattention detection system in order to monitor the driver's state using driver model and dynamic relation network based upon sensor data such as the quantity of vehicle speed and the pedal operation.

Advantages: Test of a driver inattention detection system on real road.
Disadvantages: Small sample of tested drivers to be really able to test robustness of the detection system.
Outcomes: Test on real road for the driver inattention detection system showed a percentage of the confidence score of the system output very high, between 80 to 70%.
Comparison to ADAS&ME: Usefulness of a driver model to be included in a driver inattention detection system in addition to sensor diagnosis module to monitor driver's state in the car.

Naujoks, F., Mai, C., & Neukum, A. (2014). The effect of urgency of take-over requests during highly automated driving under distraction conditions. Advances in Human Aspects of Transportation, (Part I), 431.

The study investigated the effectiveness of visual and visual-auditory take-over requests during highly automated driving under distraction conditions. Take-over requests were presented in 3 difficulty level scenarios: easy, moderate and difficult; take over requests were presented either visually or visual-auditory; Participants were asked to perform a secondary task while driving. Time until driver takes hands back on the steering wheel are lower if visual-auditory take-over requests are used in comparison to purely visual ones purely visual take-over requests may not be sufficient to ensure safe transitions.

Advantages: -
Disadvantages: -
Outcomes: Time until driver takes hands back on the steering wheel are lower if visual-auditory take-over requests are used in comparison to purely visual ones purely visual take-over requests may not be sufficient to ensure safe transitions.
Comparison to ADAS&ME: visual-auditory warning modality seems to be beneficial for take-over requests.

Ranney, T. A., Baldwin, G. H., Smith, L. A., Mazzae, E. N., & Pierce, R. S. (2014). Detection Response Task (DRT) Evaluation for Driver Distraction Measurement Application (No. DOT HS 812 077).

Research conducted to support development of NHTSA's Driver Distraction Guidelines for auditory-vocal driver-vehicle interfaces. Experiment conducted in driving and non-driving test venues to evaluate the sensitivity of Detection Response Task (DRT) metrics to differences in attentional load. Three DRT variants were used: Head-mounted DRT (HDRT), Remote DRT (RDRT), and Tactile DRT (TDRT). Differences between test venues were more pronounced than differences between DRT variants. Response times were faster in the non-driving venue but differences between secondary task conditions were consistent across venues. In the driving simulator, TDRT was slightly more sensitive than other DRT variants. Based on testing in the driving simulator, both TDRT and HDRT detected all differences while RDRT performance was weaker. The TDRT had the highest level of test-retest reliability. Potential visual conflicts associated with RDRT and to a lesser extent with HDRT may create problems when used with visual-manual tasks. They measured Detection Response Task (DRT) with 3 variants: Head-mounted DRT (HDRT), Remote DRT (RDRT), and Tactile DRT (TDRT). Single experiment with 2 scenarios: driving and non-driving test venues, participants performing a secondary task to create distraction. To simulate the demands of tasks performed with auditory-vocal interfaces, the research used a delayed response task (n-back) in which participants listened to and repeated simple auditory stimuli (digits). The task allows mental workload to be systematically varied. The n-back has no visual or manual components and thus allows a direct assessment of the effects of different levels of attentional demand on DRT metrics. Participants responded as quickly as possible to each stimulus presentation via button press. In the driving simulator venue, participants performed DRT and secondary tasks while performing a simple car-following task in a low-fidelity fixed-base simulator. In the non-driving test venue, participants performed DRT and secondary tasks with no concurrent driving task, while sitting in the driver's seat of an identical vehicle. Overall, the TDRT was consistently more sensitive than other DRT variants, albeit marginally, in the driving simulator.

Advantages: Test of sensitivity of DRT variant metrics to evaluate driver's distraction to be used at an international level in the framework of the NHTSA Driver Distraction Guidelines
Disadvantages: Uncertainty about easiness in using these metrics in real road context.
Outcomes: Identification of DRT variants sensitive to driver's distraction.
Comparison to ADAS&ME: The variants of this metric DRT may be used in several Use Cases of the project.

Mbouna, R. O., Kong, S. G., & Chun, M. G. (2013). Visual analysis of eye state and head pose for driver alertness monitoring. IEEE transactions on intelligent transportation systems, 14(3), 1462-1469.

Visual analysis of eye state and head pose (HP) for continuous monitoring of alertness of a vehicle driver. The proposed scheme uses visual features such as eye index (EI), pupil activity (PA), and HP to extract critical information on non-alertness of a vehicle driver. EI determines if the eye is open, half closed, or closed from the ratio of pupil height and eye height. PA measures the rate of deviation of the pupil center from the eye center over a time period. HP finds the amount of the driver's head movements by counting the number of video segments that involve a large deviation of three Euler angles of HP, i.e., nodding, shaking, and tilting, from its normal driving position. Experimental results show that the proposed scheme offers high classification accuracy with acceptably low errors and false alarms for people of various ethnicity and gender in real road driving conditions. A σingle camera for continuous monitoring was used (detection of the face and the eyes using the AdaBoost algorithm (Viola–Jones algorithm). Metrics were visual features such as eye index (EI), pupil activity (PA), and head pose (HP). Real road experiments were conducted during the day to record video clips with drivers completing 3 driving session: alert, drowsy and distracted. Head pose (HP) provides useful information on the lack of attention, particularly when the driver's eyes are not visible due to occlusion caused by large head movements. A support vector machine (SVM) is useful to classify a sequence of video segments into alert or non-alert driving events.

Advantages: Method to evaluate level of driver's distraction and drowsiness with accuracy has been tested in real road driving context and for various morphologies linked to ethnicity belonging.
Disadvantages: Require additional tests due to the low number of participants in the experiment.
Outcomes: Use a single camera in addition to combination of information coming from driver's eye and head in order to achieve correct identification of distraction state.
Comparison to ADAS&ME: Convincing method applicable in real road driving context to evaluate driver's distraction state.

Tango, F., & Botta, M. (2013). Real-time detection system of driver distraction using machine learning. IEEE Transactions on Intelligent Transportation Systems, 14(2), 894-905. {keywords: Accident prevention, artificial intelligence and machine learning, driver distraction and inattention, intelligent supporting systems}.

Show a method for nonintrusive and real-time detection of visual distraction, using vehicle dynamics data and without using the eye-tracker data as inputs to classifiers. Different models based on machine learning (ML) methods are compared. Data for training the models were collected using a static driving simulator, with real human subjects performing a specific secondary task [i.e., a surrogate visual research task (SURT)] while driving. Different training methods, model characteristics, and feature selection criteria have been compared. Different models were used; based on machine learning (ML): support vector machines SVM, static and dynamic neural networks with feedforward FFN and layer-recurrent LRNN, and adaptive neuro-fuzzy inference systems, ANFIS. The evaluation was based on the following: eye position extracted from the video, number of correct answers at the secondary tasks in addition to reaction time, vehicle dynamic data: speed, time to collision, time to lane crossing, steering angle, lateral position, position of the accelerator pedal, position of the brake pedal. Experiment showed that SVM outperformed all the other classifiers. The main finding was the identification of the support vector machine SVM as the ML model outperforming all the other ML methods, providing the highest classification rate for most of the participants.

Advantages: Comparison of several ML models to detect driver's distraction.
Disadvantages: Experiment conducted in a static driving simulator context.
Outcomes: Usefulness of a ML model to detect driver's distraction without using eye-tracker data but rather nonintrusive and real-time vehicle dynamic data.
Comparison to ADAS&ME: This model SVM can be useful to define driver's distraction in the objective of design of adaptive PADAS.

Dong, Y., & Hu, Z. (2013). Driver Inattention Monitoring System intelligent vehicle (IV) driver inattention monitoring system for Intelligent Vehicles intelligent vehicle (IV). In Transportation Technologies for Sustainability (pp. 395-421). Springer New York.

This paper is a review of current state of the knowledge about driver inattention monitoring, with inattention classified into 2 categories: distraction and fatigue. As the causes of distraction and fatigue are different, the appropriate corresponding real time inattention monitoring systems are different. A complete literature review of driver inattention monitoring systems: methods, measures, models were conducted. Systems included were the following: Driver Inattention Monitoring System DIMS: Saab Driver Attention Warning System: 2 miniature Infra-Red cameras Toyota DIMS: 1 IR camera Mercedes Attention Assist, Volvo Driver Alert Control camera for the road and sensors of steering wheel movements Delphi Driver State Monitor Computer vision FaceLAB, SmartEye, and InSight. The main units were the following: Saab Driver Attention Warning System: SmartEye softwareToyota DIMS: detection of obstacle by Advanced Pre-crash Safety System and warning according to evaluation of Driver Monitoring System Mercedes AA: visual and auditory alert based upon the driver's profile and detection of fatigue Volvo DAC detects uncontrolled movements of the vehicle Delphi DSM: single camera and 2 IR sources to detect driver facial features (eye closure, head pose) FaceLAB: eyelid behaviour. As the goal of a driver's inattention monitoring system is to reduce driving risk, it is recommended to combine the 3 sources: driver physical variables, driving performance variables and information from IVIS.

Advantages: with a one-camera system are that it is cheaper, easier to operate and easier to install in a vehicle. A multi-camera system will, on the other hand, provide higher availability and accuracy for areas that are far from the road centre.
Disadvantages: Some measures such as evaluation of driver's workload cannot be conducted in real time.
Outcomes: Several systems available to evaluate in real time driver's distraction and driver's fatigue.
Comparison to ADAS&ME: To monitor driver's inattention, relevant and important to clearly distinguish inattention due to distraction (external cause) and inattention due to fatigue (internal cause).

Di Stasi, L. L., Contreras, D., Cándido, A., Cañas, J. J., & Catena, A. (2011). Behavioral and eye-movement measures to track improvements in driving skills of vulnerable road users: First-time motorcycle riders. Transportation research part F: traffic psychology and behaviour, 14(1), 26-35.

In this paper a method of estimating the mental workload (MWL) of a motorcycle rider was proposed, through the application of machine learning methods. The eye movement parameters of the motorcycle rider are measured under two run objectives, the one leads to a high MWL and the other one leads to a low MWL. The parameters are saccade duration, eye fixation (short stop), tracking frequency, saccade amplitude, and most frequency eye movement velocity. They are taken as explanatory variables for a discriminant function. By applying machine learning methods, we find that we can determine rider's MWL under preset running conditions with a high accuracy (>80%). Participants in this study were 16 healthy men who were experienced in motorcycle operation and qualified to serve as test riders. The experiment was carried out on a 5 km circuit at the Japan Cycle Sports Center. All participants wore an instrument-equipped helmet. This research aimed to propose a method for detecting increasing of rider MWL during motorcycle operation, we investigated the application of machine learning methods to detect increasing of MWL through the use of eye movement parameters measured under present run objectives set to provide different levels of rider MWL. As a result, discrimination functions were found through machine learning methods that allow us to detect increasing MWL with an accuracy of over 80%, under set experimental conditions.

Advantages: Interesting method for measuring workload in riders which is not very common.
Disadvantages: Not necessarily related to any of the affective states but rather to behaviour and skills observation.
Outcomes: Measurements of rider's mental workload through machine learning methods. Comparison to ADAS&ME: The method of measurements with the helmet (included in AD

Jain, J. J., & Busso, C. (2011, September). Assessment of driver’s distraction using perceptual evaluations, self-assessments and multimodal feature analysis. In 5th Biennial Workshop on DSP for In-Vehicle Systems, Kiel, Germany.

Developing feedback systems that can detect the attention level of the driver can play a key role in preventing accidents by alerting the driver about possible hazardous situations. Monitoring driver’s distraction is an important research problem, especially with new forms of technology that are made available to drivers, which can interfere with the primary driving task. An important question is how to define reference labels that can be used as ground truth to train machine learning algorithms to detect distracted drivers. The answer to this question is not simple since drivers are affected by visual, cognitive, auditory, psychological and physical distractions. This study explored and compared three different approaches to characterize driver’s distraction: perceptual evaluation from external evaluators, self-evaluations collected from post driving questionnaires, and analysis of the differences observed across multimodal features from normal patterns. Driver's interview (N=20 interviewees) about their level of self assessed distraction, assessment of distraction by external observers based upon video recordings, analysis of CAN-bus data of the vehicle eye glance behaviour from camera and acoustic information. 3 methods were applied: 1) self-assessments (aims to identify and rank-order distracted tasks as perceived by the drivers themselves), 2) subjective evaluation of localized recordings of the drivers by conducting perceptual evaluations by external raters, 3) identification of salient features across different modalities (CAN Bus signals, eye glance behaviour), and 4) acoustic signal, giving unbiased metrics to describe the deviation in behaviour’s observed when the driver is involved in the secondary tasks. Distraction induced by visual intensive tasks was well captured by the proposed metrics. However, these measurements do not seem to appropriately describe cognitive distractions.

Advantages: Analysis of 3 different approaches to characterise drivers' distraction in real road context allowing identification of their advantages and their limits.
Disadvantages: Measurements more appropriate for visual distraction rather than cognitive distraction.
Outcomes: Identification and description of relevant metrics to describe distracted drivers.
Comparison to ADAS&ME: Methodologies to assess driver's distraction are multiple: self-assessed, observation by experts, objective data from the vehicle. To be robust, it is possible to use the combination of the 3 of them.

Ahlstrom, C. and Dukic, T. (2010) Comparison of eye tracking systems with one and three cameras. In MB '10 Proceedings of the 7th International Conference on Methods and Techniques in Behavioral Research, Article no. 3, ACM, New York, NY, USA. {keywords: Eye tracker, availability, accuracy, precision, driver's distraction, performance evaluation, User/Machine systems}

Comparison of the performance of a one-camera system with a three-camera system and to investigate if the accuracy and availability of the one camera system is sufficient to monitor driver state. The results indicate that there is not much difference between a single-camera system and a multi-camera system as long as the driver is looking straight ahead. However, with more peripheral gaze directions, the larger coverage that is provided by the additional cameras works in favour of the multi-camera system. A driving simulator experiment was conducted in order to test and to compare availability, accuracy and precision of 2 systems: one-camera system Smart Eye anti-sleep and three-camera system Smart Eye Pro, both from Smart Eye AB with 53 participants (from 30 to 60 years old). Both accuracy and availability deteriorated with distance from the central gaze target, with a larger decrease for the one-camera eye tracking systems as compared to the three-cameras.

Advantages: Advantages with a one-camera system are that it is cheaper, easier to operate and easier to install in a vehicle. A multi-camera system will, on the other hand, provide higher availability and accuracy for areas that are far from the road centre.
Disadvantages: Experiment conducted in a static driving simulator context; so these systems need to be tested in real road context.
Outcomes: Better understanding of limits and advantages in terms of accuracy in using one-camera or three-camera eye tracking systems.

Comparison to ADAS&ME: Comparison of 2 systems that could be used in the project to evaluate driver's distraction state.

Toffetti, A., Wilschut, E., Martens, M., Schieben, A., Rambaldini, A., Merat, N., & Flemisch, F. (2009). CityMobil: Human factor issues regarding highly automated vehicles on eLane. Transportation Research Record: Journal of the Transportation Research Board, (2011), 1-8.

In dual mode vehicles, the reactions of drivers are observed in case of system errors or unexpected events, focusing on the transition of control and interface design. An experiment was conducted to compare the two eLane interfaces. (City Mobil project). The design of vocal versus and acoustic user interface was tested using an CRF driving simulator. The participants were asked to drive in the simulated scenario with different situations (automatic and manual overtaking, sudden lane changing). The scenarios included were 1) Manual driving and 2) Automated driving on eLane. The participants were also asked to perform secondary tasks on IVIS (in-Vehicle information system). The CRF driving simulator providing 45 degree vertical and 135 horizontal field of view with a steering wheel placed on a moving base with 6 degrees of freedom. The subjective questionnaire measures were used. Interface evaluation questionnaire and driving performance evaluation questionnaire.

Advantages: The study showed the method to investigate two different interfaces: Acoustic and Vocal and its effect of driving performance. AIDE- HMI questionnaire measures were used for the investigation.
Disadvantages: This paper highlights only a portion of City Mobil project and only the main results were reported in this study.
Outcomes: Driving in automatic mode with the vocal modality is considered safer than acoustic one. At the same time vocal modality can be bit annoying, but this can be solved with dedicated design that allows the deactivation to expert users. In case of automation system fault the vocal modality seems to be the better one because it shortens drivers' reaction time. The visual information for the acoustic modality is considered more necessary than for the vocal modality. The labels such as «automatic overtaking", "fault" are not problematic and requires a pre warning.
Comparison to ADAS&ME: An interface design with a mixed automatic-manual modality is recommended for situation like automated driving in case of medium and low traffic, straight and high velocity streets and manual driving for medium and high traffic in the urban context, overtaking and for mountain streets.

Hancock, P. A., Wulf, G., Thom, D., & Fassnacht, P. (1990). Driver workload during differing driving maneuvers. Accident Analysis & Prevention, 22(3), 281-290.

Motorcycle-automobile accidents occur predominantly when the car driver turns left across the motorcyclist's right-of-way. Efforts to decrease this specific collision configuration, through an increase in motorcycle conspicuity, have concentrated on the physical characteristics of the motorcycle and its rider. The work reported here examines the behaviour of car drivers during different driving sequences, in particular during left-turn maneuvers. An experiment is reported that used simultaneous video-taping of the driver and the forward-looking scene. Subjects followed a preset on-road course and were observed for head movements to determine the possibility of structural interference eye-blink frequency, probe-response time, and probe response error, as measures of cognitive or mental workload. In addition, the subjects completed two major subjective workload evaluations as reflections of effort directed to different components of the driving task. Results indicated that there were significant increases in head movements and mental workload during turn sequences compared to straight driving. This result of higher driver workload may be responsible for increasing the potential for detection failure. Such a propensity is also fostered by the higher structural interference that may be expected during turns. Failures to observe during turning sequences have differing outcomes depending on the presence of opposing traffic, as during the left turn, compared with the absence of such opposition, as occurs in the right turn. Also, the less conspicuous the oncoming vehicle in the left turn scenario, the higher the probability of detection failure. At the present time the least conspicuous powered vehicle is the motorcycle.

Advantages: Considers rider's cognitive load in risk-related scenarios.

Disadvantages: Low number of participants. The author assumes that the change in parameters measured is because of workload and there is a possibility that other factors are present (e.g. demanding scenario, positive role of increased load that can be translated as acute concentration).
Outcomes: Results indicated that there were significant increases in head movements and mental workload during turn sequences compared to straight driving.
Comparison to ADAS&ME: Consideration for Use Case scenarios. Includes both objective and subjective measures. Identification of relation between head movements and increase in workload.

Annex 1.5 Affective cluster: Physiological states

Balasubramanian, V., & Jagannath, M. (2014). Detecting motorcycle rider local physical fatigue and discomfort using surface electromyography and seat interface pressure. Transportation research part F: traffic psychology and behaviour, 22, 150-158.

Whilst motorcycling is an activity of pleasure in most parts of the world, in India it is a regular mode of commuting. Incidence of fatigue is substantially higher among motorcycle riders than drivers of other modes of transport. The objective of this study was to detect physical fatigue due to motorcycle riding for an hour using surface electromyography (sEMG) and seat interface pressure. Twenty healthy male participants performed 60 min of motorcycle riding in a low traffic density environment. Muscle activity was recorded bilaterally from extensor carpi radialis (ECR), biceps brachii (BB), trapezius medial (TM), sternocleldomastoid (S) latissimus dorsi (LD) and erector spinae (ES) muscle groups. Interface seat pressure distribution was monitored using a pressure mapping system. Results showed that participants have significant ($p < 0.05$) physical fatigue in TM, LD and ES muscle groups during 60 min of motorcycle riding. Seat pressure distribution was found to be non-uniform during the course of motorcycling. Results suggest that the impact on local physical fatigue and seat discomfort are probably due to static seating demand and prolonged sitting posture balance required to ride the motorcycle for an hour.
For the tests, every participant rides a moped for 60 minutes in low traffic environment. The authors find that the occurence of fatigue can be measured on postural muscle groups (erector spinae and latissimus dorsi medial). The present study also shows that while riding the motorcycle yields dominant pressure distribution with peak pressure at the ischium region.

Advantages: -
Disadvantages: It is not clear if it is possible to integrate sEMG in the jacket (they used a very "clinic" sensor). Not clear if it is really useful to have the seat pad.
Outcomes: The authors find that the occurence of fatigue can be measured on postural muscle groups.
Comparison to ADAS&ME: Maybe investigate if there are more efficient and integrateable sEMG sensors.

Zwolińska, M. (2013). Case Study of the Impact of Motorcycle Clothing on the Human Body and Its Thermal Insulation. Fibres & Textiles in Eastern Europe.

The interest in motorcycles is growing year by year. It should be noted that motorcyclists belong to the group of most vulnerable road users who suffer the most severe consequences of road traffic accidents. During an accident, the only protection for the body is motorcycle clothing. Nevertheless motorcycle clothing hinders heat exchange between the motorcyclist's body and the environment. Unfortunately the problem of motorcyclists' assessment of thermal comfort is addressed marginally. Therefore it was decided to measure the thermal insulation of motorcycle clothing and relate values obtained to the possibility of feeling thermal comfort under various weather conditions. Apart from that, a case study under real conditions was carried out with the participation of 2 police officers. The research confirmed the problem related to high values of thermal insulation of motorcycle clothing and transport of moisture from the skin surface. By decreasing the thermal insulation of motorcycle clothing, as well as by increasing the effectiveness of channeling humidity off the skin surface. Furthermore tests of the thermal insulation of motorcycle clothing show the necessity to modify the construction of that type of clothing. The findings confirm that in summer (despite removal of the lining) the users of motorcycle clothing will not feel thermal comfort, which, in turn, can adversely influence their psychomotor skills and, as a result, the safety of driving. Motorcycle clothing is used mainly in summer, hence its thermal insulation should be reduced (but not at the cost of protection against a fall or weather conditions). The test results of selected physiological parameters of police officers also prove that the problem exists. Data relating to the skin temperature or relative humidity in the space between the body and clothing demonstrate that motorcycle clothing can cause thermal stress. High humidity values show the need to improve vaporisation and heat exchange at practically every measuring point. From the relationships presented, it can be concluded that ensemble A turned out to be a better solution from the perspective of physiological parameters; however, differences between the ensembles examined can be a consequence not only of their construction, i.e. the membrane applied, but also of the actual (diversified/heterogeneous) weather conditions. To improve air circulation in motorcycle clothing, producers apply, e.g. improved ventilation systems in the form of air vents placed in the most essential parts of the garment. Thermal comfort can be enhanced by taking out a membrane or, alternatively, by using a membrane which maintains optimal air permeability (to transfer sweat from the body) with improved protective properties against external conditions. The reduction of temperature in the underwear space is achieved by applying linings with PCM (phase change material). In the case of leather clothing, an innovative leather finish is used which makes it possible to e.g. reflect sun rays off the jacket, thus preventing the overheating of clothing. Despite a number of techniques used to improve motorcyclists' comfort, they are often not sufficient therefore the search for new ways to reduce the thermal load should be pursued. In order to better explore the matter, extensive tests of physiological differences, in particular clothing ensembles (including leather clothes), are planned in the near future. The tests, with a larger number of volunteers, will be repeated in summer, when ambient temperatures are higher.

Advantages: Investigation of the effect of clothing gear to increase of rider's temperature.
Disadvantages: A case study, no generalisability.
Outcomes: The research confirmed the problem related to high values of thermal insulation of motorcycle clothing and transport of moisture from the skin surface. by decreasing the thermal insulation of motorcycle clothing, as well as by increasing the effectiveness of channeling humidity off the skin surface.
Comparison to ADAS&ME: Thermal comfort can be enhanced by taking out a membrane or, alternatively, by using a membrane which maintains optimal air permeability (to transfer sweat from the body) with improved protective properties against external conditions.

Bogdan, A., Sudoł-Szopińska, I., Łuczak, A., Konarska, M., & Pietrowski, P. (2012). Methods of estimating the effect of integral motorcycle helmets on physiological and psychological performance. International journal of occupational safety and ergonomics, 18(3), 329-342.

This article proposes a method for a comprehensive assessment of the effect of integral motorcycle helmets on physiological and cognitive responses of motorcyclists. To verify the reliability of commonly used tests, we conducted experiments with 5 motorcyclists. We recorded changes in physiological parameters (heart rate, local skin temperature, core temperature, air temperature, relative humidity in the space between the helmet and the surface of the head, and the concentration of O2 and CO2 under the helmet) and in psychological parameters (motorcyclists' reflexes, fatigue, perceptiveness and mood). We also studied changes in the motorcyclists' subjective sensation of thermal comfort. The results made it possible to identify reliable parameters for assessing the effect of integral helmets on performance, i.e., physiological factors (head skin temperature, internal temperature and concentration of O2 and CO2 under the helmet) and on psychomotor factors (reaction time, attention and vigilance, work performance, concentration and a subjective feeling of mood and fatigue).

Technologies used include: an FT 2000 cardiometer for measuring heart rate (HR), local skin temperature and core temperature (Emtel, Poland); a Hygrolab thermometer and hygrometer to measure temperature and relative humidity (RH) in the space between the skin and the clothing or the helmet (Rotronic, Switzerland) and a MCZR/ATB 1.0 meter of choice reaction time (ATB Info-Elektro, Poland). Testing (5 participants) was made in climate chamber in 4 scenarios: V1—in a motorcycle uniform without a helmet, in thermoneutral conditions, i.e., temperature 20 °C, air velocity

0.2 m/s, RH 50%; V2—in a motorcycle uniform without a jacket or a helmet; temperature 30 °C, airvelocity 2.0 m/s, RH 45%; levels of heat and noise (88 dB) corresponding to those of an urban agglomeration; V3—in a motorcycle uniform with a helmet, in thermoneutral conditions, i.e., temperature 20 °C, air velocity 0.2 m/s, RH 50%; V4—in a motorcycle uniform with a helmet, without a jacket; temperature 30 °C, air velocity 2.0 m/s, RH 45%; levels of heat and noise (88 dB) corresponding to those of an urban agglomeration.
Measurements of mean skin temperature revealed that this was a reliable indicator for evaluating the effect of an integral helmet on a motorcyclist's physiological parameters. Temperature inside the helmet, to be significant, has to be measured with great precision.

Advantages: -
Disadvantages: reflexes and fatigue were measured using psychological test and not using physiological measures ~~--> can't be used.~~
Outcomes: -
Comparison to ADAS&ME: What about measuring CO_2 and O_2 concentrations in the helmet to understand the rider's conditions?

Di Stasi, L. L., Contreras, D., Cándido, A., Cañas, J. J., & Catena, A. (2011). Behavioral and eye-movement measures to track improvements in driving skills of vulnerable road users: First-time motorcycle riders. Transportation research part F: traffic psychology and behaviour, 14(1), 26-35.
Motorcyclist deaths and injuries follow the trend in sales rather than in growth in the number of motorcycles, suggesting that fatalities are related to the lack of driver experience with recently purchased motorcycles. The aim of the present investigation was to assess the effects of experience and training in hazard perception. We compared first-time riders (people who are not yet riders/drivers) before and after training in six different riding scenarios to expert motorcycle riders. Thirty-three participants took part in the experiment. Volunteers rode a moped in a fixed-base virtual environment and were presented with a number of preset risky events. We used a multidimensional methodology, including behavioural, subjective and eye-movements data. The results revealed differences between experts and first-time riders, as well as the effect of training on the novice group. As expected, training led to an improvement in the riding skills of first-time riders, reducing the number of accidents, improving their capacity to adapt their speed to the situation, reducing trajectory-corrective movements, and changing their pattern of gaze exploration.
We identified several behavioural and eye-related measures that are sensitive to both long-term experience and training in motorcycle riders. These findings will be useful for the design of on-line monitoring systems to evaluate changes in risk behaviour and of programs for preventing and controlling risk behaviour and improving situation awareness for novice riders, with the ultimate aim of reducing road-user mortality.
The multidimensional methodology used here provides useful information on the factors involved in risk behaviour. We identified several behavioural and eye-related measures that are sensitive to both long-term experience and short-term training in motorcycle riders. These findings could be a starting point for educational training programs. They could also be useful in the design of on-line monitoring systems to evaluate changes in risk behaviour and for the design of risk prevention programs.

Disadvantages: Results based only one driver; reliability is not sufficient.
Outcomes: Association of fatigue states with driving performance.
Comparison to ADAS&ME: Classification of states based on extracted features is extremely relevant to the FER that the project has uptake. The approach is validated and thus within the project we may replicate or replicate parts of it.

Airaksinen, M., Tuomaala, P., & Holopainen, R. (2007). Modeling human thermal comfort. In Proceedings of Clima (Vol. 2007, pp. 10-4).
Thermal comfort standards determine indoor conditions in buildings as well as the energy consumption for heating and cooling purposes. Existing thermal comfort standards are based on steadystate thermal conditions, and according to recent research these standards can not describe

thermal comfort accurately enough with transient boundary conditions. In this paper, a method based on Hui (2003) is presented to calculate local and overall human body thermal sensations in time dependent and nonuniform. In addition, local and overall thermal comfort predictions can be performed based on these thermal sensation values.
The researchers determined comfort temperatures for every part of the body.

Advantages: Use of existing thermal comfort standards.
Disadvantages: -
Outcomes: The researchers determined comfort temperatures for every part of the body.
Comparison to ADAS&ME: To know the comfort temperatures for every body region, linked with overall comfort sensation, could be very useful for UC E (ground truth definition).

Woods, R. I. (1983). Cooling of motorcyclists in various clothing during winter in Britain. Ergonomics, 26(9), 847-861.

Skin and ear-canal temperatures of seven volunteer motorcyclists have been measured during control periods and during rides of up to 161 km at air temperatures below 10°C. 54 km urban road + 40 km motorway path .While wearing their own clothing in air temperatures between 2.6 and 10-C the riders showed changes in heat storage of -438 to - 1611 Wm-'. The average of the three lowest temperatures ("C) recorded from selected sites from different subjects (and the means of the laboratory control values from all seven subjects* standard errors) were: foot, 14.7 (306f 0.93); shin, 21.4 (32.2+ 040); thigh, 17.8 (3 1.8 + 036); abdomen and chest, 25.3 (34.7 + 0.26); forearm, 288 (33.8k0.19; hand, 15.5 (308k 0.58); ear canal, 36.1 (37.2k0.7). The rate at which riders' feet cooled was not closely related to the rates their bodies cooled.
Even when there was no body cooling, their feet cooled by at least 3OC hour-', while riding. The thickness of motorcycle clothing and its wind-proofing are both important in preventing cooling. Zip fasteners need special protection beyond that needed merely to keep out rain.

Advantages: -
Disadvantages: -
Outcomes: The rate at which riders' feet cooled was not closely related to the rates their bodies cooled.
Comparison to ADAS&ME: The model to calculate skin and body temperature is interesting and could be used in UC E.

Parry, M. (1982). Skin temperature and motorcyclists' braking performance. Perceptual and motor skills, 54(3_suppl), 1291-1296.

15 male and 12 female students who had previous experience with hand-operated lever-braking systems performed braking tests with their hands at normal temperatures (mean hand temperatures 273°C) and with their hands cooled to give finger temperatures of 6°C and back of hand temperatures of 14°C. Tasks required subjects, in response to a visual stimulus of a red light, to extend their digits to grip a motorcycle brake and pull it on. Reduced times were measured for (a) responding to the stimulus by grabbing the brake lever and pulling it to full braking pressure in the hydraulic system, (b) extending the digits, and (c) flexing the digits and pulling on the brake. In each case conditions produced a significant decrement in performance. This effect may occur when riding a motorbike with cold hands, a common occurrence in Northern Europe. Cold weather affected signficantly braking time.

Advantages: Measure how cold weather affects braking
Disadvantages: Very old technologies and measures
Outcomes: In each case conditions produced a significant decrement in performance.
Comparison to ADAS&ME: Could be feasible for ADSA&ME to measure hands temperatures to give a feedback in UC E.

Annex 2. Automation strategies for motorcycles

Savino, G., Pierini, M., Thompson, J., Fitzharris, M., & Lenné, M. G. (2016). Exploratory field trial of motorcycle autonomous emergency braking (MAEB): considerations on the acceptability of unexpected automatic decelerations. Traffic injury prevention, 17(8), 855-862.

Objective. Autonomous emergency braking (AEB) acts to slow down a vehicle when an unavoidable impending collision is detected. In addition to documented benefits when applied to passenger cars, AEB has also shown potential when applied to motorcycles (MAEB). However, the feasibility of MAEB as practically applied to motorcycles in the real world is not well understood. Methods. In this study we performed a field trial involving 16 riders on a test motorcycle subjected to automatic decelerations, thus simulating MAEB activation. The tests were conducted along a rectilinear path at nominal speed of 40 km/h and with mean deceleration of 0.15 g (15% of full braking) deployed at random times. Riders were also exposed to one final undeclared brake activation with the aim of providing genuinely unexpected automatic braking events. Results. Participants were consistently able to manage automatic decelerations of the vehicle with minor to moderate effort. Results of undeclared activations were consistent with those of standard runs. Conclusions. This study demonstrated the feasibility of a moderate automatic deceleration in a scenario of motorcycle travelling in a straight path, supporting the notion that the application of AEB on motorcycles is practicable. Furthermore, the proposed field trial can be used as a reference for future regulation or consumer tests in order to address safety and acceptability of unexpected automatic decelerations on a motorcycle. The tests were conducted along a rectilinear path (not on public roads) with 16 participants. Riders can react well to unexpected 0.15g decelerations, with minor to moderate effort.

Advantages:-
Disadvantages: The scenario is very limited.
Outcomes: The outcome is important, this is a first very limited test, but results show that reaction to unexpected decelerations is good. This a is a good starting point for other experiments and to develop automated features, like autonomous emergency braking.
Comparison to ADAS&ME: The information about the reaction to unexpected decelerations is good for the implementation of the recovery mode. The deceleration was obtained simply turning off the engine, while we can think of more sophisticated controls ~~(acting on the engine management system?)~~

Konanur, P. (2005). Application of Genetic Algorithms to a Multi-Agent Autonomous Pilot for Motorcycles (Doctoral dissertation, Indiana University South Bend).

The Physics behind motorcycle driving are well understood and implemented by studying the laws of kinetics and kinematics behind the operation of the single track motor vehicle.

In this thesis I worked with an application which is currently using OpenGL and implements an interactive motorcycle simulator which is based on the laws of physics. This application involves a multi-agent pilot capable of autonomously driving the vehicle using some configurable equations.

I have applied genetic algorithms to find suitable values for the parameters of the pilot by testing it in a non graphical environment, and I visually verified the results of the genetic algorithms with the graphical interface application. The performance of the pilot derived by the genetic algorithms is also compared with the manually configured pilot. ~~Application of GA on simulation software (that simulates the behaviour of a rider).~~

Advantages:-
Disadvantages: -
Outcomes: No significant outcome.
Comparison to ADAS&ME: No interest for ADAS&ME. The paper deals with algorithms to implement in an autonomous robot rider (the author has only made simulations on computer).

Savino, G., Giovannini, F., Baldanzini, N., Pierini, M., & Rizzi, M. (2013). Assessing the potential benefits of the motorcycle autonomous emergency braking using detailed crash reconstructions. Traffic injury prevention, 14(sup1), S40-S49.

The aim of this study was to assess the feasibility and quantitative potential benefits of a motorcycle autonomous emergency braking (MAEB) system in fatal rear-end crashes. A further aim was to identify possible criticalities of this safety system in the field of powered 2-wheelers (PTWs; e.g., any additional risk introduced by the system itself).

Advantages:-
Disadvantages: -
Outcomes: -
Comparison to ADAS&ME: No direct advantage for us. It can only be cited as investigation of an autonomous function.

Savino, G., Giovannini, F., Piantini, S., Baldanzini, N., & Pierini, M. (2015). Autonomous emergency braking for cornering motorcycle. In Proceedings of Conference Enhanced Safety of Vehicles (ESV).

Autonomous emergency braking (AEB) has been indicated as a potential safety application not just for passenger cars and heavy goods vehicles, but also for motorcycles and powered two-wheelers (PTWs) at large. Motorcycle AEB (MAEB) was designed to produce autonomous deceleration of a host PTW in case of inevitable collision. Previous studies limited MAEB to the case of a PTW travelling along a straight, as the activation of AEB was considered hazardous for a leaning vehicle. This study aims to extend the applicability of MAEB to cornering scenarios. From the InSAFE database, three suitable PTW-to-car crash cases were identified and reconstructed via numerical simulations. For each case, a baseline simulation was tuned in order to reflect the kinematics and the collision configuration identified by the original InSAFE crash reconstruction. Then, for each crash case two additional simulations were performed, assuming that MAEB and MAEB+ respectively were active on the PTW at the time of the crash. Finally, the baseline results and the results obtained with MAEB and MAEB+ were compared to analyse the possible effects of these crash mitigation systems. ~~Only simulation, based on braking (while we modify torque --> act on EMS) cornering deceleration increase overall deceleration. Riders seem to accept better non invasive systems, but with increased usability. Warning on lack of confidence of the rider in cornering braking or panic reaction if the deceleration is too big.~~

Advantages:-
Disadvantages: -
Outcomes: Results are good but very limited (only computer simulation). Need for further and deeper investigations.
Comparison to ADAS&ME: Only simulation,AEB based only on braking ~~(while we modify torque --> act on EMS, more sophisticated control).~~

Savino, G., Rizzi, M., Brown, J., Piantini, S., Meredith, L., Albanese, B., & Fitzharris, M. (2014). Further development of motorcycle autonomous emergency braking (MAEB), what can in-depth studies tell us? A multinational study. Traffic injury prevention, 15(sup1), S165-S172.

In 2006, Motorcycle Autonomous Emergency Braking (MAEB) was developed by a European Consortium (Powered Two Wheeler Integrated Safety, PISa) as a crash severity countermeasure for riders. This system can detect an obstacle through sensors in the front of the motorcycle and brakes automatically to achieve a 0.3 g deceleration if the collision is inevitable and the rider does not react. However, if the rider does brake, full braking force is applied automatically. Previous research into the potential benefits ofMAEB has shown encouraging results. However, this was based onMAEB triggering algorithms designed for motorcycle crashes involving impacts with fixed objects and rear-end crashes. To estimate the full potential benefit of MAEB, there is a need to understand the full spectrum of motorcycle crashes and further develop triggering algorithms that apply to a wider spectrum of crash scenarios.

Advantages:-
Disadvantages: -
Outcomes: -
Comparison to ADAS&ME: Not relevant, dealing only with potential impact of autonomous Emergency Braking.

Savino, G., Pierini, M., Rizzi, M., Frampton, R., & Thompson, J. (2013). Can Experienced Riders Benefit from an Autonomous Emergency Braking System?. In International Motorcycle Safety Conference.

Powered two wheelers (PTWs) are becoming increasingly popular in Europe but the risk of rider injury in a traffic crash far exceeds that for car occupants. The European Powered Two wheeler Integrated Safety project (PISa), identified autonomous emergency braking (MAEB) as a priority area for reducing the injury consequences of PTW crashes. This study assessed the potential effectiveness of the PISa MAEB system, specifically in relation to its potential benefit for experienced riders .

A sample of fifty-eight in-depth PTW crashes representing typical European crash scenarios were examined, of which half involved a rider with MAIS 2+ injury. An expert team analysed the data to determine the extent to which the MAEB would have affected the crash. In 39 cases (67% of the sample) the MAEB showed high potential to mitigate the crash outcome.

Results indicated that, not only does the MAEB have potential to help novice riders but could also considerably improve safety for more experienced riders. The results shown here could encourage further development and acceptance of such systems.

Advantages:-
Disadvantages: -
Outcomes: -
Comparison to ADAS&ME: No direct advantage for us. It can only be cited as investigation of an autonomous function.

Sharp, R. S. (2007). Motorcycle steering control by road preview. Journal of dynamic systems, measurement, and control, 129(4), 373-381.

The main objectives of the work described are to devise an effective path-based motorcycle simulation capability and to add to understanding of how riders control motorcycles. Optimal linear preview control theory was previously applied to the tracking of a roadway by a car, using a simple car model operating in fixed control. Similar theory is applied to path control of motorcycles. The simple car previously employed is replaced by a much more elaborate motorcycle. The steering angle control used previously is changed into steering torque control. Rider upper body lean torque is also allowed as a control input. The machine speed is considered constant but is a parameter of the motion. The objective of the optimal control is to minimize a weighted sum of tracking errors, rider lean angle and control power. The time-invariant optimal control corresponding to a white noise disturbance and to an infinite optimization horizon is found for many situations, involving variations in machine speed and performance priorities. Tight controls, corresponding to high weightings on performance, and loose controls, corresponding to high weightings on control power, are identified. Results show the expected pattern for preview control, that information well into the future is of limited value in determining the present control inputs. Full system performance is achievable with only finite preview. The extent of the preview necessary for full performance is determined as a function of machine speed and performance priorities. This necessary preview is found to be in accord with conventional wisdom of motorcycle riding and rider training. Optimal path tracking preview controls are shown to represent the inverse dynamics of the motorcycle. New light is shed on the relative effectiveness of steering torque and body lean torque controls. Simulations of an optimally controlled motorcycle and rider combination are conducted. A typical lane change path and an S-shaped path from the literature are used. For a chosen speed, optimal controls are installed on the machine for which they were derived and simulation results showing tracking performance, control inputs, and other responses are included. Transformation of the problem from a global description, in which the optimal control is found, to a local description corresponding to the rider's view, is described. It is concluded that a motorcycle rider model representing a useful combination of steering control capability and computational economy has been established. The model yields new insights into rider and motorcycle behaviour. The work consisted of numerical simulation starting from a theoretical model. ~~The rider has two ways to control motorcycle directions (3 with the throttle control):~~
~~- modify the steer angle~~
~~- modify his lean angle (moving from the original position on the seat).~~
~~Steer torque and lean torque both applied on the steer~~

One of the results is that the steering torque effect on the vehicle dynamics and trajectories is bigger than leaning torque effect.

Advantages:-
Disadvantages: -
Outcomes: -
Comparison to ADAS&ME: The result about steer and lean angle control should be taken into account.

Levandowski, A., Schultz, A., Smart, C., Krasnov, A., Song, D., Lee, H., ... & Wang, F. (2010). Autonomous Motorcycle Platform and Navigation–Blue Team DARPA Grand Challenge 2005. Blue Team Autonomous Motorcycle Platform-DARPA. DARPA. Web, 1.

UC Berkley developed in 2004 and 2005 a autonomouse driving motorcycle called "Ghostrider". It was sponsored by DARPA. In January 2003, the Pentagon challenged engineers, students and hobbyists to create by the following year an off-road vehicle that can find its own way across up to 200 miles of rocky desert. Berkeley's Blue Team took the challenge one step further: How do you make a motorcycle that drives itself? The technologies used include: an IMU to determine motorcycle attitude, cameras and GPS to explore surrounding areas and mechanical arms to right the bike after a fall. Stability is performed by an embedded PC with an AMD Geode NX1500 1GHz Processor. Vision processing and navigation is performed on a Supermicro SuperServer with two AMD Opteron Dual Core 2.2GHz processors. Researchers used a simple PID control that worked well. ~~Methods: virtual simulation, design, lab testing, open air testing Scenarios: unmanned all terrain bikes for defenze applications~~. Bike dynamics was controlled using steering angle and engine torque as input variables.

Advantages: Tele-operated vehicle (sort of drone for military missions).
Disadvantages: No stabilization at very slow speeds (null speed).
Outcomes: It is difficult to understand the outcome of a military oriented application. ~~Please give also a look at the links in the "Other" folder.~~
Comparison to ADAS&ME: It concentrates on the navigation system (navigation and controls), but not on the stabilization (CMG), they control steering (which can be very critical on a motorcycle).They don't use momentum control to directionate the bike. It can be useful to understand the control strategy.To right the vehicle after a fall they use 2 mechanical arms.

Yi, J., Song, D., Levandowski, A., & Jayasuriya, S. (2006, May). Trajectory tracking and balance stabilization control of autonomous motorcycles. In Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on (pp. 2583-2589). IEEE.

In this paper, we present a trajectory tracking control algorithm for an autonomous motorcycle for the DARPA Grand Challenge. The mathematical dynamic model of the autonomous motorcycle is based on the existing work in modeling a bicycle and is extended to capture the steering effect on self-stabilization. The trajectory tracking control is designed using an external/internal model decomposition approach, and the motorcycle balancing is developed by the nonlinear control methods. The motorcycle balancing is guaranteed by the system internal equilibria calculation and by the trajectory and system dynamics requirements. The motion planning algorithms are based on the fused global positioning systems (GPS) and on-board computer vision systems information. The proposed control system is validated by numerical simulations, which are based on a real prototype motorcycle system.
Stabilization (also at null speeds) is performed only with steering, while the decision of the optimal trajectory is made fusing info coming from a camera and GPS. ~~, and~~ Bike dynamics is controlled using steering angle and engine torque as input variables.

Advantages: ~~Stabilisation at v=0 using steering is probably not appliable on manned and heavy motorcycles.~~
Disadvantages: Stabilisation at v=0 using steering is probably not appliable on manned and heavy motorcycles.
~~Please give also a look at the links in the "Other" folder.~~
Outcomes: It is difficult to understand the outcome of a military oriented application. ~~Please give also a look at the links in the "Other" folder.~~

Comparison to ADAS&ME: Not interesting for ADAS&ME:
- keep the bike stable at v=0 moving the steer is likely not appliable for manned motorcycles
-To take into consideration dynamic model, if we'll need it for our applications.

Yi, J., Zhang, Y., & Song, D. (2009, December). Autonomous motorcycles for agile maneuvers, part i: Dynamic modeling. In Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009. Proceedings of the 48th IEEE Conference on (pp. 4613-4618). IEEE.

The researchers have developed a dynamic model for a two-wheeler, also taking into account slide. The result is a theoretical dynamic model, taking into account also slide.

Advantages: -
Disadvantages: Limited, because for autonomous applications it considers only turning by steering and not by leaning.
Outcomes: A little indirect validation is made in the following document.
Comparison to ADAS&ME: To take into consideration dynamic model, if we'll need it for our applications (it is an update wrt to the one in the previous document)**.**

Yi, J., Zhang, Y., & Song, D. (2009, December). Autonomous motorcycles for agile maneuvers, part i: Dynamic modeling. In Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009. Proceedings of the 48th IEEE Conference on (pp. 4613-4618). IEEE.

In this paper, we present trajectory tracking and balancing of autonomous motorcycles for agile maneuvers. Based on the newly developed autonomous motorcycle dynamics in the companion paper, we present a nonlinear control design. The control systems design is based on the external/internal convertible (EIC) dynamical structure of the motorcycle dynamics. The control design of the EIC systems guarantees an exponential convergence of the motorcycle trajectory to a neighborhood of the desired profiles while the roll motion converges to a neighborhood of the desired equilibria that are estimated under a given desired trajectory. The effectiveness of the integrated control systems are demonstrated and validated by two numerical examples based on a racing motorcycle prototype. A theoretical derivation of a motorcycle control model was created where bike dynamics is controlled using steering angle and engine torque as input variables.

Advantages: -
Disadvantages: This is a dynamic model (not considering what happens at v=0).
Outcomes: The control model was not implemented on a real system. To verify it they compared the model derived trajectory with the one performed by a real motorcycle (2 examples performed) .
Comparison to ADAS&ME: To take into consideration the control model, if we'll need it for our applications.

Zhang, Y., Li, J., Yi, J., & Song, D. (2011, May). Balance control and analysis of stationary riderless motorcycles. In Robotics and Automation (ICRA), 2011 IEEE International Conference on (pp. 3018-3023). IEEE.

We present balancing control analysis of a stationary riderless motorcycle. We first present the motorcycle dynamics with an accurate steering mechanism model with consideration of lateral movement of the tire/ground contact point. A nonlinear balance controller is then designed. We estimate the domain of attraction (DOA) of motorcycle dynamics under which the stationary motorcycle can be stabilized by steering. For a typical motorcycle/bicycle configuration, we find that the DOA is relatively small and thus balancing control by only steering at stationary is challenging. The balance control and DOA estimation schemes are validated by experiments conducted on the Rutgers autonomous motorcycle. The attitudes of the motorcycle platform are obtained by a novel estimation scheme that fuses measurements from global positioning systems (GPS) and inertial measurement units (IMU). We also present the experiments of the GPS/IMU-based attitude estimation scheme in the paper.
Stabilization (also at null speeds) is performed only with steering and bike dynamics is controlled using steering angle and engine torque as input variables.

Advantages: -

Disadvantages: Stabilisation at v=0 using steering is probably not appliable on manned and heavy motorcycles.
Outcomes: -
Comparison to ADAS&ME: Not interesting for ADAS&ME since we already have a good dynamic estimation system. Furthermore keeping the bike stable at v=0 moving the steer is potentially critic for motorbikes
This paper uses the same dynamic model of the previous document

Nenner, U., Linker, R., & Gutman, P. O. (2010). Robust feedback stabilization of an unmanned motorcycle. Control Engineering Practice, 18(8), 970-978.

This paper details the design and implementation of a robust controller that stabilizes an unmanned motorcycle. A linearized model and Quantitative Feedback Theory (QFT) are used to derive a low order cascaded controller that stabilizes the motorcycle for velocities ranging from 2.5 to 6.5 [m/s]. Stabilization is achieved by measuring the roll angle and roll rate and controlling the steering torque. The approach is validated through simulations and experiments with a 50cc scooter whose throttle, brakes, and reference roll angle are radio-controlled.

Technologies used include: 1 inclinometer, 1 vibrating ring gyro, and 1 24V DC motor to control the steer, microcontroller (PIC18 series) programmed in C, and electro-actuatedmechanical steering mechanism.

The output is just one simple test (little tour on aspahalt at very low speed, including small slopes) and the control system works in the only test performed.

Advantages: -
Disadvantages: Limited to a short range of speeds (from 9 to 23.4 km/h). It considers a scooter which is easier to stabilize (lighter and with lower center of mass)~~+T13~~.
Outcomes: The control was implemented on the real system and worked, but there was only one test case.
Comparison to ADAS&ME: In this paper ~~and other papers~~ it is remarked that between curving using only steering and curvng using only leaning, the first is better, but steer control can be critical (also from a functional safety point of view). From a technical point of view it is easier to stabilise a scooter rather than a motorcycle (lower weight and center of mass cloder to the ground).

Shafiekhani, A., Mahjoob, M. J., & Roozegar, M. Adaptive Neuro-Fuzzy control of an unmanned bicycle.

In this work, an adaptive critic-based neuro-fuzzy is presented for an unmanned bicycle. The only information available for the critic agent is the system feedback which is interpreted as the last action the controller has performed in the previous state. The signal produced by the critic agent is used alongside the back propagation of error algorithm to tune online conclusion parts of the fuzzy inference rules. Stability and roll angle tracking controls for an unmanned bicycle are presented. The effectiveness of the control schemes is proved by simulation results. The stabilization is once again performed with steering angle control. The control system uses a neuro fuzzy strategy. The dynamics model is very similar to the ones used in the papers for PTWs.

Advantages: -
Disadvantages: -
Outcomes: -
Comparison to ADAS&ME: It may be interesting to use a neuro fuzzy controller.

Yetkin, H. (2013). Stabilization of Autonomous Bicycle (Doctoral dissertation, The Ohio State University).

In this thesis, we utilize the precession eject of the gyroscope to stabilize the bicycle both at zero forward velocity and varying velocities. Equations of motion ofa bicycle with a wheel mounted on its bottom are derived and a first order sliding mode controller is designed to achieve the goal of stabilization. In order to verify the designed feedback controller, two experimental setups are built; an inverted pendulum setup and a bicycle setup. SMC design for the static bicycle model is tested on both the inverted pendulum and the bicycle setups. In order to judge the performance of the controller, a well-tuned PID controller is also tested on these setups. Then, in the light of the experimental results

obtained on the inverted pendulum setup, a controller scheme for the stabilizing control of an autonomous bicycle is designed and tested on various road structures through simulation environment. Technologies used: (Lean angle sensor) CMG for stabilization, Control: PD and sliding mode controller, Arduino microcontroller, CMG moved by a DC electric motor, LOW (only one sensor, which is the lean angle sensor).
Stabilisation is performed using a gyro. The dynamic model is derived using a Lagrangian approach. The authors consider to control the bicycle along a given path using only lean effect (no steering) resulting in numeric simulation and small rides in controlled environment.

Advantages: Stabilization using gyroscopic effect should be considered
Disadvantages: Rider is not considered. Test case is poor.
Outcomes: Very little, the test was performed with a limited range of speeds and not on open roads.
Comparison to ADAS&ME: The stabilization performed using a gyro is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). Make a motorcycle curving only with lean control (no steering control) could be interesting.

Yavin, Y. (2005). Point-to-point and collision avoidance control of the motion of an autonomous bicycle. Computers & Mathematics with Applications, 50(10-12), 1525-1542.
This work deals with the stabilization and collision avoidance control of a riderless bicycle (see Figure 1). It is assumed here that the bicycle is controlled by a pedalling torque, a directional torque, and by a rotor mounted on the crossbar that generates a tilting torque.
Given two points rA, rB, and a circular obstacle in the horizontal plane. Also, given a time interval [0, t/], where 0 < tf < co. It is shown here that by applying a kind of inverse dynamics control, the motion of the bicycle is stabilized while simultaneously controlling its speed and direction in such a manner that the point of contact between the bicycle's rear wheel and the horizontal plane will be able, during [0, tf], to move from rA to rB without hitting the obstacle.
Stabilisation is performed using steering control and a reaction wheel (a disc rotor is better than a blade rotor because it can damp better the system oscillations).
The dynamic Model was derived using Lagrangian approach.

Advantages: Stabilisation using a reaction wheel should be considered.
Disadvantages: Rider is not considered.
Outcomes: Only numeric simulation.
Comparison to ADAS&ME: The stabilization performed using a reaction wheel is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). Steering control may be critical.

Beznos, A. V., Formal'Sky, A. M., Gurfinkel, E. V., Jicharev, D. N., Lensky, A. V., Savitsky, K. V., & Tchesalin, L. S. (1998, May). Control of autonomous motion of two-wheel bicycle with gyroscopic stabilisation. In Robotics and Automation, 1998. Proceedings. 1998 IEEE International Conference on (Vol. 3, pp. 2670-2675). IEEE.
A bicycle with a gyroscopic stabilisation capable of autonomous motion along a straight line as well as along a curve is described. The stabilization unit consists of two coupled gyroscopes spinning in opposite directions. It makes use of a gyroscopic torque due to the precession of gyroscopes. This torque counteracts the destabilising torque due to gravity forces. The control law of the actuator drive making the gyroscopes to precess is described.
The stabilization is performed using both steering angle control and a couple of gyros.

Advantages: Stabilization using gyroscopic effect should be considered.
Disadvantages: Only numeric simulation. Rider not considered.
Outcomes: Only numeric simulation.
Comparison to ADAS&ME: The stabilization performed using a couple of gyro is very interesting and should be considered. Steer control may be critical. Stabilizing a bicycle is much easier (lower weight and inertia).

Bickford, D. (2013). Path Following and Stabilization of an Autonomous Bicycle.

In this thesis we present the systematic multi-loop control approach outlined in Figure 1.1 to stabilize a modern bicycle. An important feature is that the technique guarantees asymptotic convergence to constant curvature paths. A key advantage of our technique is that it uses linear control theory, which readily enables stability analysis and controller tuning.
Stabilisation is performed using steering control and is limited to very low speeds. The dynamic model is derived using a Lagrangian approach.

Advantages: It is the only paper considering the rider (as a rigis rider).
Disadvantages: Only numeric simulation. Purely theoretical (non discussion on sensors and actuators).
Outcomes: Little, almost only numeric simulation.
Comparison to ADAS&ME: Very detailed for path following. Schematising rider as a rigid rider to be considered. LQR to be kept in consideration.

Kanjanawanishkul, K. (2015). LQR and MPC controller design and comparison for a stationary self-balancing bicycle robot with a reaction wheel. Kybernetika, 51(1), 173-191.
A self-balancing bicycle robot based on the concept of an inverted pendulum is an unstable and nonlinear system. To stabilize the system in this work, the following three main components are required, i. e., (1) an IMU sensor that detects the tilt angle of the bicycle robot, (2) a controller that is used to control motion of a reaction wheel, and (3) a reaction wheel that
is employed to produce reactionary torque to balance the bicycle robot. In this paper, we propose three control strategies: linear quadratic regulator (LQR), linear model predictive control (LMPC), and nonlinear model predictive control (NMPC). Several simulation tests have been conducted in order to show that our proposed control laws can achieve stabilizaton and make the system balance. Furthermore, LMPC and NMPC controllers can deal with state and input constraints explicitly. Stabilisation is performed using a reaction wheel and the dynamic model derived using a Lagrangian approach.

Advantages: Stabilization using a reaction wheel should be considered. LQR and MPC controls are sophisticated.
Disadvantages: Rider is not considered. Only numeric simulation.
Outcomes: Little, almost only numeric simulation.
Comparison to ADAS&ME: The stabilization performed using a reaction wheel is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). LQR and MPC to be kept in consideration.

Gallaspy, J. M., & Hung, J. Y. (1999). Gyroscopic stabilization of a stationary unmanned bicycle. Auburn (AL): Auburn University.
This paper presents a method for stabilizing an unmanned bicycle in the upright position. Nonlinear dynamics of the bicycle and control gyroscope are modeled using Lagrange's method. Then, a linear approximate model is developed to design a controller to stabilize the bicycle. An 8-bit fixed-point microcontroller computes control commands to actuate the gyroscope gimbal axis, thus producing a restoring torque on the bicycle frame. Simulations using MATLAB/SIMULINK are analyzed, and experimental results are summarized. Finally, recommendations for further work are given in the concluding remarks.
Stabilisation is performed using a gyro and the model derived using a Lagrangian approach. Bicycle is stabilised at v=0, but the activity is limited only to numeric simulation.

Advantages: Stabilization using gyroscopic effect should be considered.
Disadvantages: Rider is not considered. Test case very, very poor.
Outcomes: Very little, almost only numeric simulation.
Comparison to ADAS&ME: The stabilization performed using a gyro is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia).

Chih-Keng, C. H. E. N., & Thanh-Son, D. A. O. (2007). Genetic fuzzy control for path-tracking of an autonomous robotic bicycle. Journal of system design and dynamics, 1(3), 536-547.

Due to its non-holonomic constraints and a highly unstable nature, the autonomous bicycle is difficult to be controlled for tracking a target path while retaining its balance. As a result of the non-holonomic constraint conditions, the instantaneous velocity of the vehicle is limited to certain directions. Constraints of this kind occur under the no-slip condition. In this study, the problem of optimization of fuzzy logic controllers (FLCs) for path-tracking of an autonomous robotic bicycle using genetic algorithm (GA) is focused. In order to implement path-tracking algorithm, strategies for balancing and tracking a given roll-angle are also addressed. The proposed strategy optimizes FLCs by keeping the rule-table fixed and tuning their membership functions by introducing the scaling factors (SFs) and deforming coefficients (DCs). The numerical simulations prove the effectiveness of the proposed structure of the genetic fuzzy controller for the developed bicycle system.

Stabilisation is performed using steering control, but the activity is limited only to numeric simulation.

Advantages: Fuzzy Logic Control with tuning of the input and outputmembership functions performed by GA (very sophisticated control).

Disadvantages: Only numeric simulation. Rider not considered

Outcomes: Very little: only numeric simulation.

Comparison to ADAS&ME: It is far more easier to stabilise a bicycle than a bike. As already said steer control is very problematic for motorcycles that will be on market. Fuzzy control to be kept in consideration.

Dzung, D., Regruto, D., Andreo, D., & Cerone, V. (2009). Experimental results on LPV stabilization of a riderless bicycle. In American Control Conference.

In this paper the problem of designing a control system aiming at automatically balancing a riderless bicycle in the upright position is considered. Such a problem is formulated as the design of a linear-parameter-varying (LPV) statefeedback controller which guarantees stability of the bicycle when the velocity ranges in a given interval and its derivative is bounded. The designed control system has been implemented on a real riderless bicycle equipped with suitable sensors and actuators, exploiting the processing platform ABB PEC80. The obtained experimental results showed the effectiveness of the proposed approach.

Advantages: LPV control could be interesting.

Disadvantages: simulation performed at limited speeds. They researchers are considering a teleoperated bicycle.

Outcomes: Very little, the test was performed with a limited range of speeds and not on open roads.

Comparison to ADAS&ME: It is far easier to stabilise a bicycle than a bike. As already said steer control is very problematic for motorcycles that will be on market. LPV control to be kept in consideration.

Colvin, G. (2014). Development and Validation of Control Moment Gyroscopic Stabilization (Doctoral dissertation, The Ohio State University).

Two wheeled vehicles offer many advantages over other configurations such as greater maneuverability, smaller size, and greater efficiency. These advantages come at the sacrifice of stability and safety. The goal of this work is to improve the stability and safety of a two wheeled vehicle by the development of Control Moment Gyroscopic Stabilization. This technology integrated into a vehicle can deliver unparalleled maneuverability and stability for users compared to any vehicle in use today. The goal of my work was to develop and validate the system of gyroscopic stabilization to be implemented into a vehicle. To validate the concept, a MATLAB/Simulink program was created, modeling the behavior and response of an unstable body with gyroscopic stabilization applied. After completing multiple simulations on this model, a physical structure, similar to an inverted pendulum, was constructed and CMG stabilization has been tested on this setup. Gyroscopic stabilization has been validated in this configuration and has led to further study in multiple degree of freedom situations. The implementation of a vehicle which utilizes this technology can generate safer and more maneuverable vehicles for the public, military, and recreational users.

Advantages: Stabilization using gyroscopic effect should be considered.

Disadvantages: Rider is not considered. Test case is poor.

Outcomes: Very little, almost only numeric simulation.
Comparison to ADAS&ME: The stabilization performed using a gyro is interesting and should be considered. Stabilizing a bicycle is much easier (lower weight and inertia). Sliding mode controller could be considered.

Lam, P. Y. (2012). Design and Development of a Self-Balancing Bicycle Using Control Moment Gyro (Doctoral dissertation).

This work uses a control moment gyro (CMG) as an actuator. The control moment gyro (CMG) is typically used in a spacecraft to orient the vessel [5]. Appling a CMG as an actuator to balance a bicycle is a creative and novel approach; and is the first of its kind for balancing of a bicycle. Simulation exercises showed that a PD controller is adequate to for balancing the bicycle. A real-time controller was implemented on a kid-size bicycle and the bicycle was successfully balanced and able to move forward, reversing and small angle turning. Further research such as adaptive control can be added to the system so that the system can react to changes in payload.

Advantages: Stabilization using gyroscopic effect should be considered.
Disadvantages: Rider is not considered. The model is not "robust".
Outcomes: Very little, the test was performed with a limited range of speeds and not on open roads.
Comparison to ADAS&ME: The stabilization performed using a gyro is interesting and should be considered. Steer control may be critical. Stabilizing a bicycle is much easier (lower weight and inertia).

Annex 3. Transfer of knowledge from other transportation areas

Wei, Z., Zhuang, D., Wanyan, X., Liu, C. and Zhuang, H., 2014. A model for discrimination and prediction of mental workload of aircraft cockpit display interface. Chinese Journal of Aeronautics, 27(5), pp.1070-1077.

This study constructs a new comprehensive evaluation model based on the Bayesian Fisher discrimination and classification method, by designing flight simulation tasks at different levels of mental workloads. The subjects were asked to perform the whole dynamic process of flight simulation in a flight simulator, including take-off, climb, cruise, approach and landing. Each flight simulation task lasted for 13 min, and mental workloads were manipulated in separate conditions by adjusting the quantity of flight indicators and refresh frequencies time) of abnormal information. The duration of abnormal information was 2 s and inter-stimulus interval between abnormal information was random. During the simulation flight, each subject was instructed to monitor the flight indicators presented on the head-up display, and had to detect and respond to abnormal information quickly and accurately. An experimental design method, similar to that of Latin square design, was adopted to counterbalance the sequence of the flight simulation tasks to reduce the effects of sequence to the experiment results. Sixteen flying cadets from Beihang University were recruited to participate in the present study, ranging in age from 21 to 28 years (age= 24.6± 3.2 years). Bayesian Fisher discrimination and classification method were applied and Repetitive measure analysis of variance (ANOVA) as well as cross-validation. Heart rate and heart rate variability parameters were measured. The verification by the cross check method shows that the comprehensive evaluation model had the highest discrimination and prediction accuracy (85.42%), followed in succession by reaction time index (79.17%), accuracy index (77.08%), NASA_TLX scale (64.58%) and physiological indexes SDNN (39.58%).

Advantages: -
Disadvantages: The automatically monitored indicators have the lowest impact in the developed model.
Outcomes: The dynamic flight simulation experiments show that four indexes, i.e., flight operation accuracy, reaction time, SDNN and NASA_TLX scale, are significantly sensitive to the change of flight task-related mental workload.
Comparison to ADAS&ME: SDNN can be used as indicator of mental workload.

Aricò, P., Borghini, G., Graziani, I., Taya, F., Sun, Y., Bezerianos, A., Thakor, N.V., Cincotti, F. and Babiloni, F., 2014, August. Towards a multimodal bioelectrical framework for the online mental workload evaluation. In 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 3001-3004). IEEE.

In this study, a framework able to classify online different levels of mental workload induced during a simulated flight by using the combination of the Electroencephalogram (EEG) and the Heart Rate (HR) biosignals has been proposed. Ten healthy subjects were involved in the experimental protocol, performing the NASA - Multi Attribute Task Battery (MATB) over three different difficulty levels in order to simulate three classic showcases in a flight scene (cruise flight phase, flight level maintaining, and emergencies). The analyses showed that the proposed system is able to estimate online the mental workload of the subjects over the three different conditions reaching a high discriminability ($p<.05$). In addition, it has been found that the classification parameters remained stable within a week, without recalibrating the system with new parameters. Scalp EEG has been recorded from 16 EEG electrodes (FPz, F3, Fz, F4, AF3, AF4, C3, Cz, C4, P3, Pz, P4, POz, O1, Oz, O2) referenced to the earlobes and grounded to the AFz electrode (sample rate of 256Hz). Also, the HR and the vertical EOG activity were recorded at the same time of the EEG. The system has been entirely implemented in Matlab®, using the TOBI interfaces. All the post processing of the signals seems to have been performed in Matlab. ross validation, Area Under Curve (AUC) of the Receiver Operating Characteristic, Repeated measures ANOVA. Stepwise Linear Discriminant Analysis was applied. Too many to be included all. The ANOVA analyses revealed that the score distributions related to the different subtasks (Easy, Medium and Hard) for all the three classifiers were significantly separated (EEG-based: $F(2,18)=37.84$, $p=10^{-6}$; HR-based: $F(2,18)=13.69$, $p=2.4 \times 10^{-3}$, Fusion-based: $F(2,18)=36.52$, $p=10^{-7}$).

Advantages: The approach seems to be robust against different subjects. The authors claim that it could be enough to calibrate the system with the specific parameters of the operator once and then just use it without further adjustments maintaining a high reliability over at least a one-week period. **Disadvantages:** The best performance was acquired using all EEG recordings. The system has only been tested in a simulation environment.

Outcomes: By combining information coming from different biosignals (e.g. EEG and HR), it is possible to have more reliable and faster information about the mental states of the user.. It has been also demonstrated that i) the system is able to significantly differentiate three workload levels related to the three difficulty level tasks employed with a high reliability; ii) the subjective features used for the evaluation of the mental workload remain stable over one week.

Comparison to ADAS&ME: This study is only concerned with the mental workload. The idea is to be used as part of a system that "could intervene in real-time before the operator becomes overloaded while performing safety-critical tasks". The extracted indicators can be tested within ADAS&ME.

Borghini, G., Astolfi, L., Vecchiato, G., Mattia, D. and Babiloni, F., 2014. Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. Neuroscience & Biobehavioral Reviews, 44, pp.58-75.

This paper reviews published papers related to neurophysiological measurements (electroencephalography: EEG, electrooculography EOG; heart rate: HR) in pilots/drivers during their driving tasks. The aim is to summarise the main neurophysiological findings related to the measurements of pilot/driver's brain activity during drive performance and how particular aspects of this brain activity could be connected with the important concepts of "mental workload", "mental fatigue" or "situational awareness". Overall: From the review of the current literature, it appears that the accuracy of the detection of the mental states in driver/pilot using neurophysiologic signals such as EEG, EOG and HR is close to 90%.

Advantages: The paper provides an extensive list of available systems.

Disadvantages: Identified shortcoming by this paper (not a disadvantage of the paper per se)"However, no device or convincing algorithm has been published orpractically applied for a robust online recognition of such mental

states to date. "
Outcomes: Review of the literature suggests that exists a coherent sequence of changes for EEG, EOG and HR variables during the transition from normal drive, high mental workload and eventually mental fatigue and drowsiness. In particular, increased EEG power in theta band and a decrease in alpha band occurred in high mental workload. Successively, increased EEG power in theta as well as delta and alpha bands characterise the transition between mental workload and mental fatigue. Drowsiness is also characterised by increased blink rate and decreased HR values.
Comparison to ADAS&ME: This paper does not only address pilots but drivers as well. Therefore it is directly related to the scopes of ADAS&ME.

Sauvet, F., Bougard, C., Coroenne, M., Lely, L., Van Beers, P., Elbaz, M., Guillard, M., Leger, D. and Chennaoui, M., 2014. In-flight automatic detection of vigilance states using a single EEG channel. IEEE Transactions on Biomedical Engineering, 61(12), pp.2840-2847.

These conditions, voluntary or even involuntary sleep periods may occur, increasing the risk of accidents. The aim of this study was to assess the performance of an in-flight automatic detection system of low vigilance states using a single electroencephalogram channel. Fourteen healthy pilots voluntarily wore a miniaturized brain electrical activity recording device during long-haul flights. The authors claiming that their results confirm the efficiency of a miniaturized single electroencephalographic channel recording device, associated with an automatic detection algorithm, in order to detect low-vigilance states during real flights. A miniaturized multichannel ambulatory recording device (Actiwave, CamNtech Ltd England) was used to collect two EEG derivations (C3-M2 and O1-M2) and a transversal EOG channel (E1-M2 and E2-M2). The data were post-processed with Matlab. The area under the curve was calculated aiming to compare thresholds. The study was carried out during 15 operational real flights of more than 8 h. Recordings were carried out mainly during overnight flights. After preflight briefing, 30 min before the flight, electrodes and recording devices were installed by a medic for each pilot. The quality of the signal was visually checked after a 2 min recording period (1 min with opened eyes and 1 min with closed eyes), using a software developed on MATLAB. This period was considered as an awake and artefact free period and was then used as a reference period. Data were recorded continuously for each subject from before take-off to after landing, while they performed their regular activities. FPrate was upper (5%) for α and β indices. The best TPrate was observed using β, ratio and fuzzy fusion (i.e., between 0.87 to 0.92). Moreover, using β, $(\alpha + \theta)/\beta$ ratio and fuzzy fusion, the percentage of good classification (sensitivity) was > 90, $\kappa > 0.80$, and AUC > 0.9. The TPrate, the percentage of good classification, AUC, and κ were all higher for the $(\alpha + \theta)/\beta$ ratio method using the O1-M2 channel than the C3-M2 channel ($p < 0.05$).

Advantages: It requires the use of only one EEG recording and a quite simple processing procedure.
Disadvantages: It was tested only on 14 participants. One of them declared that he would not be willing to wear again that specific apparatus.
Outcomes: The best concordance between automatic detection and visual scoring was observed within the O1-M2 channel, using the ratio of energies in frequency bands.
Comparison to ADAS&ME: This study is only concerned with one state condition. No Assistant System and a relative mechanism is considered. The approach is actually one that has been already been tested in drivers.

Çakır, M.P., Vural, M., Koç, S.Ö. and Toktaş, A., 2016, July. Real-Time Monitoring of Cognitive Workload of Airline Pilots in a Flight Simulator with fNIR Optical Brain Imaging Technology. In International Conference on Augmented Cognition (pp. 147-158). Springer International Publishing.

In this study a preliminary LDA based classifier was developed and evaluated that aim to predict low, moderate and high mental workload states of pilots in real-time based on a set of features computed over a moving window of HbO and HbR measures obtained from 16 locations distributed on the prefrontal cortex. Tests were carried out at a thales Airbus A320 simulator, Functional near-infrared spectroscopy (fNIR) system developed at Drexel University (Philadelphia, PA), manufactured and supplied by fNIR Devices LLC (Potomac, MD; www.fnirdevices.com). A flexible head-piece (sensor pad), and a control box for hardware management. The fNIR sensor holds 4 light sources and 10 detectors, which obtains oxygenation measures at 16 optodes on the prefrontal cortex. Data were collected with COBI Studio software for data acquisition, DAQ Station module of fNIRSoft for real-time low level processing of fNIR data, and a software application for real-time classification of mental workload level of the participant . A script executed by the DAQ station converts raw signals into HbO and HbR measures by using the Modified Beer Lambert Law by considering the first 10 s as a baseline. The script also computes the mean, standard deviation, slope, minimum, maximum and range values for HbO and HbR signals, Linear Discriminant Model for classification. Data from one pilot for training and data from the rest 7 pilots for testing. Labeling: A training dataset was prepared by performing a qualitative analysis of the video files to judge the level of mental workload experienced by the subject during each of the three scenarios. Pilots' self-assessments of their mental workload which is collected after the experiment and the differences between the scenarios in terms of the presence of unexpected events such as failures are used as additional cues while manually marking the episodes for low, moderate and high mental workload. Pilots performed 4 flight scenarios during the experiment. The first scenario involved a free play task that took about an hour including sensor installation and demonstration of the flight simulator. After a rest period, the second scenario was run, which started in cruise mode and ended with normal workload landing. After the second scenario there was a lunch break. The third scenario also included cruise mode flight followed by a landing which was diverted to a different airport by the ATC, with the aim to increase the mental workload level. The final scenario simulated a high workload landing by having the ATC to initiate a sudden go-around due to late aircraft incursion on runway. During the climb an instrument failure (e.g. flap or engine failure) was initiated in order to further increase the mental workload level. The initial classifier was trained over a single pilot who ran through all three flight-scenarios with an accuracy of 92 %. This model was then used to predict the mental workload levels of the remaining 7 pilots in real-time while they were running the scenarios. A qualitative analysis of 69 events sampled from these simulated flights showed that the model trained over a single pilot could predict the expected workload level in 68 % of the cases.

Advantages: n alternative method for brain activity monitoring. (Functional near-infrared spectroscopy (fNIR) is a neuroimaging modality that enables continuous, non-invasive, and portable monitoring of changes in blood oxygenation and blood volume related to human brain function).
Disadvantages: The placement of the sensor does not seem user friendly.
Outcomes: An LDA based classification system for mental workload was developed based on features extracted from fNIR data. The results seem to be affected by the presence of noise during the recording.
Comparison to ADAS&ME: The proposed sensoring method with the current technology can only be used (for practical applications) by riders.

Anund, A., Fors, C., Kecklund, G., Leeuwen, W. V., & Åkerstedt, T. (2015). Countermeasures for fatigue in transportation: a review of existing methods for drivers on road, rail, sea and in aviation. Statens väg-och transportforskningsinstitut.

The overall aim with this study was to gather knowledge about countermeasures for driver fatigue (including sleepiness) in road, rail, sea and air transportation. The knowledge has been used as an input for evaluating advantages and disadvantages with different countermeasures and to estimate their potential to be used regardless mode of transportation. The method used was a literature review and a workshop with experts from all transportation modes. At the workshop the effectiveness of countermeasures for a single mode, but also regardless mode were discussed and a ranking was done. The report discuss the potential of fighting fatigue among drivers for specific mode of transport but also from a more generic point of view, considering scheduling, model prediction of fatigue risk, legislation, a just culture, technical solutions, infrastructure, education, self-administered alertness interventions and fatigue risk management (FRM). The overall judgement was that a just culture, education, possibility to nap and schedules taking the humans limitations into consideration as the most effective countermeasures to fight fatigue, regardless mode of transportation.

Advantages: The report contains all fatigue related countermeasures up to 2014
Disadvantages: -
Outcomes: Technical solutions are available only in exceptional cases in especially transport modes aviation and sea. The available solutions are rather old, don't use state-of-the-art technology and less innovative compared to what has been developed for car and truck industry. There is reason to believe that rail is the transport mode were you most easily can use less innovative solutions like "dead man's switch" and activation monitoring.
Comparison to ADAS&ME: The report contains a thorough investigation of available countermeasures of fatigue. Some of them could be part of ADAS&ME. The leading partner is also involved in ADAS&ME.

Lehrer, P., Karavidas, M., Lu, S.E., Vaschillo, E., Vaschillo, B. and Cheng, A., 2010. Cardiac data increase association between self-report and both expert ratings of task load and task performance in flight simulator tasks: An exploratory study. International Journal of Psychophysiology, 76(2), pp.80-87.

The aim of this study was to evaluate whether cardiac data add sensitivity for assessing flight task mental workload and pilot performance under simulated flight conditions, over that provided by a simpler, inexpensive, and well-validated self-report measure. After physiological monitoring equipment was attached, the following tasks were administered, in a single session, each task lasting for approximately 5min. First assessed baseline physiology and reactivity using a standardized "plain vanilla" baseline. The WinCPRS software program (Absolute Aliens Oy, Turku, Finland) was used for analysis. A number of HRV parameters were calculated. Motion was detected from a crystal accelerometer embedded in the LifeShirt at the anterior surface of the abdomen, Models: random effects logistic regression models , mixed model analysis. Eighteen standard flight tasks were then presented. The tasks were grouped in three flight phases, presented in the following order: Takeoff, in-flight (climb, cruise, descent), and approach/landing. Testing involved a total activity time of 90 to 110 min in a two hour period, allowing approximately 10 to 15 min for debriefing and resetting the flight simulator for the next task. Task load (high [H], moderate [M], low [L]) was determined by a senior flight simulator operator. the area under the receiver operating characteristic (To determine whether there were fewer false positive and negative detections of high task load with cardiac measures added to the TLX vs. with the TLX alone) and Akaike's Information Criterion (AIC) (Akaike, 1974) to evaluate the improvement of model fit (prediction) of evaluator scores by the cardiac measures over TLX alone.

Advantages: Evaluate the sensitivity of cardiac data to workload using TLX alone and with cardiac measures. Heart rate is particularly useful for operational assessments because it is inexpensive and simple to acquire and analyse.
Disadvantages: Because of the small number of participants, some of our statistical findings may have resulted from response peculiarities of particular participants.
Outcomes: Technical solutions are available only in exceptional cases in especially transport modes aviation and sea. The available solutions are rather old, don't use state-of-the-art technology and less innovative compared to what has been developed for car and truck industry. There is reason to believe that rail is the transport mode were you most easily can use less innovative solutions like "dead man's switch" and activation monitoring.
Comparison to ADAS&ME: EKG indicators can be part of the ADAS&ME system.

Luig, J., & Sontacchi, A. (2014). A speech database for stress monitoring in the cockpit. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 228(2), 284-296. {keywords: pilot stress monitoring flight}

This article presents a new database of speech produced under cognitive load for the purpose of non-invasive psychological stress monitoring. The recording session consisted of four different challenging scenarios (F1–F4) plus one 'reference flight' (F0) at the very beginning. The four scenarios are: [A] cockpit preparation, [B] takeoff and initial climb, [C] en route flight, [D] approach and landing. A strain trajectory, graded by experience, had been sketched by the instructors for each of the four demanding scenarios. Measures of interest: perceived, substantial imbalance between demand and response capability, under conditions where failure to meet the demand has important and the perceived consequences. The Fokker F70/100 series full flight simulator at Aviation Academy Austria (AAA, Neusiedl/See, Austria (www.aviationacademy.at) glass cockpit simulator was used. A patch written in the graphical programming language PureData (pd) was used to record all relevant channels to the hard disk and to create speech activity information data at the same time - standard headset microphones - beat-to-beat heart rate signal was recorded with a high-precision (8 kHz sampling rate, 16-bit resolution.) mobile measurement device, the ChronoCord. The ChronoCord offers the opportunity to set marker flags at the push of a button, so that heart rate and speech data could easily be synchronized by setting an ‘acoustical marker’ while pushing the button at the same time. HRV parameters were calculated as potential stress indicators. Speech parameters with prosodic relevance were extracted. The discriminative power of the HRV parameters is investigated through paired one-way ANOVA comparisons. Results are reported using colour matrix coding (significance matrix).

Advantages: Recording and analyzing speech is the least intrusive way of stress monitoring with promising result.
Disadvantages: Paired one-way ANOVA comparisons of HRV parameters before, during, and after each single event evidence statistically significant differences in HRV parameters for nearly half of the events (7/15). This is not satisfactory.
Outcomes: there is no ‘universal descriptor’ for changes in stress level, but different events lead to changes in different parameters.
Comparison to ADAS&ME: Speech is one of the targeted measurements of ADAS&ME. The database is available on request (Access is subject to approval and limited to academic institutions only.) for non-commercial research purposes.

Gentili, R. J., Rietschel, J. C., Jaquess, K. J., Lo, L. C., Prevost, C. M., Miller, M. W., & Hatfield, B. D. (2014, August). Brain biomarkers based assessment of cognitive workload in pilots under various task demands. In Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE (pp. 5860-5863). IEEE.

This study is an initial step in identifying and selecting multiple biomarkers to form a composite metric sensitive to the dynamic construct of cognitive workload and attentional reserve. Each scenario was composed of a 1-minute familiarization period followed by a 10-minute flight challenge during which performance (i.e., airspeed, altitude, heading, and vertical speed) was recorded. The three progressively challenging scenarios (S1, S2, and S3) were defined as follows: i) S1 (low demand). A flight simulator (Prepar3D® v1.4, T-6A Texan II SP2 USN aircraft, Lockheed Martin Corporation™) – Four dry-sensor EEG (g-Tech™, Schiedlberg, - ECG sensor) was used. The EEG: To estimate cognitive workload, spectral analysis was used using a Fast Fourier transform (1-Hz resolution). The spectral power was then computed for each scenario. The frequency bins were log-transformed and summed to obtain spectral power for the Theta (3-8 Hz) / Alpha (8-13 Hz) ratio. ECG: The square root of the mean squared successive differences (RMSSD) was calculated. An one-way ANOVA tests were used for assessing differences for different scenarios, measures etc. Thirty-eight healthy young participants (ages ranged from 19 to 23 years). Although differences in the RMSSD were not significant when comparing the three scenarios ($p>0.05$), it was found to be significantly lower for the individuals who perceived the task as demanding a high degree of concentration ($p<0.05$), which indicates a reduction of vagal influence on the heart under elevated load. EEG spectral analysis revealed that the theta/alpha ratio increased as the challenge increased; significant differences were found between all levels of challenge (S1 vs.S2:$p<0.05$; S2 vs. S3:$p<0.01$; S1 vs. S3:$p<0.001$)

Advantages: A dry EEG system composed of only few sensors does not require using conductive gel and the very limited number of sensors can reduce the preparatory and computational burden, which is promising for operational settings.
Disadvantages: simulation only.
Outcomes: This study confirms and extends previous research by identifying multiple biomarkers to assess cognitive workload and attentional reserve during progressive simulated piloting task demands.

EEG power and HRV were used to assess cognitive workload while the ERPs assessed attentional reserve. Cognitive workload and attentional reserve were negatively related.
Comparison to ADAS&ME: The extracted biomarkers could be used as part of the ADAS&ME system.

Oh, H., Hatfield, B. D., Jaquess, K. J., Lo, L. C., Tan, Y. Y., Prevost, M. C., & Blanco, J. A. (2015, August). A Composite Cognitive Workload Assessment System in Pilots Under Various Task Demands Using Ensemble Learning. In International Conference on Augmented Cognition (pp. 91-100). Springer International Publishing.

Thus, this study aims to devise an ensemble model that is able to select optimal features from multiple metrics for a more accurate classification according to three levels of task demand to determine an operator's current cognitive workload in ecologically valid tasks.
Tuning: the optimal model was selected by taking the minimum balance (BAL) error (εBAL) to balance large biases due to a small sample size, which is a convex combination of resubstitution (RESB) and cross-validation (CV) errors. - Performance assessment: Lastly, the classifiers were assessed using the confusion matrix and the Receiver-Operating Characteristic (ROC) curve, and the rank of attributes was assessed through the ReliefF algorithm. Three systems were employed: (1) electrocortical and physiological data acquisition system, (2) a flight simulator cockpit and the Flight Data Recorder (FDR) known as one part of the black box, and (3) auditory stimuli with synchronous trigger delivery system-Four active gel-free EEG electrodes (g.SAHARA electrodes®) - Presentation®(v18.1, Neurobehavioral Systems) delivered auditory probes to the subjects through earphones - ECG sensor. EEG. Thirty-nine healthy volunteers (35 men and 4 women) between the ages of 19 and 24 years. The re-referenced EEG were processed using an IIR filter with a 20-Hz low-pass cut-off frequency and 48-dB/octave roll-off. Next, each baseline of 1-s epochs that were time-locked to the auditory stimuli was corrected using the pre-stimulus interval (−100 to 0 ms). Those epochs retaining significant artifacts (e.g., eye-blink, etc.) were excluded. The remaining epochs were averaged per sensor for each scenario. The average ERP amplitudes were derived for the novelty P3 (P3a; 270 to 370 ms). ECG. HRV was measured through the following methods along with average heart rate, which are appropriate for short 5 min samples from the middle section of the whole 10 min experiment: (1) SDNN, (2) RMSSD, (3) the low (LF; 0.04 to 0.15 Hz) and high frequency (HF; 0.15 to 0.4 Hz) ratio (LF/HF) of R-R intervals using a Welch's method. Five individual classifiers were examined: classification trees (CTREE), k-nearest neighbors (kNN), quadratic discriminant analysis (QDA), naïve Bayes (NB), and error-correcting output codes using support vector machine (ECOC-SVM). For an ensemble of classifiers, bagging, boosting, stacking, and voting algorithms were scrutinized. Specifically, bagging derived the final prediction through a simple majority rule from multiple CTREEs Boosting combined weak CTREEs using a weighted majority rule, where each classifier was sequentially built as a better model than previous classifiers by considering misclassified observations. Unlike bagging and boosting, stacking employed a higher level model (CTREE) to combine five base learners (i.e., individual classifiers) rather than using one algebraic rule, and voting averaged the predictions of the five base learners.

Advantages: Ensemble learning is a very powerful classification scheme.
Disadvantages: The use of such methods makes the results hard to interpret.
Outcomes: Boosting, stacking, and voting showed very reliable performance as expected. In particular, stacking and voting could be easily extensible through a hierarchical structure particularly when any new feature set is included in the future to produce more reliable results.
Comparison to ADAS&ME: Ensemble learning is a valid candidate for state classification.

Binias, B., Myszor, D., Niezabitowski, M., & Cyran, K. A. (2016, May). Evaluation of alertness and mental fatigue among participants of simulated flight sessions. In Carpathian Control Conference (ICCC), 2016 17th International (pp. 76-81). IEEE.

During the experiment measurements, each subject was asked to repeat a basic manoeuvre on a simulator for 15 to 20 times. There were no significant breaks between consequent sessions. These were intermittent only by the procedure of restarting the position of simulated plane on the airstrip.

Each session consisted of 6 basic events: take-off, for right turns and landing. Each event was signalized to the participant by an auditory cue (sound of a gong). The total duration of one session was approximately 7 minutes. In total each of the performed measurements took about 3 hours. Flight Navigation and Procedures Trainer Level II simulators:
• Elite S812 FNPT II in Cessna 172RG variant,
• Elite S923 FNPT II MCC in Piper Seneca III variant - The EEG data used in this research was recorded using the Emotiv EPOC+ Headset -electrodes AF3 and AF4 were used for EOG. Band-pass filtering was applied to the recorded signals. Thresholding was used to remove artifacts. A variant of the Common Average Reference (CAR) method is used for spatial filtering. Normalized Beta and Theta power are used as indicator of mental condition. 5 people, with no or little previous experience with flight simulators participated in the study. No statistically valid results were derived "“Due to insufficient number of participants, achieved results should be treated more as evaluation of the proposed signal processing and data analysis methods, rather than proof of experimental hypothesis”".

Advantages: Cheap and easy to use equipment.
Disadvantages: no statistically valid results. Only simulations were involved.
Outcomes: Proposed approach proved to be highly effective when dealing with contaminated and noisy data. Due to insufficient number of participants no general hypothesis can be drawn from performed analysis.
Comparison to ADAS&ME: The utilization of the power of frequency bands as fatigue indicators will be part of the ADAS&ME approach.

Roveda, J.M., Fink, W., Chen, K. and Wu, W.T., 2016, March. Psychological health monitoring for pilots and astronauts by tracking sleep-stress-emotion changes. In Aerospace Conference, 2016 IEEE (pp. 1-9). IEEE.
This paper employs sensors and real time sensory data processing to quantify and interpret sleep quality and stress levels. The prognostics sensors include the Phillips Actiwatch for sleep monitoring and electrocardiogram (ECG) sensor for heart rate and heart rate variability (HRV) to monitor emotion changes. Data were collected before, during, and after sleep for the single case study. No other information is provided. Phillips Actiwatch for sleep monitoring and electrocardiogram (ECG) sensor for heart rate and heart rate variability (HRV) to monitor emotion changes. BioPatch incorporates ECG sensor, accelerometer, and temperature sensor, respiration rate detector onto one single chip. A Samsung smartphone accepts measurements from wearable sensors through Bluetooth communications. The Android Operating system is used to create Application Program Interface (API) between the wearable sensor node and the smartphone. On the cloud, various data analysis and data mining approaches are exploited to provide reliable stress level estimation.

Advantages: An integrated monitoring system was presented.
Disadvantages: The assessment was not performed during driving but for a whole day using only one subject.
Outcomes: A combination of several data categories (i.e., HR, RR, R-R intervals, and HRV) may provide an indicator for the quality of sleep and thus may be a way to track sleep-stress-emotion changes in pilots and astronauts in particular, and the public in general.
Comparison to ADAS&ME: The platform described incorporates many of the sensors that are to be tested for ADAS&ME.

Borghini, G., Aricò, P., Di Flumeri, G., Salinari, S., Colosimo, A., Bonelli, S., & Babiloni, F. (2015, August). Avionic technology testing by using a cognitive neurometric index: A study with professional helicopter pilots. In Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE (pp. 6182-6185). IEEE.
This study investigates the possibility to evaluate the impact of different avionic technologies on the mental workload of helicopter’s pilots by measuring their brain activity with the EEG during a series of simulated missions. EEG is used as gold standard for assessing mental workload. Helicopter simulator (AW189 helicopter’s cockpit). Electroencephalogram (EEG) has been recorded by the

digital monitoring BEmicro system (EBNeuro, Italy). Each pilot wore the EEG-cap under the headset and the eight EEG channels (F3, Fz, F4, AF3, AF4, P3, Pz, and P4) have been collected simultaneously with a sampling frequency of 256 (Hz).
The study was conducted with a helicopter simulator (AW189 helicopter's cockpit). Electroencephalogram (EEG) has been recorded by the digital monitoring BEmicro system (EBNeuro, Italy). Each pilot wore the EEG-cap under the headset and the eight EEG channels (F3, Fz, F4, AF3, AF4, P3, Pz, and P4) have been collected simultaneously with a sampling frequency of 256 (Hz). The EEG signal of each experimental condition has been digitally band-pass filtered by a 4th order Butterworth filter (low-pass filter cut-off frequency: 30 (Hz), high-pass filter cut-off frequency: 1 (Hz)) and then artefacts have been removed by using the Gratton method and other specific procedures of the EEGLAB toolbox based on threshold methods. At this point, the EEG has been segmented in epochs of 4 (sec), shifted of 0.5 (sec) and then the EEG PSD has been estimated by using the Fast Fourier Transform (FFT) in the EEG frequency bands defined, for each pilot, by using the Individual Alpha Frequency (IAF) value. The MWL is then calculated. Simple statistical test (t-test) is used for comparing MWL (normalized by the Coefficient of Determination) considering all the different visual conditions. Twenty-seven flight scenarios have been defined as combination of visibility, display and symbology and they have been proposed randomly to the pilots in order to avoid habituation and expectation effects. The hypothesis was that the integration of FG or RO could reduce significantly the mental workload in different operational and visibility conditions when compared to the use of only the FC. The results showed that the use of the HUD significantly decreased ($p<10^{-5}$) the workload level for the accomplishment of the scenarios with respect to the HMD. - the execution of same flight conditions have been significantly easier than those with the only FC, both with the HMD (p<10-5) and the HUD ($p<.05$). In fact, in the condition with only FC, the MWL was statistically higher ($p<.05$) than with the FC+FG.

Advantages: -
Disadvantages: The results are based on simulation trials.
Outcomes: The present study suggested as cognitive neurometrics could provide more objective and quantitative information with respect to the subjective methodologies, in order to test and compare different avionic technologies in terms of requested mental workload.
Comparison to ADAS&ME: The use of EEG measures to quantify mental workload which is related to fatigue/stress can be used for monitoring driver's state. The results could also be exploited during the HMI design.

Barnett, M., Pekcan, C., & Gatfield, D. (2012, April). The use of linked simulators in project "HORIZON": Research into seafarer fatigue. MARSIM.
Project "HORIZON" (http://www.warsashacademy.co.uk/about/resources/final-horizon-report-final-as-printed.pdf?t=1477776993979) was a Framework 7 European funded research study to investigate the effects of fatigue on the cognitive performance of ships' watch keeping officers, using a range of linked simulators and under different watch patterns and conditions of workload. The simulator-based experiments were focussed on two different watch patterns – the conventional 4 hours on, and 8 hours off regime, and the more arduous 6 on and 6 off watch pattern. This paper describes the scenario used in the Warsash experiment, the participants in the study, the measurements used, and some initial findings. EEG and Bridge Simulator, produced by Kongsberg, were used. EEG recordings (from 20 participants) measure the electrical activity of the brain, through several electrodes that are attached on the head. The participants were fitted with these on two occasions during the week by specialists. This occurred on the second and sixth days, and the participants wore them for a complete 24 hour period, thus wearing them for two watches and for two rest periods.

Advantages: -
Disadvantages: -
Outcomes: Sleepiness and neurobehavioral performance, as measured by the EEG electrodes, are particularly affected towards the end of the 0000-0600 watch. Sleepiness and fatigue are enhanced and brain performance reduced. In addition, there is a gradual increase of fatigue during the work periods as the week progresses.

Comparison to ADAS&ME: It is nor clearly described how the EEG recordings were utilized.

Varoneckas, G., Martinkenas, A., Andruskiene, J., Stankus, A., Mazrimaite, L., & Livens, A. (2015). Web-based Databank for Assessment of Seafarers' Functional Status During Sea Missions. Safety of Marine Transport: Marine Navigation and Safety of Sea Transportation, 49.

This paper concentrates on the development of data bank for seafarers' functional status assessment. The Web system is based on client-server architecture and the international open source technologies including Apache web server, PHP scripts and MySQL database. Database was created using MySQL, Apache, PHP, Java scripts. Holter Monitoring. Different statistical, spectral and non-linear dynamic parameters of RR interval time series are stored in the databank.

Advantages: The main operational advantage of the developed system is the access to the data bank for several users at the same time.
Disadvantages: The automatic monitoring part off the HR ıs not clearly described.
Outcomes: According to the authors "The study results demonstrated that sea farer's functional status mostly depends on the physical and mental fatigue during operational activity. The functional status is also influenced by gender, age, physical fitness, pain, boredom and emotions."
Comparison to ADAS&ME: ADAandME will also have a data repository where, however, the most crucial information will come from sensors instead of questionnaires.

Arima, M., & Kii, S. (2013, June). Development of an Autonomous Human Monitoring System for Preventative Safety in Sea Transportation. In ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering (pp. V02AT02A040-V02AT02A040). American Society of Mechanical Engineers.

This paper deals with autonomous facial expression monitoring system and ECG analysis using a mini physiological measuring system. Microsoft's 'KINECT for Windows' sensor and multiple network cameras (Canon's VB-M40). The KINECT sensor has a colour sensor, an infrared (IR) emitter and an IR depth sensor for detecting human body and estimating his/her three-dimensional position in real time. A mini Electro Mechanical Systems (mEMS) apparatus was newly developed by ERATO Maenaka Human-Sensing Fusion Project. ontours of both eyes and mouth can be quantified by using the Fourier Descriptors. The relationship between six fundamental emotions and facial expression was modelled using the neural
network technique. Indices for representing the sympathetic and parasympathetic nervous system were derived using the PSD of the R-R time series data. Primarily qualitative assessment of the system based on one field trip were collected. Face of navigation officer (only one participant) was followed by the KII system during operation near Shodo-shima Island in Seto Inland Sea, Japan. The officer was walking around in the navigation bridge for ensuring the safety of a ship. Only qualitative analysis is presented.

Advantages: The proposed face monitoring system can track the user while he is moving around.
Disadvantages: There is no quantitative measurement of the performance of the system.
Outcomes: The index of the sympathetic nervous system (SNS) can be a useful index to detect subject's psychological condition. The facial monitoring system can detect and follow subject's face even though he/she walks around in a navigation bridge.
Comparison to ADAS&ME: The sympathetic and parasympathetic indices can be part of the indicators used by ADAS&ME. Multiple cameras could also be part of the monitoring system. The proposed method however has not been properly validated.

Macii, D., Dalpez, S., Passerone, R., Corrà, M., Avancini, M., & Benciolini, L. (2015). A safety instrumented system for rolling stocks: Methodology, design process and safety analysis. Measurement, 67, 164-176.

In this paper, the design process of a novel dead-man's vigilance devices (DMVDs), is described with a special emphasis on safety issues. Vigilance detection relies on the measurement of the time intervals between two consecutive switches of one of the signals coming from one of the input electromechanical devices used by the operator to move the rolling stock. Emergency brake was investigated.

Advantages: easy to implement.
Disadvantages: The vigilance detector is not measuring any physiological measures.
Outcomes: The full design process of a novel dead-man's vigilance device (DMVD) was presented.
Comparison to ADAS&ME: The vigilance detector is well suited for trains but might not be adequate for drivers/riders since the rules that trick the detector might not be realistic outside the locomotive setting. On the other hand the methodological approach might be of interest if an FPGA implementation it pursuit.

Dorrian, J., Lamond, N., Kozuchowski, K. and Dawson, D., 2008. The driver vigilance telemetric control system (DVTCS): Investigating sensitivity to experimentally induced sleep loss and fatigue. Behavior research methods, 40(4), pp.1016-1025.

The aim of this study was to investigate whether a new device, designed to detect lowered states of arousal using electrodermal activity (EDA), would be sensitive to experimentally induced sleepiness and fatigue. The device consists of a wrist and a ring component (worn by the individual) that send signals to a box with a luminescent-rule-style vigilance indicator. For validation a standard montage of electrodes was applied to each participant's face and scalp, to allow continuous monitoring of brain activity (EEG) and eye movements (EOG). The York driving simulation program (DriveSim 3.00, York Computer Technologies, Kingston, ON) was used. The indicator counts down as lowered states of arousal are detected. When vigilance, as indicated by ring or wrist EDA, reaches sufficiently low levels, an alarm sounds, and the driver is required to press a response button. his was a repeated measures study, in which 15 participants underwent a period of 28 h of sustained wakefulness (independent variable). Dependent variables, recorded every 2 h, included psychomotor vigilance response times, subjective fatigue, driving simulator performance, and DVTCS output. Within-subjects comparisons were used to investigate the impact of hours awake (experimentally induced fatigue). Repeated measures ANOVA with one within-subjects factor (hours of wakefulness) (GLM procedure, SPSS 13 for Mac OSX). The Greenhouse–Geisser procedure was applied to correct for sphericity. Fifteen individuals (6 of them female, 9 male) participated in the study. Average vigilance, as indicated by the DVTCS device, did not significantly change across the testing period. The number of seconds that it indicated zero vigilance varied significantly ($p <.05$), with 2100 and 2300 h significantly ($p <.05$) higher than 0900 h on Day 1 (Table 1). However, in real terms, this change represented an average of between 4 and 5 sec out of a test total of 600 sec 2)DVTCS indicators did not significantly ($p <.05$) vary during the driving simulator task.

Advantages: comfortable sensor.
Disadvantages: The results suggest that the vigilance indicator part of the DVTCS device is not sensitive to the fatigue levels produced in the present study.
Outcomes: The results indicated that the EDA indicator was not sensitive to increased sleepiness and fatigue at the levels produced in the present study.
Comparison to ADAS&ME: Even though this system is meant to be used in trains, the experiments were conducted using a car-driving simulator. Therefore the results can be exploited by ADAS&ME.

Lal, S., Lal, S. J., Fisher, P., Penzel, T., & Agbinya, J. (2011, November). Brief overview of technology and applications in railway operator safety. In Broadband and Biomedical Communications (IB2Com), 2011 6th International Conference on (pp. 252-258). IEEE.

This paper provides a brief review of the know how in the area of safety in the railway environment back in 2011. This is a review paper. No specific equipment is described in particular. An overview of different approaches and factors that are related to fatigue is presented. More space is devoted the "standard" frequency related indicators and the past work of the authors.

Advantages: -
Disadvantages: -
Outcomes: an overview of technologies that can affect driver's status was presented.
Comparison to ADAS&ME: This paper is a bit old. However the main findings suggestions are in agreement with the ADAS@ME approach "There is an ongoing need to advance existing know-how and technology to further improve the safety in the railway transportation sector".

Sinha, U., Mehta, K. K., & Shrivastava, A. K. (2016) Real Time Implementation for Monitoring Drowsiness Condition of a Train Driver using Brain Wave Sensor.

A system for processing brain activity in order to be used for drowsiness is described. The development is still in its infancy. A single channel, wireless headset that monitors the brain activity was used. No results were presented regarding the effectiveness of the system.

Advantages: Single channel wireless EEG.
Disadvantages: Battery needs recharging every 7-8 hours.
Outcomes: A prototype in its very early stage was presented.
Comparison to ADAS&ME: No verified results presented for the effectiveness of the methods.

Rahman, A., Izzah, N., Dawal, S. Z. M., & Bahreininejad, A. (2013). The Effects of Driving Environment on the Mental Workload of Train Drivers. In Advanced Engineering Forum (Vol. 10, pp. 93-99). Trans Tech Publications.

In this study, the mental activity of human operators is investigated via experiment, whereby each participant is required to drive under three environmental conditions (i.e. clear sunny day, rainy day and rainy night). The brain activity of each participant was recorded using EEG BIOPAC MP150 System equipped with AcqKnowledge 4.0 software as well as Electrode Cap (CAP100C). The electrooculogram (EOG) was used to detect the presence of eye blinks in the EEG data. A computer-based train driving simulator (Mitsubishi Electric Advance, Japan) provided by Keretapi Tanah Melayu Berhad (KTMB). Fast Fourier Transform (FFT) analysis was performed to extract and estimate the mean alpha power. The Friedman Test was used to analyze the significant difference between the mean alpha power data for the three train driving sessions. Fifteen train drivers (male) were recruited to participate in the experiment, aged between 24 to 48 years old (40 ± 6.9 years) and working experience of 14 ± 6.1 years. hree sessions were conducted to simulate three driving conditions, one session for clear sunny day, rainy day and rainy night, respectively. The participants were requested to complete 60 minutes of monotonous train driving session, in which each session has a total duration of 20 minutes. The measurement procedure was repeated for each session, and the participants were given a 5-minutes break after each session. The participants were required to complete all three driving sessions and they were given a few minutes to familiarize themselves with the controls and the experimental setup in order to perform the train driving task. he difference in mean alpha power values at the FZ and PZ locations is found to be statistically significant for the three driving conditions, $P = 0.042$.

Advantages: Easy to compute indicators.
Disadvantages: Well-known indicator. No new knowledge provided.
Outcomes: The results reveal that the mean alpha power values are higher during rainy night condition, which indicate that the train drivers experience reduced levels of vigilance. The EEG measurements taken at the PZ locations (i.e. points that contribute to the primary visual perception of humans) show a decrease in mental workload towards the end of the driving period for rainy night condition, which clearly indicates an increased level of sleepiness.
Comparison to ADAS&ME: standard frequent band indicator. Can be used at ADAS&ME.

Jap, B. T., Lal, S., Fischer, P., & Bekiaris, E. (2007, August). Using spectral analysis to extract frequency components from electroencephalography: Application for fatigue countermeasure in train drivers. In Wireless Broadband and Ultra Wideband Communications, 2007. AusWireless 2007. The 2nd International Conference on (pp. 13-13). IEEE.

Investigation of spectral measures that can act as fatigue indicators evaluated using simulation driving sessions. Thirty two channel of EEG, using NeuroScan system (Compumedics, Australia) and a driving simulator were used. 52 non-professional drivers participated in the study. Thirty-two channel of EEG, using NeuroScan system (Compumedics, Australia), was collected simultaneously during a 5-minute active driving session followed by 1-hour of monotonous and continuous driving. Blood pressure and heart rate were collected before and after the driving task. Significant differences were found at temporal sites only for alpha ($F = 2.0$, $p = 0.030$), and beta ($F = 2.3$, $p = 0.011$). - Delta showed significant differences for the frontal site ($F = 3.5$, $p < 0.001$), - theta showed significant differences for central (F = 2.3, p = 0.013), frontal (F = 2.3, p = 0.013), and parietal (F = 3.6, p < 0.001). - Beta activity revealed significant difference between alert baseline and time section 10 (p = 0.031). - Post-hoc Bonferroni analysis for delta activity at frontal site revealed significant differences in activities between alert baseline and time sections 1 (p < 0.001), and 2 (p= 0.024), and between time sections 1-4 (p = 0.017), 1-5 (p = 0.021), 1-8 (p = 0.008), 1-9 (p = 0.036), and 1-10 (p = 0.032). - Post-hoc Bonferroni analysis for theta activity for central (p = 0.006), and frontal (p = 0.006) sites revealed significant differences between alert baseline and time section 2, -whereas result for parietal site revealed significant differences between alert baseline and time section 2 (p < 0.001), and between time sections 2-4 (p = 0.028), 2-5 (p = 0.015), 2-6 (p = 0.037), 2-7 (p = 0.048), 2-8 (p = 0.035), 2-9 (p =0.023), and 2-10 (p = 0.021).

Advantages: Indicators are simple to compute.
Disadvantages: too many electrodes involved. The study was performed using a simulator.
Outcomes: The result of the current study showed a significant change in the brain activity during a fatigue instigating driving session, and several sites that showed significant changes during fatigue could potentially be used to detect fatigue.
Comparison to ADAS&ME: Frequency band indicators as well as the identified sites demonstrating the higher sensitivity to fatigue manifestation could be use in ADAS&ME.

Ridwan, S. D., Thompson, R., Jap, B. T., Lal, S., & Fischer, P. (2008, November). Single channel wireless EEG: Proposed application in train drivers. In Broadband Communications, Information Technology & Biomedical Applications, 2008 Third International Conference on (pp. 58-63). IEEE.

A prototype or a single channel wireless EEG section was presented. The design was still in experimental phase. The whole system presented is a wireless single channel EEG sensor (LabVIEW programming language (National Instrument, version 8.2)). 1 subject was used to test the functionality of the sensor. ECG and EEG signals were recorded once by a single subject.

Advantages: Wireless technology.
Disadvantages: The prototype is obsolete.
Outcomes: A prototype was delivered which "has to be miniaturized in the future work in order to fit into a headband or a cap".
Comparison to ADAS&ME: Wireless sensors will be part of the ADAS&ME. The presented technology is outdated. Off the shelf solutions exist.

Jap, B. T., Lal, S., & Fischer, P. (2011). Comparing combinations of EEG activity in train drivers during monotonous driving. Expert Systems with Applications, 38(1), 996-1003.

Investigation of several frequency related measures that could act as fatigue indicators evaluated using simulation driving sessions. A computer-based train driver simulator, Trainz Classics Railroad Simulator 1st and 2nd edition (Auran Holdings Pty Ltd., Australia), was used. Simultaneous physiological recording was obtained during the monotonous train-driving session using FlexComp physiological system (ThoughtTechnology Ltd., USA). Two channels of EEG (from frontal and temporal sites) and one channel of electrooculogram (EOG) were acquired with a sample rate of 2048 samples per second. A bipolar montage was used when recording the EEG channels. A bipolar montage recorded the difference between two active EEG electrodes (Stern & Engel, 2005). The international 10–20 system for EEG electrode placement was used when attaching the active electrodes (Jasper, 1958). The two active electrodes for the frontal site were attached at the Frontal-Polar 1 (FP1) and FP2 sites, and to the temporal, T3 and T4 sites. The reference electrodes were attached to the ear lobes to reduce the common-mode noise present at the active electrodes (Winter & Webster, 1983). The EOG was used to identify blinks artefacts. Blood pressure and heart rate was recorded before and after the driving task. Analysis performed using in-house software, developed with LabVIEW programming language (National Instrument, version 8.2). A total of 50 male train drivers, aged 21–65 years. All participants were asked to complete 30–40 min of a monotonous driving session. The participants were allowed approximately 5 min of practice driving session to be familiarised them with the controls used to drive the train. After the practice driving session, the monotonous driving session commenced. Participants were instructed to drive the train as normal, and to pick up passengers at all stations. Statistical analysis was performed for consecutive time segments (ANOVA and Post-hoc Fisher LSD analysis was applied following ANOVA to identify where exactly the differences existed.

Due to the extent of the results section only the major finding is reported here: Significant differences was also found for equation (theta + alpha)/beta between S2 and S3 (p = 0.01), S4 (p = 0.004), S5 (p = 0.01), and S8 (p = 0.01), and between S4 and S6 (p = 0.03), and between S5 and S6 (p = 0.048).Where S_i, i=1,2,…,10 are consecutive non overlapping sections.

Advantages: The results seem to be in agreement with the literature. The measures/indicators presented can be easily estimated. Very few electrodes required.
Disadvantages: The fatigue state is subjectively assigned.
Outcomes: Simultaneous decreases in beta and increases in theta activity have been shown as the train drivers entered the repetitive phase of transition from the alert state to a fatigued state. A greater amplitude of difference between the alert and fatigued state was found when using the computation based on (theta+alpha)/beta. The results of the current study indicate that the outcome of using the equation (theta+alpha)/beta, combined with detecting decreases in beta and increases in theta activity, can be utilised as an indicator of fatigue and for implementation of EEG based countermeasures. **Comparison to ADAS&ME:** The proposed indicators could be part of ADAS&ME "indicator's bank".