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Adapted Human Machine Interaction concept for Driver Assistance Systems DrivEasy

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Abstract: Thanks to the important improvements in perception technologies as well as computing efficiency the development of Driver Assistance Systems is now a real growing market. Nevertheless these new functions that interact with the drivers are not without acceptance problems from the users. The DrivEasy concept that is presented within this paper is proposing adaptive solutions taking care about the current and contextual situations to improve the efficiency of such systems.

Keywords: ADAS, perception, HMI, diagnostic, classification, adaptive

1 INTRODUCTION

After two decades of continuous technological progresses leading to reliable, safe and comfortable vehicles, new automotive concepts are emerging. This evolution develops on three main axes: a change in society values, new practices, and important technological evolutions. The first axis leads to a complete redefinition of the automotive mobility

- A new class of population is accessing to mobility in emerging countries while in developed countries new driver profiles emerge with the ageing of the population, and people who want to preserve their mobility.
- The increase of urban conurbation and the generalization of traffic issues are changing the context of driving. Furthermore wealth is more and more concentrated in megalopolis and in the seashore while country side is deserted. This concentration leads to local issues.
- The reference values are changing: engine capacity and power are not anymore the first attempt but more ecology and citizen responsibility. Many drivers are expecting a stress free driving.

In addition to these deep changes in society values, new practices are being observed.

- New information and communication technologies such as mobile phone and internet allow citizens to be always and everywhere connected to their information ecosystem, to communicate between themselves or with dedicated infrastructures and service providers
- The increasing cost of energy, the growing ecological awareness as well as the constant safety requirements and traffic rule pressures are redefining the use of vehicle.
- Evolutions of practices are re-defining the role of the vehicle and by consequence the driving task itself

Last but not least the technological evolutions are supporting these sociologic and custom changes

- The tremendous development of information and digital technologies are supporting the raise of the services contributing to stress free driving
- The development of new Human Machine Interface, more intuitive, including haptic devices, head up display technologies ... allow better human machine cooperation.
- The automatization of the vehicles started many years ago (engine control, automatic starter, ABS, ESP...) and more recently the development of Advanced Driver Assistance Systems (ADAS) has generated a real technological break. These new functions inform the drivers, warn them in critical situation or even substitute them. They relieve the driver mental workload and help the respect of the driving rules to increase safety, to save energy, while keeping a good mobility. ADAS includes for example Navigation Systems, Lane Departure Warning and Lane Keeping Systems, Traffic sign recognition, Headlight assist, Pedestrian detection, Automated Collision Avoidance systems (e.g. Adaptive Cruise Control), speed control (e.g. Intelligent Speed Adaptation (ISA)), Parking assist etc... Such developments have been supported by new smart sensor generations able to fulfill automotive constraints like Radar, Cameras, Lidar, GPS, wireless technologies as well as data fusion techniques.

Nevertheless, the deployment in the vehicles of such new assistance concepts requires a good acceptance and legibility from the drivers. Thus the design of the corresponding driver/system interaction and HMI is a critical issue. Formerly the design of HMI inside vehicles was following a very simple process "one function = one interface". A first generation of ADAS systems was designed following such a process and led to a juxtaposition of information. The complexity of use and the relative lack of flexibility were not really adapted to the human dimension, driver situation, capacity, needs and requirements. The result of these first tentatives was a poor acceptance of such systems resulting in low production quantity and high cost. This approach is not anymore acceptable because of the increasing number of information available and the drivers' expectations.

New Human Machine Interaction design principles must be considered to overcome these problems. They should use multimodal interfaces mixing different communication modalities, depending on the context and the task to be performed, as well as adaptive interactions. They should focus in two major directions:

- **Transparence**: These concepts must appear as much transparent as possible to the users. They must not interrupt his mind and action flows. Thus they should use familiar and natural interface principles. They should assist the driver in his driving task providing adapted information (to the driver, to the vehicle, to the environment) and advices in an intuitive and none intrusive way. They should reduce the large quantity of information from the car and the driver and filter that information to give a better desired assistance.

- **Personalization**: The interactive experience target is to create an emphatic relation between the system and the driver in order to encourage the usage of the system in a permanent way. The driver has the possibility to configure the assistance systems in relation with his understanding and capacity. Moreover he should be assisted to perform this configuration or part of the configuration could be done automatically by the system.

The DrivEasy concept presented in this paper is one of the first "real dimension" tentative to design and demonstrate a complete and global human centered ADAS. The main object is to develop a new Human Machine Interaction concept increasing vehicle/Driver/Passenger safety providing legible, adapted and accepted assistance to all drivers. The elaboration of this concept assumes that information about the driver and the vehicle environment are available. Thus, a specific attention has been paid to the development of **various driver monitoring and supervision systems involving the design of complex real time algorithms**. Furthermore, DrivEasy has been designed as **an open modular architecture**. This architecture can easily be adapted to various existing or future ADAS and constantly enriched with additional information about the driver and the vehicle environment.

In a first step, information provided by existing driver assistance functions like lane departure warning and obstacle detection were used to demonstrate the adaption of the warnings to both the driver and the situation.

DrivEasy concept was implemented into an experimental vehicle and tested in real use conditions.

This paper proposes a global overview about DrivEasy. The general concept is described in section 2; the various modules are introduced in section 3. The vehicle implementation is explained in section 4. The in-vehicle real driving evaluation and experimental results of the acceptability study are given in section 5.

2 DRIVEASY concept

DrivEasy is an interaction concept that autonomously decides *when* and *how* the driver has to be informed about the current issues. Depending on the situation and the context, it selects the most appropriate interaction mode and the best suited level to communicate information/alerts, as explained below.

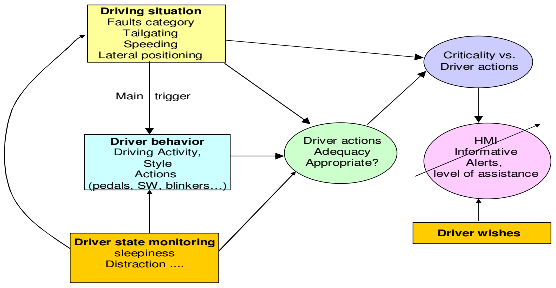


Figure 1: DrivEasy concept

In order to decide on the most appropriate interaction, the system does a cross analysis of the following information: (see

Figure 1).

- **The driving situation**

This is the main trigger, when a driving fault is detected by any assistance system. For example, it could be an unexpected lateral deviation of the vehicle, an over speeding violation... This information is provided by on board ADAS.

- **The driver state monitoring**

Information about the driver state is provided by specific on-board applications based on the observation of the driver with cameras or deduced from the analysis of driver and vehicle behaviors.

Depending on his state (alert, drowsy, distracted), his awareness about the situation can change and his sensitiveness to particular modalities (e.g.: visual /vs. audio) can be altered. Furthermore his behavior and reaction to specific issues should be modified; e.g. a drowsy driver has not the same reaction time than an awaked driver.

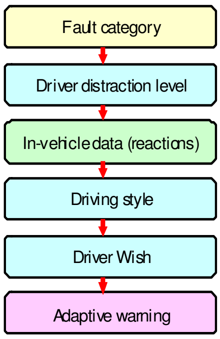
- **The driver behavior**

The behavior of the driver is characterized by the driving profile (relax, normal, sporty...). It has a direct impact on the evaluation of the risks. For example, a sporty driver driving on a curved road should not have the same behavior than a cool driver. In some situations he could for example "cut" the curves and overpass the central white line. Then the system should be a bit more tolerant, filtering some driving faults, otherwise the driver would be "bored" with too many warning messages. The Driving style is estimated through the observation and data fusion of in-vehicle parameters and ADAS information. The real time analysis of the driver actions-reactions (*e.g.*: braking in case of obstacle detection or reducing speed in case of over speeding) has to be considered when determining the timing and level of information to be displayed.

- **The driver wishes for assistance**

Last but not least, it is important to consider the wishes of the drivers themselves. Some of them are expecting a very high assistance while others would prefer a limited assistance that will only be active in very critical situation. Several levels of assistance may be considered: no assistance, low, medium, high assistance.

- **DrivEasy decision principles**



This information is analyzed thanks to a set of decision rules to provide the driver with an adapted, scalable assistance, removing all un-necessary warning. The fault category is the main driver of this process as it appears in Figure 2. In the event of a fault, is the driver taking some corrective actions and are they enough to guarantee a good safety?

Figure 2: DrivEasy logic

A very simple example of decision rule is given in Figure 3. This use case combines the lateral departure and distraction information. The information displayed to the driver in case of abnormal lateral deviation is adapted with respect to his level of distraction. The level of distraction is provided by the values provided by two indicators VTSD and VDD (see 3.2.2). The lateral position category is issued from the information provided by the lane departure warning system and allows detecting abnormal driving situations (see 3.3.1). Additionally the system informs the driver when he is inattentive during a too long period. At last when a problem is detected an inhibition timer avoids displaying again warnings during a given period. On this diagram it can easily be understood that the system provides more freedom to the driver in case of normal driving. Stronger messages are only displayed when the driver is distracted and lateral deviations are detected. Otherwise softer messages are provided.

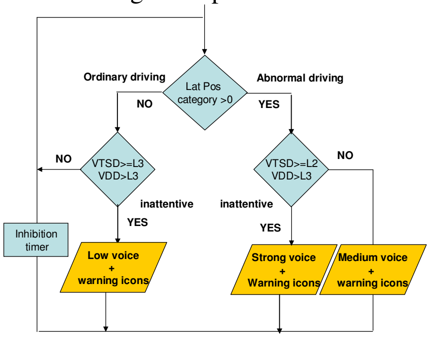


Figure 3: Example decision rule architecture

Of course this decision rules can be also adapted taking care of the driver's wishes, driving profiles and current actions of the driver (see Figure 2)
Such decision algorithms have been designed for all the situations that can be foreseen with the various available data (Tailgating, speeding, lateral positioning and driver state).

3 DrivEasy modules

DrivEasy is a modular concept including several modules contributing to the knowledge about the driver and the vehicle environment. The data provided by these modules are then fused in order to provide the driver with adapted information. The following paragraphs are describing the various modules that are currently implemented.

3.1 The driver behavior module

The Driver behavior is characterized by the driving style of the driver, which estimation is based on the observation of in vehicle parameters and provides a 3 levels diagnostic estimate: relaxed, normal, nervous.

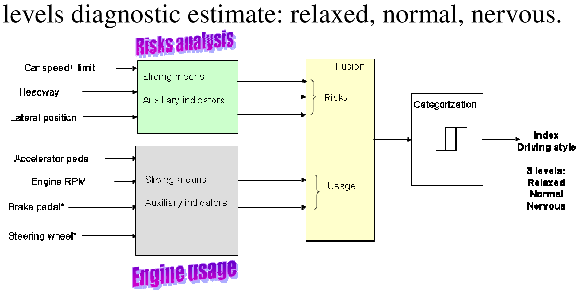


Figure 4 Driver style assessment module

The driving style is drawn from the analysis of the risks during driving fused with the way the driver uses the engine. The risk evaluation was conforming to Janssen et al. (2008) which was drawn from Batley R. (2005) and Carsten, O. *et al*, (2005)... Stated Preferences study. The engine usage is evaluated from the accelerator activity and position and from the gear shift strategy.

3.2 The Driver state monitoring module

The driver state diagnostic is based on the real time monitoring of two independent parameters, **the drowsiness level** (sleepiness vs. awakeness) and **the visual inattention** (e.g. the driver "is/is not" looking to the road) see *Figure* 5..

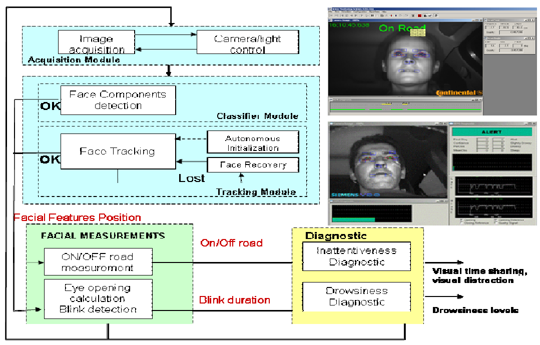


Figure 5: Architecture of the Driver monitoring

The Driver state monitoring includes a compact low consumption and high dynamic range (120db) CMOS camera sensor. The camera is equipped with a global shutter for the synchronization with a set of pulsed NIR lights (850nm). Algorithms are implemented in a distant processing unit (DDS and DDM computer in Figure). This set of algorithms analyzes in real time the image flow provided by the camera to extract information about the driver's eyelid and blinking patterns)(see

Boverie et *al 2008),* the head position and orientation. It delivers a four levels vigilance diagnostic and two inattention diagnostics: the estimation of the visual distraction level (VDD) and the visual time sharing level (VTSD). The system is fully automatic and works by night and day.

3.2.1 Driver drowsiness assessment

The driver drowsiness algorithms are based on the real time analysis of the driver's eyelid movements and closure duration. The algorithms are divided in several modules (see Figure 5*) (*see Boverie *et al 2008):*

- o Within the image provided by the camera the initialization process detects the driver's face as well as different small characteristic regions from it (features): eyes, eyes corners, mouth, nose and nostrils.
- o The face tracking tracks in real time, within the image flow, those features using kalmann filtering.

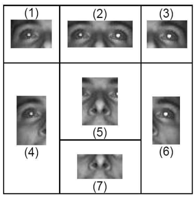
It should be noticed that this feature approach allows robust eye detection, in real time, by reducing the image analysis to the feature regions. Nevertheless it requires an accurate localization of a minimal set of features including the eyes corners, the corner of the mouth and the eyebrows. Thus the field of view of the camera must include the driver's face from the chin to the eyebrows.

- o The facial measurement uses the output of the face tracker to rebuild a model of the driver's eyes and eyelids, to extract the eyelid patterns and provides the blink detection duration information.
- o A fuzzy rule based diagnostic classifies the blinks in accordance with their duration and depending on the blinks from each class (short, medium, long, very long).

It provides an estimation of the driver state (Boverie *et al.*2002). Four different classes are used to qualify the driver's vigilance level: Alert, Slightly Drowsy, Drowsy and Sleepy.

3.2.2 Driver inattention

The Driver's inattention module is based on the estimation of the head orientation classifying the head position in two classes On Road vs. Off Road. The algorithms are using a learning based approach (ADABOOST) and Viola Jones classifiers which are trained on a huge data base including a large variety of driver face appearances (men, women, different hairs and skin colors, glasses, etc). Only the On Road pose (Mono pose detector) is learned. In order to guarantee good computational performances 7 face regions (components) are considered, that is enough to ensure the robustness of the classification: Right Eye, Nose Bridge, Left Eye, Right Cheek, Whole Nose, Left Cheek, Nostrils (see Figure 65). Each component is learned off-line with a low resolution input image (Adaboost). The components are selected using inter component geometrical constraints (relaxation), Three size Viola Jones classifiers are used to take into account scale factors. The algorithm output a score map by classifier (components positions for which the component scores are above a define threshold). The best classifier map using maximum score criteria is then selected and the outlier position are filtered using a blob-like filtering.



The final decision is based on the number/type of components detected. When a minimum number of components correctly placed are detected the driver head gaze is classified "On road" else "Off road".

Figure 6: Components for inattention

The module provides two inattention indicators.

The VDD (Visual Distraction Detection) that measures short momentary distractions -eyes-off-road- from the road scene ahead. The VDD is classified in 4 categories depending on the off-road glance duration $VDD \in [L0, L1, L2, L3]$.

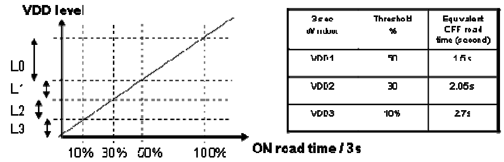


Figure 7: VDD estimation

The VTSD (Visual Time sharing distraction) - when the driver is continuously sharing his/her visual focus between the road ahead and something else- The VTSD depends on the sum of off-road time durations on a given time window. The VTSD is classified in 4 categories depending on the percentage of off-road time vs. the reference window duration (see **Figure 8**): $VTSD \in [L0, L1, L2, L3]$ - from not critical L0, when most of the time the driver is looking to the road to very critical L3, when the driver is looking to the road less than 15% (for VTSD) of the time on the reference time window.

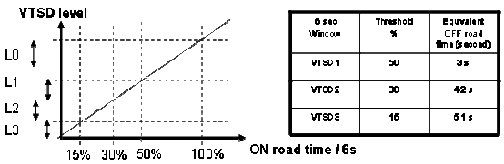


Figure 8: VTSD estimation

3.3 Driving situation

The driving situation is provided by the on-board ADAS. In that experimental vehicle 3 ADAS are implemented, providing the lateral position of the vehicle, the distance to the vehicle ahead (tailgating) and the speed limitation information. A short description of these systems is given below.

3.3.1 The Lateral position of the vehicle

Lane departure Warning algorithms are processing the image provided by a camera looking ahead the vehicle. From these images the right and left distance to the road line marking are estimated. The lateral behavior of the vehicle is analyzed and abnormal behaviors identified. The module provides a 3 level risk indicator (normal, abnormal, critical) that is a function of the abnormal behaviors characteristic: occurrence, repetitvity, criticity.

3.3.2 The tailgating information

A multi beam ACC lidar is observing the road ahead the vehicle and measuring the distance to on-road moving obstacles. A time to Collision (TTC) is estimated from this distance and the current vehicle speed. The module provides a 4 levels risk indicator (no risk, low risk, medium risk, critical) that is a function of TTC value.

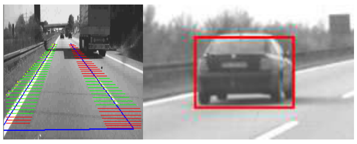


Figure 9: Obstacle detection and lateral position

3.3.3 The speed limit module

The GPS system provides an accurate positioning of the vehicle. A data base including the legal speed limits is loaded in the system or learnt for specific areas. Then a match between real time position and database is performed to give overspeeding information. This module provides a 4 level risk indicator as above that is a function of the over speeding value (see Figure 10).

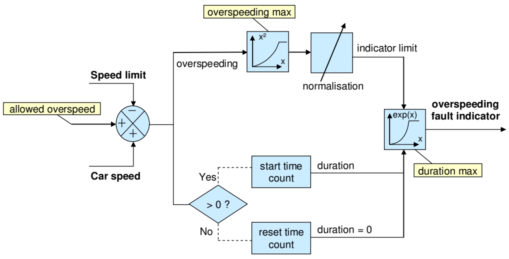


Figure 10: Speed limit module principles

3.4 Driver wishes

It is important that the driver should have the possibility to configure himself the level of assistance he requires from the system depending on his understanding and capacity. This function allows doing so. The driver can select his level of assistance among several possibilities:

No Assistance: the driver doesn't want any assistance; the system only cares about avoiding crashes, no early warning is given.

Low Assistance: The system warns the driver only in case of critical issues.

Normal Assistance: The system warns the driver in case of unusual driving errors and using soft warnings.

High Assistance: The system cares for vehicle safety, looks for a tight usage of driving rules and provides a strong support to the driver. This level is more intrusive.

Economy: in addition to the high assistance, the system provides some guidance information concerning engine and gear usage. This level is even more intrusive.

4 Demo car equipment

4.1 In vehicle information

The vehicle has been equipped with different sensors: Driver monitoring camera, Lidar, Front camera, GPS. Additionally all the information displayed on the vehicle communication buses (CAN) is available: Speed, tachometer, steering angle, pedal activation, etc.

Various functions exploiting these sensors have been implemented in several computers installed in the vehicle:

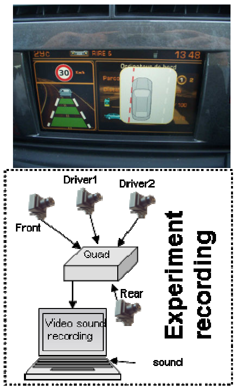
- Driver Drowsiness Monitoring (DDM)
- Driver Visual Distraction Monitoring (DDS)
- Driving Style (DS)
- Lane departure warning (LDW)
- Tailgating
- Speed limit data base coupled with GPS

Figure 11: Sensors implemented onto the vehicle

Several HMI components are implemented into the vehicle combining different modalities:

Visual information is displayed onto the central console display. They include: informative data (limits), visual warnings, tuning button.

Audio information is using the embedded vehicle audio. Both Sound and voice are used as audio warnings.



Haptic warnings have also been implemented: seat with lateral vibration and vibrating gas pedal.

Turn push button associated with a visual and audio feed back for displaying and selecting the driver's wishes. For acceptability study, video recording of driver and environment is performed in order to be able to replay some specific situations. 4 additional cameras are connected to a PC which records video and sound.

4.2 In-vehicle architecture

A specific open architecture has been designed to implement all these sensors and functionalities. It includes a dedicated CAN bus, Several PCs, Pathway to dialog with the vehicle communication buses

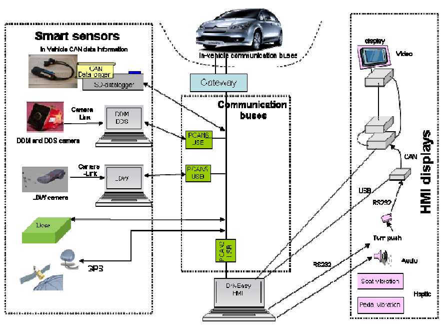


Figure 12: DrivEasy in-vehicle architecture

5 Experimentations

5.1 Objectives of the experimentations

Assess the acceptability of the concept and its influence on the driving performance.

5.2 Set up of the experimentations

For each driver the experimentation was performed on a mixed circuit on open road including, urban conditions, peri-urban, freeways and highways. The experiments have been performed with a set of 12 drivers (from 28 to 55 years), including only one woman plus 3 reference-drivers for check. During each experiment the driver is accompanied by a test supervisor.

Prior to the experiment the car equipment was presented to each driver. Additionally each driver had to fulfill a preliminary questionnaire about road perception.

The experiments were performed in two phases on the same circuit; the first without DrivEasy and the second with DrivEasy, giving the driver the possibility to select his level of assistance. During the experiment all available in vehicle parameters as well as ADAS parameters were recorded. Additionally videos of the driver and the vehicle environment (ahead and back of the vehicle) were recorded. All the driving events were also recorded by the test supervisor. After the experiment the driver had to fulfill a satisfaction and acceptability questionnaire.

5.3 Results

The questionnaire about road perception before driving was composed of typical situations description, and the driver had to answer how he would react to these situations. The situations describing questions relative to similar areas were aggregated to provide a score, which finally was presented on a radar type display, (see Figure 13).

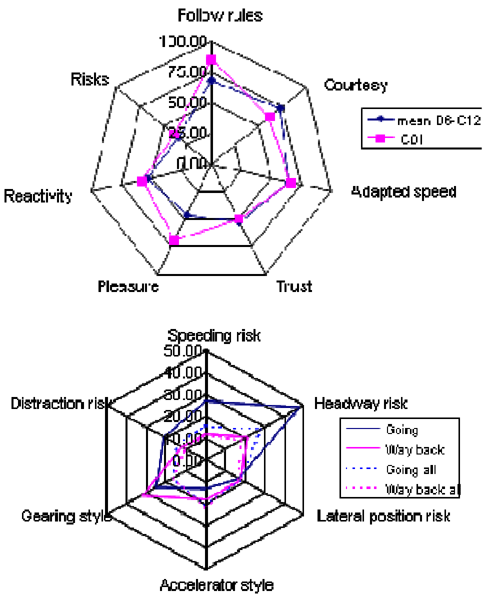


Figure 13: synthetic results to the questionnaire

The data on the effective calculated driving risks and style were recorded and averaged over the test phase and displayed again as a radar image. Then, objective data concerning the car parameters were analyzed (consumption, travel time...)

On this example we can see that despite the fact this driver was more nervous during the way back (increase for both accelerator and gearing), the speeding and tailgating risks decrease, the efficiency was better and fuel consumption was lower.

Finally, some statistics were built using all test data to smooth a single test influence and to assess a global tendency for risk benefit and acceptability of the test drivers towards this innovative concept.

	Driver C01:		Average:	
	Go	back	Go	back
Speeding risk	27.00	12.00	15.58	11.42
Headway risk	48.00	21.00	28.25	18.33
Lateral position risk	17.00	18.00	18.00	16.67
Accelerator style	13.00	18.00	20.75	21.75
Gearing style	25.00	32.00	16.42	16.42
Distraction risk	21.00	12.00	14.50	10.33
Driving time (s)	3243.00	3350.00	3356.33	3411.50
Mean speed	72.00	70.00	69.17	68.75
Consumption (liters	5.19	4.99	4.96	4.72
Meteo:	Cloudy	Cloudy		
Driving style declared /10:	6	4		
Efficiency (km/h per litre):	13.9	14.0	13.9	14.6
Mean risks	28.25	15.75	19.08	14.19

6 Conclusion

A new concept using many already available functions of modern cars have been designed and implemented in a car to provide an adaptive assistance in order to influence the driver behavior without acting effectively on the car. This assistance is customizable with the aim to provide a greater acceptance and to allow all drivers to take benefit of these technologies. The result of acceptance study of the DrivEasy concept showed a high demand of informative data on the environment. The specific filtering was appreciated and proved to be efficient to decrease the driving risks especially when the driver was adhering to the concept. As far as the system aims at influencing the driving behavior, it should be further tested on a larger scale using different car types and many drivers' profiles. The tuning of the system is a compromise and allows each car manufacturer to impulse a different spirit for differentiation.

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