HMI FOR ELDERLY AND DISABLED DRIVERS TO GET SAFELY REAL-TIME WARNINGS AND INFORMATION WHILE DRIVING

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ABSTRACT

Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) are growing in importance within vehicle on-board telematics. However, most automotive industries focus mainly on the needs of average driver cohort, thus the needs of other particular driver cohorts are in many cases overseen. Provision of in-vehicle Information and Communication Technologies (ICT)-based services in conjunction to the ADAS, needs careful design in order to avoid conflicts (when an ADAS warning and information arrive concurrently at a channel) and not increase the workload, especially of elderly and disabled drivers (due to their specific needs and limitations), when applied on top of the overall driving task responsibility and complex traffic environments. The paper presents developments and evaluation results from research projects, focusing on the Human Machine Interaction (HMI) and algorithms proposed to be used for the presentation of information and warning messages to a disabled or elderly driver, through an on-board display channel or a nomadic device (e.g. mobile phone) while driving. Evaluation results with drivers from three European countries are included.

Keywords: ADAS, IVIS, mobility impaired drivers, elderly drivers, HMI, adaptation

INTRODUCTION

Special in-vehicle services have been developed in ASK-IT research project, aiming to cover the needs of mobility impaired (including both elderly and disabled) persons (Bekiaris et al, 2007). One of the main focus groups in the project have been the mobility-impaired drivers. These in-vehicle services have been adapted in terms of HMI and functionality for the specific target group. Both ADAS and IVIS have been integrated in the final system. These specific services developed within ASK-IT have been further enhanced, optimised and integrated in the framework of a next generation project, called OASIS (Leuteritz et al., 2009). OASIS special focus was on elderly users. Among the developed services, specific applications were built for the elderly drivers.

The main aim of ASK-IT and OASIS in-vehicle services was to warn drivers in a simple way, through a nomadic device (either a PDA or their mobile device, which is responsible for the processing of vehicle's data and for providing the appropriate output message to the driver). The advantage of using the driver's mobile device for warning or information is than it can be applied to vehicles that do not contain dashboard screen and also to vehicles that although they may include a dashboard screen, it is not feasible to access it and display any software application on it.

State of the art

Most automotive industries focus mainly on the needs of ordinary driver cohort. This however excludes, in many cases, the needs of other particular driver cohorts. Specific research on the ADAS/IVICS functionalities and HMI preferences of special user groups are also rather scarce to find. An algorithm that takes into account the needs of the elderly and disabled drivers, when offering ADAS and IVIS support has not been implemented so far. Elderly drivers have specific problems that are due to the age related deterioration of their physical functionalities. Among the usual problems they have is the increase of reaction time, their difficulty in driving in complex traffic environments, in complex intersections, etc. They also have specific needs in terms of the user interface (UI) type that provides the information/warning. Similarly, drivers with various disabilities (i.e. motor or hearing ones) have specific needs regarding the use of Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) HMI. In general, drivers with special needs prefer longer headways than the standard driver (TELAID Project, 1993). Different problems exist depending on the type of disability. Indicatively, it is mentioned that people with problems on the upper body encounter difficulties in reaching equipment placed at certain angles and have a limited field of vision (LFV) because they cannot turn around. In conclusion, MI drivers need special HMI to support them in their particular needs, that will provide warning in appropriate time (probably earlier comparing to other drivers) and at the right timing/modality.

Advanced age affects cognitive perception and consequent visual field limitations increase accident risk for elderly drivers. The application of a nomadic device (PDA, mobile phone) controlled system targeting to increase comfort and alleviate stress would enhance quality of stress control and allow elder drivers to manage driving activities with increased confidence. Moreover, dynamic driving variables (e.g. lateral and longitudinal acceleration) allow the drivers to adjust 'risky' behaviour and increase driver and road safety. Such a system is expected to support and supplement driving skills which are declining with age. Familiarization with the system helps the drivers to improve driving behaviour due to age-related impairments. Thus, these drivers need specially adapted HMI to support them in their particular needs that will provide them with warning and information in appropriate time, at the right sequence and through an appropriate for them modality.

METHODOLOGY

Based on a thorough survey (from literature, research and evaluation results) on the relevant critical gaps in the design and development of ADAS and in-vehicle information systems, the main needs of elderly and mobility-impaired drivers for using efficiently and benefit optimally from such systems were defined within the ASK-IT project. Taking into account the main issues to be considered for the optimisation of ADAS warning/information messages for elderly and disabled drivers, specific algorithms for HMI adaptations have been extracted.

The ADAS considered (which have been included both in ASK-IT and OASIS systems) are the following:

- Adaptive Cruise Control (ACC) and Collision Avoidance System (CAS)
- Lane Departure Warning (LDW).
- Driver Monitoring (through a specifically equipped driver seat, focusing mainly on fatigue monitoring).

The goal was to adapt the functionalities of the above ADAS to mobility-impaired user groups, while at the same time providing the ASK-IT services to the driver, also properly adapted. Conflicts, such as when an ADAS and an ASK-IT info are concurrently arriving at a channel for being given to the driver, are handled. The hypothesis is that the driver keeps receiving the ASK-IT info from his/her ASK-IT nomad device and no transfer to an in-vehicle system takes place. On the other hand, the ASK-IT nomad device is connected to the car through a Bluetooth gateway. Thus, the ASK-IT services HMI adaptation is presupposed to have taken place for the MI users. Only the related ADAS HMI is thus adapted, when needed. As a conclusion, the requirements of this part of the system were:

- to adapt the selected ADAS warning algorithms and/or HMI to the needs of the specific MI users;
- to adapt (limit) the ASK-IT services while the vehicle is on the move;
- to synchronise the operation of ADAS with ASK-IT services provision.

ADAS HMI adaptation rules

ADAS warning and related HMI may be adapted to the needs of mobility-impaired users in terms of:

- o timing of warning;
- o modality of warning;

- o intensity of warning.

Adaptation rules have been developed for the selected ADAS, per user group type. Here, the algorithms for the driver monitoring are included indicatively, in the table that follows.

Table I – HMI adaptation rules for the driver monitoring system

MI user group	**Adaptation of timing**	**Adaptation of modality**	**Adaptation of intensity**
1. Hearing	Not applicable	Haptic, with visual as secondary information mode (instead of vocal). Alternatives: seat belt vibration, seat vibration, brake pulses, etc.	Not applicable
2. Colour blindness	Not applicable	Adaptation of colours/ frequency at the secondary warning and status LEDs at central mirror.	Not applicable
3. Illiterate	Not applicable	Simplified vocal outputs: sound and message "Stop driving, you are too tired!".	Not applicable
4. Elderly	Adaptation of sensors and algorithms to focus upon elderly drivers' hypovigilance peaks (at mid-day instead of midnight). Eyelid camera with shutter function and monitoring algorithm adaptation.	Vocal and haptic feedback lights and LEDs are not visible, even as secondary feedback channels at midday.	Mild intensity, longer duration (not to startle the elderly driver).
5. Upper limbs	Not applicable	Alternative system on/off operation, without hands.	Not applicable

According to the above table, the HMI is adapted in terms of timing, modality and intensity, according to the driver type.

In-vehicle information services adaptation rules

The project analysed an IVIS environment. The modality to access services and the user interaction mode have been selected as high priority issues. As definition, IVIS represent a set of telematic applications for mobility, providing support to the user during a trip or while planning the trip him/herself. Two main concepts are hidden in IVIS:

- the personalization of contents and so the possibility to receive information and instruction from a control centre → on line services,
- the device personalization and adaptation to user needs and impairments → HMI issue and personal device usage.

ASK IT dealt with both the service and content preparation on the one side, and on the other side with the development of the needed tools to guarantee the opportunity to use the personal device and HMI in different context.

Thus, further to the ADAS HMI adaptation (see above), specific rules have been developed to adapt in-vehicle information services, when the mobility impaired user is in the car. The idea is that the services are automatically implemented when the vehicle travels faster than a predefined speed limit (selected to be between 10-15km/h). Examples of these rules are included in the following table, focusing on elderly drivers needs, as regards the ASK-IT information services.

Table II: ASK-IT services adaptation rules for elderly drivers to be applied in an in-vehicle environment.

ASK-IT service	**Generic adaptation**	**Additional for elderly drivers**
Receive reminders on everyday events		Vocal reminder, with visual feedback at PDA or automotive screen.
Get info on domotic status	Request given vocally or else disabled.	Vocal feedback on specific home device status.
Control domotic functionalities	Command given vocally or else disabled.	Vocal feedback on specific home device status.
Get info on POI	Info on POI given automatically, without the need for 'click'.	Visual feedback on map. Rest info acoustic.
Pushed touristic/ personal info	Pushed info on nearest gas stations in case if low gas level.	Vocal warning and visual info on map.
User requesting help	Connection to button on steering wheel. Automatically cutting-off gas and operating alarms.	Vocal feedback. Vocal and visual feedback.

Of course, there are several services that are disabled when the driver is in the vehicle, such as establishment of contacts, meetings, e-payments, e-bookings, etc., as they put further workload to the driver and are considered dangerous to be performed while driving. As a general rule, ADAS warnings have priority over all other services offered to the drivers while driving. Thus, when an ADAS message is given, the other, secondary messages will be interrupted or delayed by, e.g. 20 seconds.

APPLICATION OF ALGORITHMS IN OASIS SERVICES

The algorithms described above were applied and further optimised for elderly drivers needs, within applications and services that were developed in OASIS project.

Lane deviation and frontal collision warning systems

The research vehicle (Lancia Thesis) of the Hellenic Institute of Transport is instrumented with a Lane Departure System. A camera is fixed behind the windshield, near to the central rear-view mirror. The Lane Departure unit is controlled by electronic control units (ECUs) and their messages are also retrieved by an industrial PC.

A frontal radar is used in order to measure the headway. It is located in the vehicle's frontal bumper. The driver is warned when the headway is below the limit threshold. The limit is set with the default value of 1.1 seconds (Visintainer et al., 2010). Thus, in practice the HMI for elderly is adapted in terms of timing of the warning provision.

Figure 1: Frontal radar

The lane deviation and frontal collision systems are connected with Symbian mobile devices. They are enabled when one of the OASIS applications is running and the driver is on the road. The Symbian device retrieves the values of the CAN signals from the vehicle industrial PC and then it generates the corresponding type of message to the driver. The physical connection between Symbian OS device and the industrial PC is both wired and wireless, as an alternative solution. Thus, in case there is a Lane Departure warning, the industrial PC will send it to Symbian OS mobile device.

Driver monitoring

One of the main objectives of OASIS was to provide comfort support services to the elderly driver. A sensing seat has been installed in the research vehicle.

Figure 2: The sensing seat within vehicle

The vehicle PC software application which collects data from seat sensors estimates the driver’s stress status and finally it sends the information to the Symbian mobile device. The mobile device which is located next to driver enables the corresponding warning or informative message to the driver.

Figure 3: Mobile device location in the Lancia Thesis vehicle

In addition to the sensing seat system described above, a wearable multi-parametric monitoring system was integrated in the same research vehicle CAN bus network, for the wireless detection of the driver fatigue. The system helps to automatically identify and address major driver fatigue deficits. During his/her driving, the performance of a subject is continuously evaluated in order to recognize immediately the onset of possible problems related to reduced performances correlated to fatigue. The system is able to acquire surface electromiographic (sEMG) and electrocardiographic (ECG) signals, as well as behavioural activity through micro-accelerometers and intelligent signal processing algorithms.

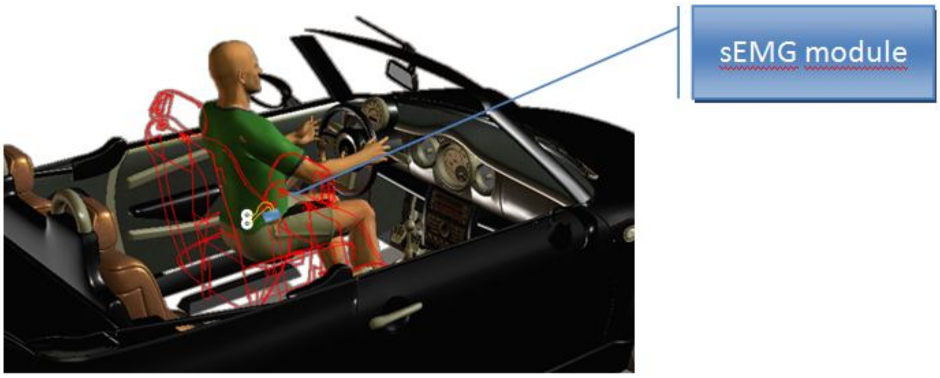

Figure 4: sEMG module position

Traffic information and navigation

A real-time traffic information service was developed in OASIS Integrated Project, whose aim is to offer support for elderly users making trips by car (Spence et al., 2011). The objective of the development carried out for OASIS was to create an 'elderly-friendly' interface for smart phones which would make easy for users to obtain traffic information before or during a car journey. The service includes traffic information for accidents, roadworks, queues and traffic congestion and dangerous weather conditions (e.g. snow, fog, flooding, etc.). The road name is accompanied by information regarding the presence of any traffic problems (colour coded to show how critical is the event) and the number of events which have been reported. The location of a traffic event can be viewed in map form at two levels of zoom. The travel information service is available through a PDA.

The principal objective of the interface design was to make available all necessary information, but to keep the interaction as simple as possible for the user. In practice, this was achieved by using 'easy-to-understand' icons instead of text, where possible, by adopting a colour code to indicate the traffic problem criticality and by presenting a minimum of information on the screen (further details can be viewed by the driver upon request on a second step).

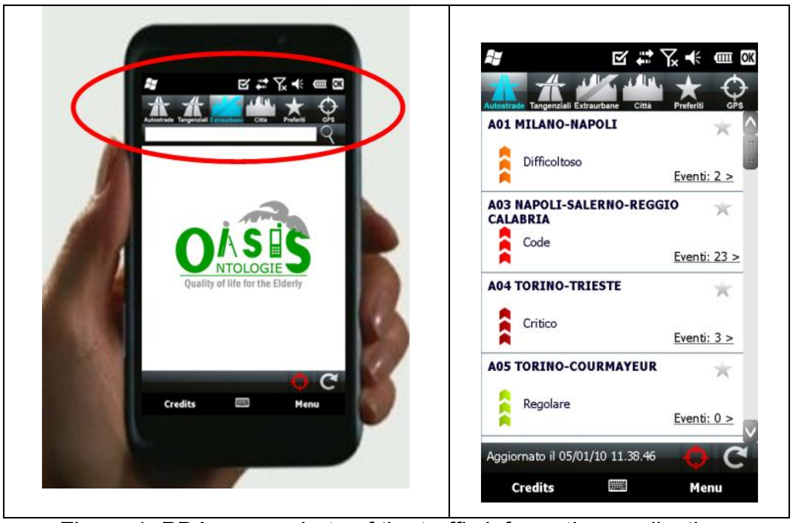

Figure 1: PDA screenshots of the traffic information application

EVALUATION RESULTS

Results from the Greek pilots

33 elderly users evaluated the OASIS in-vehicle services, through driving in a controlled environment, thus accident data is not available at this point. These users were recruited through a call that was announced on the website of the Hellenic Institute of Transport, as well as through visits at elderly recreation centers. The sample was representative in terms of age groups (mean age: 64 years old) gender (19 male, 14 female).

Four key questions were asked about the usefulness, reliability, privacy and contribution to health and wellbeing. Participants were asked to rank the in-vehicle services in a scale of 1-5. The following figure presents the results in terms of the perceived usefulness by the participating elderly drivers. Clearly, the vast majority of the drivers (64%) stated that the applications tested were very useful. Also, a significant number of them (24%) found the services quite useful, while only 4 provided a neutral or negative reply.

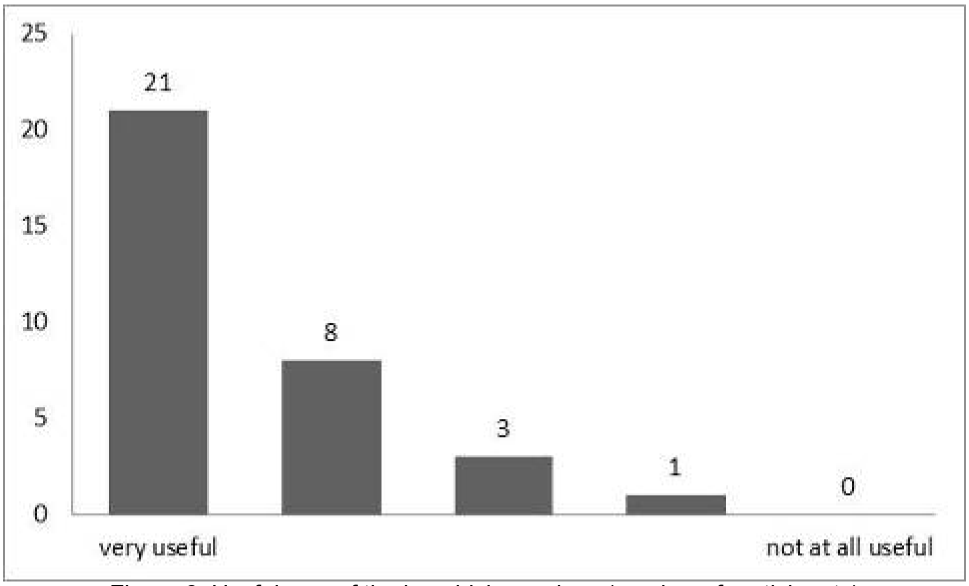

Figure 6: Usefulness of the in-vehicle services (number of participants)

In terms of the reliability of the tested services, 85% of the drivers gave the highest or the second highest positive mark, followed by a few (15%) participants that gave a neutral opinion. There were no negative marks at all.

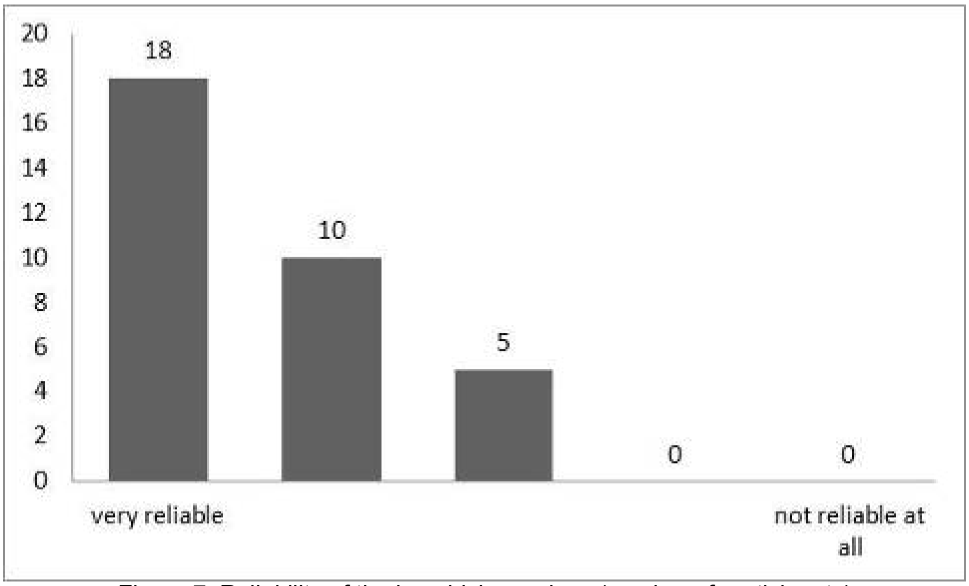

Figure 7: Reliability of the in-vehicle services (number of participants)

Results are encouraging regarding the contribution of the developed in-vehicle services to the health and wellbeing of the elderly, as 22 users (66,7%) replied positively and only 3 gave a negative scoring. 8 people (24%) were not positive neither negative.

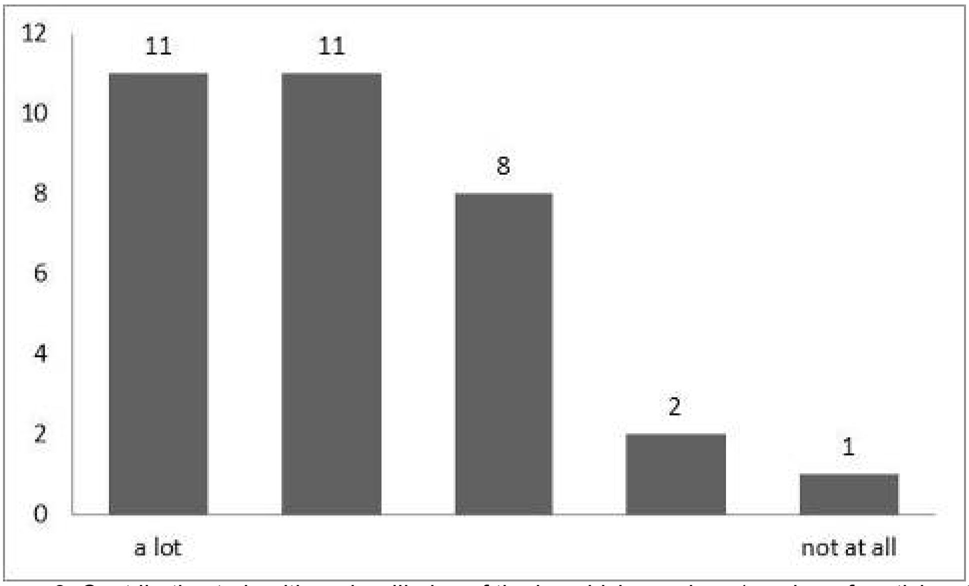

Figure 8: Contribution to health and wellbeing of the in-vehicle services (number of participants)

Summarizing, the results are as follows:

- 29 people found this application useful or very useful.
- 28 people found this application reliable or very reliable.

22 people thought this application would improve personal health and wellbeing.Consolidated results from 3 pilot countries

In addition to the Greek pilots, the OASIS in-vehicle applications were tested in another two countries, Italy and the UK. The results that follow next attempt to provide a comparison among the pilot countries, with a total number of 106 elderly drivers participants.

It is evident from the graph below, that increased usefulness was reported in all sites and most (79%) participants were positive and interested about elderly-friendly and oriented transport related services and applications. No differences among pilot sites were found.

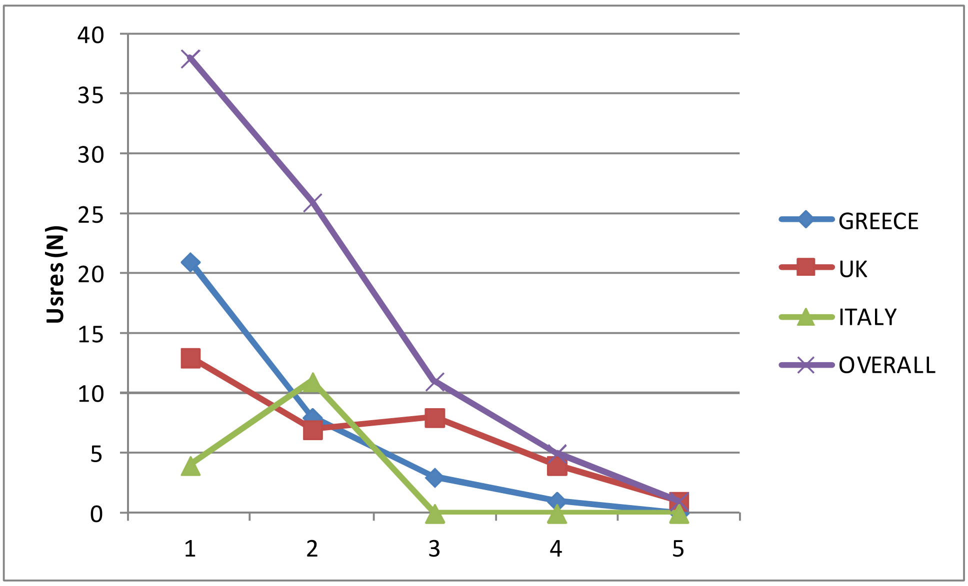

Figure 9: Usefulness of the in-vehicle services (1: very useful to 5: not useful at all)

Reliability was ranked as very high in the Greek pilot and high for both the UK and Italian pilots. In total, most participants (71.4%) described the system as highly reliable and (34.3%) as reliable.

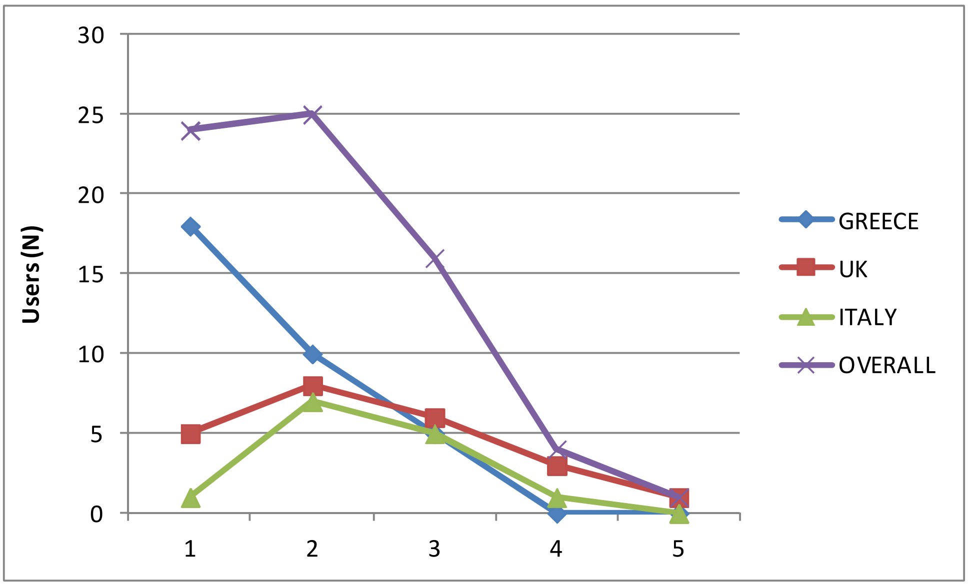

Figure 10: Reliability of the in-vehicle services (1: very reliable to 5: not reliable at all)

CONCLUSIONS

Optimized ADAS and in-vehicle information systems according to the needs of special driver categories, such as the elderly and mobility-impaired users, are key issues for a safe driving. In-vehicle ADAS and IVIS are of particular importance for disabled and elderly drivers and certainly of greater need than by the average driver. This is due to their restrictions and increased needs. Lack of adequate systems results in mobility impaired users being reluctant to drive their car, thus being of reduced mobility. As shown in this paper, there are three main issues to be considered in the design of ADAS for mobility-restricted drivers: the adaptation of ADAS warning algorithms (in terms of timing, intensity and modality of warning), the limitation of secondary information services while the vehicle is on the move (indicating specific cut-off thresholds) and the synchronisation of the operation of ADAS with other ICT-based infomobility services provision.

Evaluation results with drivers indicate that adapted systems increase indeed their safety while driving and ease the driving task, encouraging them to use their car more and thus enhance their mobility. Clearly, the adaptations of warning and information systems discussed in this paper, have a significant impact towards the establishment of interoperable and standardized solutions for elderly and disabled drivers. The cost of the proposed solutions is negligible, as it is main software-based. However, as the integration of the algorithms lies upon the vehicle and ADAS/IVIS manufacturers, it is up to them to decide if it will be provided for free or with an additional cost. Finally, accident-based tests in the framework of naturalistic observation are needed as a follow-up step, in order to extract outcomes from the comparison of adapted versus not-adapted vehicles.

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