Integration of driver support functions: the driver's point of view*

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Abstract - *Integration of driver support functions is a key issue in the development of in-vehicle systems that assist the driver with the driving task. This paper discusses a user needs survey that provides more insight into this issue from the perspective of the driver. Car drivers are asked to indicate their needs for driver assistance during certain driving tasks (e.g. congestion driving) and circumstances (e.g. reduced visibility). From this, consequences for the integration of functions can be deduced with respect to technology, HMI and functional operation. Preliminary results of a pilot test of the user needs survey are highlighted in this paper. These results indicate starting points for integrated driver assistance, such as the adaptability of systems based on personal needs for support, and the functional integration of driver support functions, for instance with respect to inter-vehicle communication.*

Keywords: ITS, integrated driver assistance, user needs survey

1 Introduction

Modern societies are increasingly confronted with problems in traffic and transport such as traffic accidents, congestion and emissions. An important contribution to the solution of the problems might be Intelligent Transport Systems (ITS) [3, 9]. In the coming years motorists will have an increasing variety of ITS at their disposal, including in-vehicle systems that assist the driver with the driving task. This raises the question how these driver support systems should be integrated.

1.1 Aspects of integration

Integration of driver support functions may be related to technology, human-machine interface (HMI) and functional operation.

One of the first projects on the integration of driver support functions was GIDS: Generic Intelligent Driver Support System [5]. Its objective was to determine the requirements and design standards for a class of intelligent co-driver systems. GIDS aimed at providing the driver with the output from several driver support functions such as navigation and collision avoidance support. The GIDS project mainly showed the feasibility of *technical* integration of driver support functions by using the same components such as sensors and processors.

The amount of information from different in-vehicle systems can be large, while the driver's capacity to process this information is limited. This can result in high mental workload and driver distraction. Subsequently, this may lead to negative effects on driver performance, thus endangering safety. Therefore, current research in the field of integrated driver assistance is focused on the *HMI* [1, 7, 11]. Research involves finding suitable ways to present information from different systems to the driver, while minimizing possible negative effects on workload and distraction, for example by using an integrated HMI and information management. An integrated HMI consists of the integration of the interfaces of separate functions, possibly resulting in a multimodal HMI. Modalities for presenting information to the driver can be visual (e.g. text, symbol, icon), auditory (e.g. beep), haptic (e.g. counter-force on accelerator pedal) and tactile (e.g. steering wheel vibrations). A centralized intelligence 'behind the HMI' can provide information management to decide when, where and how information should be given to the driver. This could be done in an adaptive way, for example based on the current driving context, the driver state (workload) or the preferences of the driver. In the COMUNICAR project it was found that in high workload situations driver workload decreases when information is presented to the driver that is managed by a so-called Information Manager [8].

Almost all information to be presented to the driver concerns 'existing' information from separate driver support systems, based on their actual functions. However, new possibilities to support the driver with his driving task may appear when these systems work together, for example by exchanging information. Systems can communicate with systems inside the same vehicle, inside other vehicles or with roadside systems. A benefit for the *functional* operation might be the extension of operative scenarios for single systems. Consider for example the operation of an Adaptive Cruise Control (ACC), regulating speed and headway, depending on road shape information from a navigation system or weather information from rain sensors. The latter ACC has an increased headway for wet roads and reduced visibility. After driving with this system, 78% of the test drivers noticed a gain in comfort and 89% a gain in driving safety [2].

1.2 Assessment of integrated assistance

Much research is performed to assess (integrated) driver assistance. Although these studies are valuable with respect to their results and approach, they have some limitations, among which:

- Technical point of view. Most studies present driver support systems to potential users based on technical possibilities and envisaged user requirements. But to what extent does the driver really want assistance from the car during driving? And which combinations of driver support functions are preferred?
- Focus on technology and HMI issues. Less attention is paid to the functional operation of integrated driver support functions. But what should happen if one or more driver support functions of an integrated system fail? And to what extent should a driver support system imitate or optimize 'normal' driving behaviour according to the driver? An integrated system with longitudinal and lateral control could for example maintain a relative high speed and short headway on rather narrow roads.

With these limitations of current research kept in mind a project on the assessment of integrated driver assistance has been started. Its aim is to gain insight into integrated driver assistance from the perspective of the driver and the traffic system by examining the needs for integration of driver support functions and its impacts on the driver and the traffic flow, resulting in concepts of integrated driver assistance. The outcome of this project is interesting for car industries/suppliers to develop and sell driver support systems, which are based on the preferences of the driver with respect to safety and comfort. The outcome is interesting for governments to stimulate or regulate the implementation of systems, depending on their impacts on the traffic system in terms of traffic safety and efficiency.

The main research questions of the project are:

- What are the needs of the driver with respect to integrated driver assistance?
- What are the impacts of integrated driver assistance on the driver, in terms of acceptance and driving behaviour?
- What are the impacts of integrated driver assistance on the traffic flow, in terms of traffic safety and efficiency?

The remainder of this paper focuses on a user needs survey to answer the first research question.

1.3 User needs analysis

To maximize the match between characteristics of users and driver assistance, and to minimize the risk of omitting vital user and user context information, user needs analysis is an important part of the design process of driver support systems. Earlier research into needs for driver assistance provides some insight into the extent to which motorists are eager to have 'intelligent vehicles'.

On average drivers and fleet operators judge it somewhat unattractive to have driver support systems for distance keeping, lane keeping, lane changing, and route guidance in their cars [14]. However, this finding needs to be nuanced as the stated preferences depend on the specific system characteristics. Warning support on distance keeping is preferred to throttle control and throttle- and brake control. For lane keeping and changing warning devices are preferred to no support or steering assistance. It was further found that truck drivers and car fleet operators consider driver support systems more attractive as compared to the other driver and fleet operator groups. Chalmers [4] reports on user attitudes towards driver assistance systems, such as ACC. Generally, there is a major acceptability of systems which control longitudinal distances between vehicles and systems which monitor the driver and are able to park the vehicle to prevent unfit drivers from driving. There is a high resistance among car drivers towards the compulsory use of systems that control the vehicle speed to keep within speed limits. Truck drivers, on the other hand, are particularly enthusiastic about this system. In terms of benefits, there is an overall feeling that driver assistance systems would increase driver confidence and safety, and that it would make driving more comfortable. Technical failure is the first and foremost concern. The results of the IN-ARTE user survey show that a higher level of support is expected in more critical situations, and reveal a strong preference for information warning for front obstacles [6]. Users were generally negative about automatic intervention, probably because personal control is a crucial issue in driving behaviour. Acceptance of system intervention was limited to situations with dense traffic (i.e. convoy driving).

Although the above-mentioned results are valuable, these preferences for 'separate' driver support functions do not say much on preferred combinations of functions. Which functions should be included in an integrated driver assistance system?

2 Methods

The issue of integration will be investigated starting with the driver's point of view. Drivers are asked to indicate their needs for driver assistance by means of a survey. From the results of this user needs survey it will be clear which driver support functions are preferred. The needs of the driver determine implications for possible integration of these functions with respect to issues surrounding technology, HMI and functional operation.

2.1 Participants and procedure

The target group of the user needs survey is the Dutch population of car drivers. Passenger cars are considered because of: (a) the high number of vehicle kilometres driven by passenger cars, (b) the high number of accidents with passenger cars involved, (c) the attention from government and automotive industry to driver assistance inside passenger cars and (d) a practical reason, namely using the TNO passenger car driving simulator in the next phase of the project.

Participants are asked to fill in a computer-based questionnaire for distribution on the Internet. The structure of the survey consists of four parts:

- Perception of car driving. What do drivers think of car driving? What are easy and difficult driving tasks and circumstances?
- Needs for driver assistance. To what extent do drivers want assistance from the car during driving? For instance, on which type of road, during which driving tasks and circumstances, and with what kind of support (e.g. warning)?
- Ideal driver support system. What is the ideal assistance according to the driver? For instance, which combinations of driver support functions, what kind of feedback (e.g. auditory), and which other typical characteristics?
- General information. Background questions about car possession, driving experience, socio-economic variables, etc.

Besides getting answers with respect to the above-mentioned parts of the survey the following analyses will be conducted: (a) relationship between needs for driver assistance and type of car driver, e.g. age, gender, driving experience, (b) relationship between needs for driver assistance and perception of car driving, e.g. support for difficult driving tasks and circumstances and (c) consequences for integration of driver support functions.

The actual user needs survey will be performed in the near future. The required sample size consists of 750-1000 car drivers. A professional market agency will be called in to invite members of their Internet panel. Besides, participants will be invited via personal and business contacts. Recently a pilot test has been concluded (see section 2.3).

2.2 Driver support functions

Most research on user needs for driver assistance concerns drivers' preferences for one or more systems [4, 13] in contrast to drivers' preferences for certain functions that support the driving task. This user needs survey therefore focuses on driver support functions. So instead of presenting a system such as Intelligent Speed Adaptation (ISA), that regulates speed according to the speed limit, several driver support functions with respect to regulating speed are presented.

The part of the questionnaire on needs for driver assistance starts with some information about ways in which the car can assist the driver with several driving tasks and circumstances. Table 1 shows the driving tasks and circumstances that are included in the questionnaire. A distinction is made between three types of road: motorway, rural road and urban road.

Table 1. Driving tasks and circumstances in survey

Driving tasks on motorway, rural road and urban road	Regulating speed Regulating course Car following Lane changing Congestion driving
Driving tasks on rural and urban road	Negotiating non-signalised intersection Negotiating signalised intersection
Circumstances	Reduced visibility Driver fatigue Imminent crash

For each driving task and circumstance several driver support functions are defined. Participants have to indicate on a five-point scale to what extent they would like to have these functions on each road type (1 = great need, 5 = certainly no need). Figure 1 depicts an example of speed assistance. The driver support functions can consist of information, warning or control. In this survey it is assumed that the driver can overrule the driver assistance, for instance by turning it off. Several driver support functions include a form of integration. Consider for example the function 'warning for unsafe speed regarding actual situation, e.g. fog, curve, nearby school'. Communication with other vehicles or roadside systems is necessary with respect to detecting fog, and communication with a digital map is necessary with respect to detecting a curve or nearby school.

After having introduced possibilities for driver assistance, the next part of the survey focuses on the ideal driver support system. First, participants are asked

Driver support function	Motorway					Rural road					Urban road				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Information on speed limit	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Warning for exceeding speed limit	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
The car automatically regulates speed according to speed limit	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Warning for exceeding self-chosen speed	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
The car automatically regulates speed according to self-chosen speed	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Warning for unsafe speed regarding actual situation, e.g. fog, curve, nearby school	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
The car automatically regulates speed according to actual situation	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Warning for downstream traffic condition, e.g. congestion, accident, road works	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
The car automatically regulates speed according to downstream traffic condition	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Figure 1. Speed assistance in survey

whether they would like to have a system that combines all driver support functions for which they have a (great) need according to their previous answers. It is assumed that drivers prefer a system that consists of less driver support functions than a summing-up of 'separate' functions. Certain combinations of functions may strengthen or weaken each other for example. Next, participants can formulate their ideal driver support systems by indicating favoured functions and, in case of information and warnings, type of feedback. With this, consequences for integration with respect to the HMI can be deduced. Finally, questions about typical characteristics of the ideal system are presented. For instance about imitation or optimisation of 'normal' driving behaviour: should the ideal system make car driving easier or better? Or about taking into account the driving environment: should the ideal system give more support during heavy traffic?

2.3 Pilot test

A pilot test has been performed to check whether the survey will provide the needed information, and to sharpen the questions by a rough inspection of the relevance of the answers. Twenty-one persons participated in the pilot test by filling in a paper version of the questionnaire. The persons included colleagues, friends and family. Based on their answers and comments the questionnaire has been revised (e.g. shortened and clarified). Currently it is programmed into an Internet version. Preliminary results of the pilot test are discussed in the next section.

3 Results

The results of the pilot test of the user needs survey about integrated driver assistance indicate the type of results that can be expected from the actual survey that will be performed in the near future. These preliminary results are presented below, including driver assistance per road type, preferred driver support functions, difficult driving tasks and circumstances, and components of the ideal driver support system.

3.1 Perception of car driving

It was found that the majority of the respondents enjoy car driving. Driving on a motorway is regarded as being easier than driving on a rural road, which in turn is regarded as being easier than driving on an urban road. Driving tasks that people think are more difficult than others are lane changing (i.e. overtaking) on rural roads, congestion driving on motorways and negotiating a non-signalised intersection on rural and urban roads. Difficult circumstances during driving are reduced visibility (i.e. bad weather, at night, into the sun), road works and driver fatigue.

3.2 Needs for driver assistance

The results of the pilot test show that there seems to be a (great) need for driver assistance during driving on a motorway. Respondents want less help from their car with driving on a rural road and even less on an urban road. This tendency is especially noticeable for driver support functions that are concerned with regulating speed and car following. For example, warnings for unsafe speed or headway regarding actual situation (e.g. fog) seem most preferred on a motorway, less preferred on a rural road and least preferred on an urban road.

Driving tasks and circumstances with the biggest need for assistance are regulating speed, lane changing, reduced visibility and imminent crash. The most favourite corresponding driver support functions are presented in Table 2 (M = motorway, R = rural road, U = urban road). These functions are wanted by a (large) majority of the respondents ($N \geq 12$). Help from the car in negotiating (non-)signalised intersections was not very popular. However, it was more wanted on an urban road than on a

Table 2. Most favourite driver support functions

Driving task	Driver support function	M	R	U
Regulating speed	Information on speed limit	x	x	x
	Warning for exceeding speed limit	x	x	
	The car automatically regulates speed according to self-chosen speed	x		
	Warning for unsafe speed regarding actual situation, e.g. fog, curve, nearby school	x		
	Warning for downstream traffic condition, e.g. congestion, accident, road works	x	x	
Lane changing	Warning for traffic in blind spot	x		
	Warning for traffic in blind spot + warning for traffic with high speed approaching from back	x		
	Warning for oncoming traffic		x	
	Information on safe situation for overtaking		x	
	Warning for unsafe situation for overtaking		x	
Circumstance				
Reduced visibility	On windscreen presented view of badly visible objects on road ahead, e.g. pedestrians, animals			
Imminent crash	The car automatically gets passive safety systems ready for use, e.g. pre-tension of seat belt			
	When crash inevitable: the car automatically calls in aid (car total loss, driver unconscious)			

rural road, in particular warning for traffic in blind spot and information on right-of-way and colour of traffic light. Of all driver support functions 'warning for downstream traffic condition' (regulating speed) was preferred most: wanted by all respondents. The function 'the car automatically parks and calls in aid in emergency case when driver does not respond to warning' (driver fatigue) was preferred least. In general there is hardly any need for driver support functions that consist of control, except for the ones with respect to speed, such as automatically regulating speed according to speed limit or self-chosen speed.

3.3 Ideal driver support system

The majority of the respondents of the pilot test would like the ideal driver support system to consist of less driver support functions than the summing-up of their previous answers (i.e. preferred 'separate' functions). The ideal driver support system seems to be very personal, because only a few respondents chose the same driver support functions. Figure 2 shows six types of driver assistance: the first three were most popular in the ideal system (N = 9, 10) and the last three were least popular (N = 0, 1).

Assistance from the car with an imminent crash was not mentioned a lot, but six respondents thought that this should be the most important type of assistance of the ideal system. Assistance in lane changing on a rural road should consist of warning for oncoming traffic. Respondents would like to have help in car driving during reduced visibility by means of a view of badly visible objects on the road ahead presented on the windscreen. With respect to regulating speed on a motorway the functions 'information on speed limit' and 'warning for exceeding speed limit' were favourite.

Respondents of the pilot test were asked to indicate the preferred type of feedback for each driver support function of the ideal system. With respect to assistance in regulating speed, information and warnings are best given by visual feedback according to the respondents. There is no general preference for the type of feedback of warnings for oncoming traffic when overtaking on a rural road. Both visual and auditory feedback were mentioned. Haptic and tactile feedback seem less preferred. This is possibly due to the fact that respondents cannot visualize these types of feedback very well.

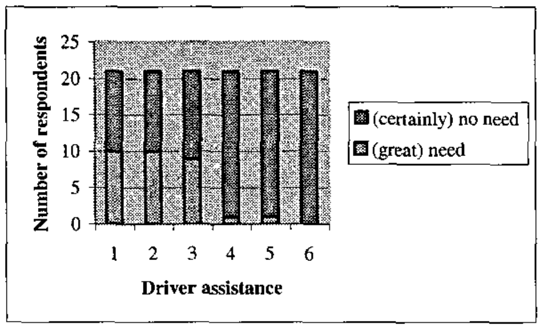

Figure 2. Most favourite assistance in ideal system

1 Lane changing – rural road
2 Reduced visibility
3 Regulating speed – motorway
4 Lane keeping – rural road
5 Negotiating signalised intersection – urban road
6 Negotiating signalised intersection – rural road

4 Discussion

The aim of the user needs survey is to reflect the needs of the driver with respect to integrated driver assistance during car driving. The performed pilot test gives an idea of the type of results that can be expected from the actual survey. Below, likely explanations for the desired help and consequences for the integration of driver support functions are discussed. Possibilities and limitations of the used method (i.e. survey) are examined as well.

4.1 Reasons for driver assistance

The results of the pilot test reveal that the respondents have a greater need for driver assistance on a motorway than on a rural and urban road. This seems not to be connected with the perceived difficulty of driving on these road types. After all, driving on a motorway was regarded as being easiest and driving on an urban road as most difficult. Most respondents indicated that regulating speed on a motorway is a (very) easy driving task. At the same time most respondents prefer driver assistance in regulating speed on a motorway. It may be concluded that a need for help with a rather easy driving task is motivated by a wish for comfort. One of the driving tasks that people think is more difficult than others is lane changing on a rural road. The most favourite type of assistance in an ideal driver support system was assistance in lane changing on a rural road. In this case it may be concluded that a need for help with a rather difficult driving task is motivated by a wish for safety. This holds true for driver assistance with reduced visibility. However, it does not apply to the driving task of negotiating a non-signalised intersection on a rural road. Most respondents perceived this driving task as being rather difficult, while their need for assistance with this task was least popular. There is no clear explanation for this. Maybe car drivers think they can handle this driving task better than a system can. Or maybe they do not have a good impression of how the car can exactly help. However, this latter could have been the case of help with lane changing as well, nevertheless this type of assistance was most popular.

4.2 Consequences for integration

Relying on the results of the pilot test it seems that drivers would like to have a reasonable number of driver support functions inside their cars. This indicates clear consequences for integration of functions. Firstly, technical integration should be taken into account by using the same components such as sensors and processors. Most preferred driver support functions consist of information and warnings. Issues surrounding the HMI are important to prevent the driver from overload and confusion during car driving. Information management seems indispensable.

The need for driver assistance appears to be different on the three road types. For example, if a driver would like to have speed assistance only on a motorway, the driver support system would ideally detect the type of road and provide the desired assistance. This implies communication with a digital map. This type of communication is also needed when the driver wants information on the speed limit or a warning when he/she exceeds this limit. One of the most preferred functions seems to be warning for oncoming traffic in order to overtake on a rural road. This type of function may be dependent on inter-vehicle or vehicle-roadside communication. The pilot test revealed that the ideal driver support system is assumed to be very personal. Therefore, the system should be adaptive and have the ability to take into account the driver's preferences. From what has been stated above, it follows that attention should be given to the functional operation of integrated driver assistance as well.

4.3 Conducting a survey

Research into driver support systems is often technology driven [10]. In most cases a new system is presented to potential users – in hypothetical or real form – after the first development phase. Instead of starting from technical possibilities and envisaged user requirements, the aim of this study is to depart from the driver's point of view. Drivers can be regarded as 'hands-on' experts of car driving. Therefore it seems useful to ask them to indicate their needs for driver assistance. It is decided to design a questionnaire study to collect individually comparable data on characteristics of the driver, car driving (tasks and circumstances) and driver support functions.

A limitation of this user needs survey about integrated driver assistance can be the fact that the driver support functions are presented hypothetically. To an extent it is uncertain whether respondents will understand everything and interpret it the same. Besides, research shows that in most cases drivers are more positive about a system after having gained experience with it [13]. This user needs survey will be continued by a driving simulator experiment (see section 6). It is thought to hold a group interview (i.e. focus group) before the experiment to gather more information, for example on reasons for wanting certain functions and characteristics of an integrated system.

Several ways exist to distribute a questionnaire, for example by mail, Internet or telephone. In this study the choice has been made to design a computer-based questionnaire for distribution on the Internet. This type of questionnaire has some advantages, including: (a) visualization of what the respondents are being questioned about (e.g. pictures), (b) personalization of the questionnaire by interactively showing relevant questions and responses, based on previous answers, and (c) collection and storage of data in an electronic database. In spite of the many benefits, there is one major drawback to this approach. Access via Internet introduces bias, because only Internet users can fill in the questionnaire. However, the number of current Internet users is rather high and still growing [12]. At the end of 2001 the Internet usage in the Netherlands amounted to 59%: over 7.2 million persons with the age of 16+ regularly make use of the Internet.

5 Conclusion

The car driver of tomorrow will enjoy an increasing variety of in-vehicle systems that assist in the driving task. This paper discusses the integration of driver support functions starting with the driver's point of view, in contrast to the often-used technology driven approach. By means of a user needs survey car drivers are asked to indicate their needs for driver assistance during certain driving tasks (e.g. regulating speed, lane changing) and circumstances (e.g. reduced visibility, driver fatigue). Based on these needs more insight can be provided into integration of driver support functions with respect to technology, HMI and functional operation.

Recently a pilot test of the user needs survey has been performed. The results of this pilot test indicate the type of results that can be expected from the actual survey that will be performed in the near future. It appears that the need for driver assistance does not always correlate with the drivers' opinion on the difficulty of driving tasks and circumstances. Relying on the results of the pilot test, drivers see most in support from their car during driving on a motorway. Generally, they would like to have a reasonable number of driver support functions inside their cars. This indicates clear consequences for integration of functions. For instance, there is a (great) need for speed assistance on a motorway and lane change assistance on a rural road. Examples of preferred driver support functions are warning for exceeding speed limit and downstream traffic condition (regulating speed) and warning for oncoming traffic (lane changing). This emphasizes the importance of the functional integration of driver support functions, for instance with respect to communication with a digital map or with other vehicles. Besides, the preliminary results indicate the importance of adaptive systems, which take into account the driver's preferences.

6 Outlook

The user needs survey is part of a research project on the assessment of integrated driver assistance based on: (a) user needs, (b) impacts on driver behaviour and acceptance and (c) impacts on traffic safety and efficiency. The results of the survey serve as a basis for putting together an integrated driver support system. The impacts of this system on the driver will be investigated by means of a driving simulator experiment. These outcomes are placed in perspective by assessing the impacts of the integrated system on the traffic flow using microscopic traffic simulation. The results of the project reflect concepts of integrated driver assistance. It will be clear which driver support functions should be integrated and which aspects of integration will be of importance, for example issues surrounding the functional operation.

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