Investigation of user needs for driver assistance: results of an Internet questionnaire

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Advanced Driver Assistance Systems (ADAS) aim at supporting the driver with the driving task and are expected to lead to a safer, cleaner and more efficient and comfortable transport system. This paper presents the results of an Internet questionnaire among more than 1000 Dutch car drivers. Respondents indicated their needs for driver assistance with certain driving tasks and situations. It appeared that warnings for downstream traffic conditions and traffic in blind spots were favoured. Apparently, the needs for warnings for downstream traffic conditions on motorways significantly differed from the needs for other driver support functions. Moreover, drivers preferred the ideal system to help them with critical situations (i.e. imminent crash and reduced visibility) and car following on motorways to other driving tasks and situations. Characteristics of the driver, system and traffic scene affected the needs for driver support. Besides, these needs indicated consequences for the integration of driver assistance. Driver support functions should exchange information to extend their individual fields of activity, for example by inter-vehicle communication (e.g. warning for downstream traffic conditions) or sensor data fusion (e.g. warning for an imminent crash).

Keywords: ADAS, integrated driver assistance, Internet questionnaire, user needs

1. Introduction

Over the coming years, drivers will have an increasing variety of Intelligent Transport Systems (ITS) at their disposal, including Advanced Driver Assistance Systems (ADAS). ADAS are in-vehicle systems that support the driver with the driving task. High expectations rest on ADAS (European Commission, 2002; Ministry of Transport, 2004). Governments expect them to lead to a more efficient, safer and cleaner transport system. Car industries and suppliers hope to contribute to the safety and comfort of their customers by developing and selling distinctive driver support systems. The driver that will use these systems faces the prospect of travelling in a safer, faster and more comfortable way. However, whether ADAS will meet the high expectations, is greatly dependent on the willingness of drivers to purchase and use the systems. An important question is to what extent they are eager to have 'intelligent vehicles'. The aim of this paper is to clarify to which extent drivers have a need for systems that support them with their driving tasks. The methodology used is not based on polling the opinions of drivers on specific systems, but focuses on driving tasks and situations. The research was conducted using an Internet survey.

This paper is structured as follows. After this introductory section, section 2 is devoted to a review of literature. In section 3 the research method is described. In section 4 we present and analyze the results, after which the results are discussed in section 5. Finally, in section 6 we present our conclusions and an outlook on future work.

2. Literature review

In this section, an overview is given on the needs for ADAS among potential users who were not (yet) exposed to the systems. The explored studies are discussed using a conceptual framework that shows an overall picture of earlier research into user needs for driver support systems; see figure 1. The opinion of the driver on driver assistance is presented by arrow [1]. This opinion may be influenced by characteristics of the driver and the system. Besides, it may be influenced by characteristics of the traffic scene; see arrow [2]. The conceptual framework is explained below by referring to some of the explored studies.

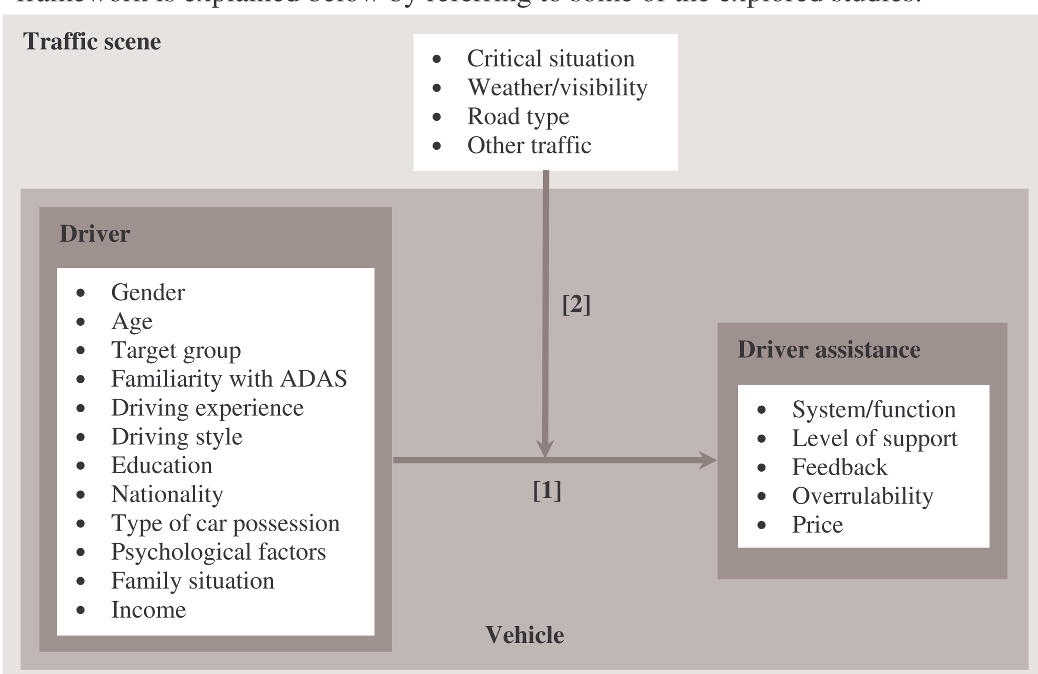


Figure 1. Conceptual framework of user needs for driver assistance

Characteristics of the driver

Gender seems to have an effect on the needs for driver assistance. Generally, women were more positive about help from their cars during driving than men (TRG, 1998; Chalmers, 2001). However, Blythe & Curtis (2004) found that men had a more positive attitude than women thinking ADAS should assist or take over instead of simply warn. Also the preference for typical ADAS can differ between men and women. According to Piao et al. (2004), men liked ACC best and women ISA. Also Rienstra & Rietveld (1996) found that women were more in favour of speed-regulating devices. However, in the COMUNICAR survey no differences with respect to gender were found (Mariani et al., 2000). With respect to age, older drivers were in general more positive about driver support systems than younger drivers (CRA, 1998; TRG, 1998; Chalmers, 2001; Piao et al. 2004). Truck drivers and car fleet operators considered driver support systems more attractive than other driver and fleet operator groups (Marchau et al., 2001). Chalmers (2001) found that bus and truck drivers generally had a greater need for driver assistance than private drivers. There seems to be a relation between driving experience and needs for driver assistance as well. Especially drivers that had encountered a (near-)accident due to tiredness rated a driver monitoring system positive (Bekiaris et al., 1997; CRA, 1998). Personal experience with congestion also motivated positive reactions to Stop & Go (Piao et al., 2004). Piao et al. (2004) also stated that the indicated needs for ACC were connected with the dissemination activities about ACC for the last ten years. They found that drivers with experience with cruise control were significantly more willing to purchase ACC than those without. However, this was not the case in the study of Turrentine et al. (1991). Avid users of cruise control appeared not to be early adopters of more automated controls, like ACC.

Characteristics of the driver assistance

The general accepted notion in literature was that systems should be 100% reliable and have no false alarm rates. Besides, it appeared to be of influence which driving tasks or situations the system supports. In general, lane keeping systems did not seem to be very popular among drivers. Lane Departure Warning (LDW) was rated (much) lower than Stop & Go, ACC and ISA (Piao et al., 2004). The results of the IN-ARTE survey also showed that respondents were indifferent to lateral control functions (Wevers et al., 1999). However, participants in the study of Regan et al. (2002) felt that LDW was a good idea. In contrary to lane keeping systems, anti-collision systems seem to be popular. CRA (1998) found that all participants viewed Collision Avoidance Systems favourably. The IN-ARTE survey revealed a strong preference for warnings on front obstacles and warnings to slow down (Wevers et al., 1999). The results of the COMUNICAR survey showed that functions related to the primary driving task and enhancing safety were valued as the most preferred ones: automatically set cruising speed, and warnings on lateral collision, front obstacles and car overtaking (Mariani et al., 2000). According to Blythe & Curtis (2004), respondents were most positive about Collision Warning and Prevention, ACC and Driver Alertness Monitoring. Chalmers (2001) indicated that generally there was a major acceptability of systems that control longitudinal distances between vehicles. Besides type of system or function, level of support seems to affect the needs for driver assistance. CRA (1998) found that the appeal to ACC was more limited, possibly due to the automatic control of car following. Similarly, the results of the IN-ARTE survey showed that users were generally negative about automatic intervention, probably because personal control is a crucial issue in driving behaviour (Wevers et al., 1999). Also the COMUNICAR survey revealed that there was a greater need for information and warnings than automatic actions (Mariani et al., 2000). Blythe & Curtis (2004) found that nearly half of the respondents thought ADAS should simply warn the driver; the other half thought ADAS should assist (38%) or take over (16%).

Overrulability appears to be very important in the acceptance of driver assistance as well. Regan et al. (2002) came to the conclusion that voluntary systems, which drivers can choose to disable, were more acceptable among the respondents than mandatory systems, which cannot be turned off by the driver. If the driver cannot switch off ADAS, the attitude of the majority of respondents was negative; only Collision Warning and Prevention still received a favourable attitude (Blythe & Curtis, 2004). According to Comte et al. (2000), participants thought mandatory ISA would be most useful, however, they preferred the idea of a voluntary system. In general, it can be stated that the willingness to pay for ADAS is rather low. Van der Heijden & Molin (1999) found that respondents were prepared to pay little for ISA. However, the willingness to purchase such a system seemed to be higher when it was combined with other ADA systems. Marchau et al. (2001) concluded that, as expected, higher prices had a negative influence on the acceptability of ADAS. A majority of respondents were either not prepared to pay anything extra for ADA applications (50%) or would be willing to pay a sum of up to £500 (37%) (Blythe & Curtis, 2004). This low willingness is contrary to the 'noncommitment bias' stated by Polydoropoulou et al. (1997). They suggested that respondents in stated preference studies might overestimate their willingness to pay, because no actual payment was concerned. Becker et al. (1995) stated that the use of questionnaires with text descriptions of the system performance may not provide a sufficiently detailed picture of the system for the subject to give an accurate response. Therefore, price is frequently considered in (follow-up) studies that include gaining experience with a system. TRG (1998) referred in her study to earlier research showing that 30% of the participants were willing to purchase an ACC at an average price of $490, rising to 87% and $616 after prototype rides.

Characteristics of the traffic scene

There seems to be a greater need for driver assistance in critical situations, such as near-accidents. Bridger & Patience (1998) concluded that in normal driving situations, the driver wants to be in control. In more adverse situations, assistance from the car is wanted and in dangerous situations, the driver even relies on assistance from the car. A higher level of support in more critical situations was also found by Wevers et al. (1999) in the IN-ARTE survey. According to Várhelyi (2000), a majority of the respondents accepted ISA that warns the driver or even automatically reduces the driving speed in imminent crash situations. Weather/visibility conditions also appear to be connected to the acceptability of ADAS. TRG (1998) showed that drivers would like to use ACC especially when it is foggy or at night. A majority of the respondents was positive about ISA during slipperiness or reduced visibility situations (Várhelyi, 2000). Besides, road type seems to influence the needs for driver assistance. Schmeidler (2002) reported that respondents thought ACC was especially useful on motorways and rural roads, while ISA should be used mainly on urban roads. This result on ISA was also found by Van der Heijden & Molin (1999) and Van Hoorebeeck (2000). Participants in the study of Regan et al. (2002) felt that LDW was a good idea in rural areas. The presence of other road users may also be of importance when considering the opinions on ADAS. Participants in the study of TRG (1998) liked to use an ACC or Collision Warning system when the traffic density was low. It was concluded in the IN-ARTE survey that the needs for certain driver support functions were related to external factors and driving situations, such as a car cutting in from the right or driving in convoy (Wevers et al., 1999). For example, the acceptance of autonomous braking was higher in situations with dense traffic as compared to clear running situations. Note that this result is somewhat contrary to the earlier mentioned result about using ACC (that may brake automatically) when the traffic density is low.

Conclusions
Despite the amount of literature on the needs for ADAS, no general theory – more specific than the conceptual framework – was found so far to describe the relations between the driver, the system and the traffic scene. Although the conceptual framework provided more insight into the needs for driver assistance, still some knowledge gaps can be distinguished. Most studies presented one or more driver support systems to potential users based on technical possibilities and envisaged user requirements. Therefore, little is known about the 'ideal' system according to the driver. Which (combinations of) driving tasks and situations should be supported? This research aimed at giving an answer to this question. Besides, in contrast to earlier research, the survey in this research focused on driver support *functions* related to driving tasks and situations. So instead of presenting a system such as ISA, several driver support functions that regulate speed were presented. Clear relations between the driver, the driver assistance and the traffic scene were not always present in the studied literature. Characteristics, such as the age of the driver and the driving task to be supported by the system, seem to be of influence on the needs for ADAS. However, a more consistent view on these relations is wanted. Thus, this research aimed at filling knowledge gaps in the conceptual framework and moving the state-of-the-art on driver assistance forward.

3. Research method

3.1 Questionnaire design

Participants were asked to fill in an Internet questionnaire that consisted of the following three parts:

- Driver support functions: to what extent do drivers want assistance from the car during driving? On which type of road, during which driving tasks and situations, and with what level of support?
- Ideal driver support system: what is the ideal assistance according to the driver? Which combinations of driver support, and which other characteristics?
- General information: background questions about car possession, driving experience, socio-economic variables, and the like.

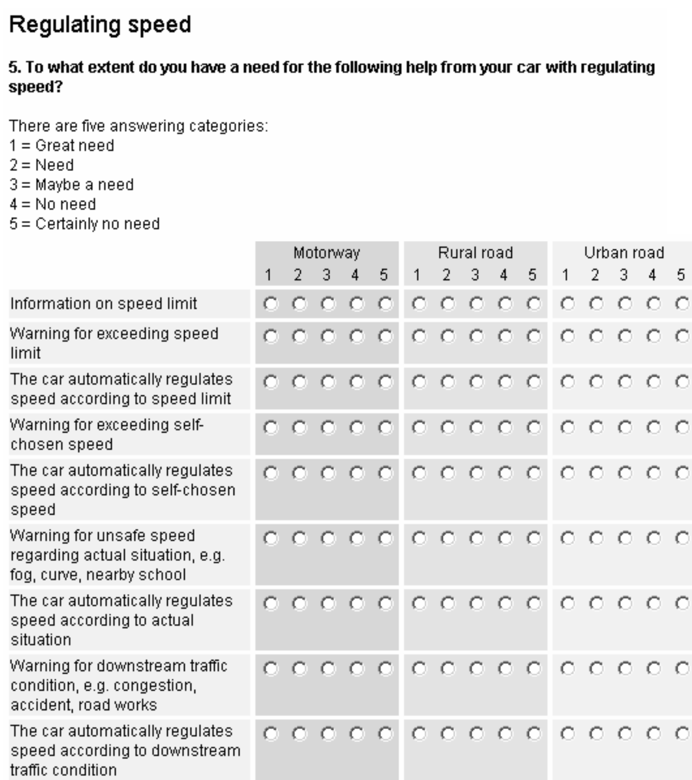
Driver support functions
The survey started with information about the goal and procedure of the survey. Next, some background questions on car possession and usage were asked, followed by questions on the needs for driver support functions. Table 1 shows the driving tasks and situations that were included in the questionnaire. This list was established by using the work of McKnight & Adams (1970) on task analysis of car driving. The driving tasks related to the operational and

tactical level of driving (Michon, 1985). A distinction was made between three road types: motorways (M), rural roads (R) and urban roads (U).

Table 1. Driving tasks and situations in the survey

Driving tasks	Situations
Regulating speed (M, R, U)	Reduced visibility
Lane keeping (M, R, U)	Driver fatigue
Car following (M, R, U)	Imminent crash
Lane changing (M, R, U)	
Congestion driving (M, R, U)	
Negotiating non-signalised intersections (R, U)	
Negotiating signalised intersections (R, U)	

For each driving task and situation, several driver support functions were defined. Participants had to indicate on a five-point scale to what extent they have a need for these functions on each road type (1=great need, 5=certainly no need). Figure 2 shows an example of speed assistance. The driver support functions consisted of information, warning or control. In this survey, it was assumed that the driver could overrule the driver assistance, for example by turning it off.


Regulating speed

5. To what extent do you have a need for the following help from your car with regulating speed?

There are five answering categories:
1 = Great need
2 = Need
3 = Maybe a need
4 = No need
5 = Certainly no need

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

Figure 2. Example of a survey question: speed assistance

Ideal driver support system
After having introduced possibilities for driver assistance, the next part of the survey focused on the ideal driver support system. A 'personalized' table was presented first that showed all driver support functions for which the participant had a significant need according to his or her previous answers (i.e. category 1 or 2). It was assumed that drivers prefer a system that consists of less driver support functions than a summing-up of single functions. This summing-up might be 'too much', for example. Participants could formulate the ideal driver support system by indicating at most six favoured types of assistance out of maximal twenty-two. These types of assistance corresponded to the driving tasks and situations in the first part of the questionnaire; see table 1.

Statements about typical characteristics of the ideal system were also presented in the questionnaire. Participants had to indicate on a five-point scale (1=totally agree, 5=totally disagree) to what extent they agree with these statements. For example, should the ideal system provide more support when the traffic is busy or when the weather is bad? When participants were indifferent or negative about the driver support functions presented in the first part of the survey, they did not have to fill in the second part about the ideal driver support system. They were directly referred to the remaining background questions about socio-economic variables and the like. Before going on-line, pilot tests of the user needs survey were performed to check whether the survey would provide the necessary information.

3.2 Participants

The target group of the user needs survey consisted of Dutch car drivers of a passenger car. Participants had to have a valid driving licence. Passenger cars were considered because of:

- The high number of vehicle kilometres driven by passenger cars: 146.1 billion km (76.5%) by car drivers and passengers in the Netherlands in 2003 (CBS, 2003);
- The high number of accidents with passenger cars involved: 607 deaths (64.6%) and 6442 in-patients (70.1%) among car drivers and passengers in the Netherlands in 2002 (SWOV, 2002);
- A practical reason, namely using the TNO passenger car driving simulator in the next phase of the project.

The required sample size was estimated by using the guidelines in Buijs (1993) and Cohen (1988). It was aimed to gather responses to the survey from a minimum of 500 car drivers. Participants for the user needs survey were invited in two ways. One way was by calling in market agency RM Interactive to invite members of her Internet panel. It was tried to represent the target group of Dutch car drivers with respect to gender, age and education. The other way of inviting participants was via personal and business contacts. An invitation by e-mail containing a hyperlink to the questionnaire was sent to family, friends, colleagues and representatives of the government and the business sector. It was also asked to forward the e-mail to possibly interested others (snowball method). Besides, an invitation to the questionnaire was put on the websites of research organisation TNO and consumer organisation ANWB. The questionnaire was online from 24 August 2004 until 1 October 2004.

4. Results

4.1 Sample

The results of the questionnaire were based on the usable answers from 1049 respondents. Of those, 740 respondents were invited via personal and business contacts and 309 respondents were members of the Internet panel of the market agency. Table 2 shows some characteristics of the sample and the target group of Dutch car drivers (CBS, 2003). 757 of the respondents were male, 292 were female. The average age of the respondents was 41 years (SD 12, minimum 18, maximum 79). Most of them were highly educated. Chi-square tests were carried out to check whether the distributions of gender, age and education in the sample differed from the distributions of these variables in the target group. It turned out that the sample significantly differed from the target group ($p<0.05$).

Table 2. Characteristics of the sample and target group

Characteristic	Sample	Target group
Gender		
male	72.2%	54%
female	27.8%	46%
Age		
18-24 years	6.8%	16%
25-44 years	51.9%	32%
45-64 years	38.7%	32%
>= 65 years	2.6%	20%
unknown	0.1%	-
Education		
primary education	0.2%	10%
lower secondary education	9.2%	27%
higher secondary education	22.6%	30%
higher education/university	67.8%	33%
other	0.2%	-

Answers to the background questions revealed that most respondents had a driving licence for more than 10 years, possessed their own car and drove in it frequently (more than 3 times a week). Almost half of the respondents were somewhat familiar with ACC. Nearly 25% of the respondents indicated to be (very) familiar with this system, regardless of possessing it.

4.2 Driver support functions

More insight is gained into the needs for certain driver support functions by analyzing the answers to the first part of the questionnaire. In this part the respondents indicated to what extent they want assistance from the car during driving: during which driving tasks and situations, on which type of road and with what level of support.

Driving tasks and situations

The results of the survey showed that the most popular driver support functions related to the following driving tasks and situations: regulating speed, lane changing, negotiating intersections, imminent crash and reduced visibility. Table 3 shows these most popular functions based on the answers 'great need' and 'need' (categories 1 and 2 respectively). Especially warnings for downstream traffic conditions and warnings for traffic in blind spots were favoured.

Table 3. Top 10 of most popular driver support functions

Driver support function	(Great) need (%)
1. Warning for downstream traffic condition – motorway	90.2
2. Warning for downstream traffic condition – rural road	84.3
3. Blind spot warning during lane changing – motorway	82.1
4. Blind spot warning at non-signalised intersection – urban road	82.0
5. Blind spot warning at non-signalised intersection – rural road	79.4
6. Blind spot warning during lane changing – rural road	75.0
7. Blind spot warning at signalised intersection – urban road	73.3
8. Blind spot warning at signalised intersection – rural road	71.4
9. Warning for imminent crash	70.2
10. Presentation of badly visible objects on windscreen	70.0

It was investigated to what extent there seemed to be a significantly greater need for certain driver support functions than others. Therefore, McNemar tests were performed with data from table 3. The McNemar test is a nonparametric test for two related dichotomous variables (Rice, 1994). It focuses on changes in responses from one sample response (e.g. function 1) to another (e.g. function 2) using the chi-square distribution. It appeared that the first function 'warning for downstream traffic condition – motorway' significantly differed from the other functions ($p<0.001$). This also applied to the functions 2 to 5, which significantly differed from the first function and from the functions 6 to 10. Based on this, the top 10 of functions could be divided into three groups; see table 3. Within the groups the perceived (great) need for the specific functions did not differ significantly, except for function 2 versus 5.

Furthermore, the results showed that only three respondents were indifferent or negative (categories 3 to 5) about all driver support functions presented in the first part of the survey. 107 respondents out of 1049 (10.2%) indicated to have (certainly) no need for lane keeping support. Also support with lane changing was not very wanted. Almost 9% of the respondents did not need any help from the car with this driving task. However, it should be kept in mind that more than 82% of the respondents indicated to have a (great) need for a blind spot warning during lane changing on motorways.

Road type

In general, the results showed that there was a great need for driver assistance during driving on motorways. Respondents wanted less help from their cars with driving on rural roads and even less on urban roads. However, this tendency did not hold up for all driver support functions. It appeared from McNemar tests, that information on speed limit and warning for exceeding speed limit were most wanted on rural roads ($p<0.001$). Six functions were wanted on rural roads as much as on motorways, among which warning for unsafe speed regarding actual situation (e.g. fog, curve) and automatic lane keeping on winding roads. According to McNemar tests, also six functions scored higher on rural roads than on urban roads, among which warning for opposing traffic (lane changing) and information on approaching a dangerous (non-) signalised intersection ($p<0.001$). There was no greater need for specific functions on urban roads compared to rural roads.

Level of support

According to the results, respondents would mainly like their cars to help them by giving information or warnings. They indicated hardly any need for driver support functions that consisted of control. The most unpopular driver support functions were related to automatic actions with respect to lane changing, negotiating intersections and lane keeping. However, in some cases respondents did want the car to take over control. McNemar tests showed that respondents preferred automatic actions from the car when they want to maintain a self-chosen speed on motorways or rural roads ($p<0.001$). They also would like the car to take over the longitudinal driving task or even the whole driving task when they are driving in traffic jams, irrespective of the road type.

4.3 Ideal driver support system

More insight is gained into the ideal driver support system by analyzing the answers to the second part of the questionnaire. In this part the respondents indicated at most six driving tasks and situations that the ideal system should provide help with.

Types of driver assistance

The respondents chose various types of driver assistance in their ideal driver support system, so the ideal system seemed to be personal. Most respondents (56.2%) thought the ideal system should provide support with six driving tasks and situations. According to 29 respondents (2.8%), the ideal system should only help with one driving task or situation. Table 4 shows the most popular driving tasks and situations that the ideal system should provide help with. The ideal system should not support lane keeping on urban roads and negotiating signalised intersections on rural and urban roads. Less than 2.8% of the respondents indicated to want assistance from the ideal system with these driving tasks.

Table 4. Top 10 of most popular types of assistance in ideal system

Type of assistance	Yes in system (%)
1. Reduced visibility	60.5
2. Imminent crash	56.2
3. Car following – motorway	51.1
4. Regulating speed – motorway	43.8
5. Congestion driving – motorway	42.3
6. Driver fatigue	35.3
7. Regulating speed – rural road	33.8
8. Car following – rural road	28.5
9. Negotiating non-signalised intersection – rural road	22.4
10. Negotiating non-signalised intersection – urban road	19.9

Comparable to the single driver support functions, it was investigated to what extent there seemed to be a significantly greater need for certain types of driver assistance in the ideal system than others. McNemar tests were performed with data from table 4. It appeared that the first three types of assistance did not significantly differ from each other ($p<0.001$). However, the difference between these three and the rest of the top 10 was significant. So, help from the ideal system with reduced visibility, imminent crash and car following on motorways was most popular of all. Within the group of type 4 to 10 the perceived need for the specific types of assistance differed significantly, except for consecutive numbers. For example, respondents were indifferent about help from the ideal system with regulating speed on motorways (type 4) and congestion driving on motorways (type 5), but they preferred help with regulating speed on motorways (type 4) to help from the system when they are fatigued (type 6). The three most frequently mentioned pairs of driver assistance consisted of combinations of the three most popular 'single' driving tasks and situations in the ideal system.

Ideal system in relation to single functions
Respondents had to formulate their ideal driver support system by indicating driving tasks and situations (not functions) that the system should support. Therefore, the ideal system was not "directly" linked to the single driver support functions. Although there was not a direct relationship, it was investigated to what extent the composition of the ideal system was related to the indicated needs for the driver support functions. Driving tasks and situations "corresponding" with the driver support functions for which respondents indicated a (great) need, could or could not be chosen in the ideal system. For example, 64.9% of the respondents that indicated a (great) need for the presentation of badly visible objects on the windscreen wanted the ideal system to help with reduced visibility situations. In this case, most respondents that had a need for the single driver support system related to reduced visibility also indicated a need for help from the ideal system with this situation. Such results show a certain consistency in the answers to the first and second part of the survey. However, this did not apply to, for example, help with negotiating signalised intersections on rural roads. Only 2.3% of the respondents that indicated a (great) need for blind spot warnings at signalised intersections on rural roads wanted the ideal system to help them with this driving task. It can be concluded that when having to establish priorities, it seems that respondents thought it was more important to receive other types of assistance from the ideal system, for example support during reduced visibility, than support with negotiating signalised intersections.

4.4 Influence of sample characteristics

It is interesting to investigate whether the results of the user needs survey were dependent on characteristics of the sample. First, the effects of corrected proportions between the sample and the target group on the results were studied by weighting cases. Second, the influence of driver characteristics, such as age and driving experience, on the perceived needs for driver assistance was examined. Finally, it was tested whether the way participants were gathered for the survey was of influence.

Weighting cases
The sample of the user needs survey significantly differed from the target group with respect to gender, age and education. Therefore, the results are only valid for this subset of the target group. However, by weighting cases the proportions between the sample and the target group were corrected. Again, the needs for driver support functions and the composition of the ideal driver support system were analysed. After weighting cases, it appeared that the top 10 of most popular driver support functions and the top 10 of most popular types of driver assistance in the ideal driver support system were (almost) identical to these top 10s without weighting cases. It was concluded that, although the sample did not statistically resemble the target group, the results of the sample gave a clear indication of those of the target group.

Driver characteristics
It was studied to what extent eight driver characteristics were of influence on the results of the user needs survey. Table 5 shows these characteristics and their categories.

Table 5. Driver characteristics and categories on behalf of statistical tests

Characteristic	Categories
Gender (gen)	male, female
Age (age)	18-24 years, 25-44 years, 45-64 years, ≥ 65 years
Education (edu)	primary & lower secondary, higher secondary, higher & university
Frequency of car driving (frq)	>3 times a week, 1-3 times a week, 1-3 times a month, <1 time a month
Years of driving experience (yrs)	<5 years, 5-10 years, >10 years
Average annual mileage (km)	<10.000 km, 10.000-20.000 km, >20.000 km
Type of car possession (car)	private, business
Familiarity with ACC (acc)	not familiar with, somewhat familiar with, (very) familiar with

First, it was studied to what extent driver characteristics affected the needs for the most popular driver support functions (table 3). Chi-square tests were performed that focused on the group of respondents that indicated to have a (great) need for the function in question. It was stated that driver characteristics were not of influence on the perceived needs, when the distributions of the eight variables in this sub-sample were equal to the distributions of these variables in the total sample. The tests showed one significant result concerning the distribution of type of car possession with respect to the group of respondents that indicated to have a (great) need for the presentation of badly visible objects on the windscreen ($p<0.05$). Based on the distribution of this variable in the total sample, it was expected that more private and less business car drivers would have a need for this function; see table 6. The results indicated the opposite, so it can be said that this driver support function was more popular among business drivers than private drivers.

Table 6. Car possession and 'presentation of badly visible objects on windscreen'

	Observed #	Observed (%)	Sample (%)
Private	568	82.9	85.8
Business	117	17.1	14.2
Total	685	100.0	100.0

Second, it was studied to what extent driver characteristics affected the needs for the most popular types of driver assistance in the ideal driver support system (table 4). The chi-square tests focused on the group of respondents that indicated to want the ideal system to include the type of driver assistance in question. For some popular types of driver assistance, the distribution of several variables in the sub-sample differed from the distribution of these variables in the total sample ($p<0.05$); see table 7. It can be seen that especially needs for help with congestion driving on motorways was influenced by several driver characteristics. Furthermore, the composition of the sub-samples that indicated the ideal system to support with imminent crash situations, car following on motorways and driver fatigue situations appeared to be equal to the composition of the total sample with respect to the eight driver characteristics. So, respondents had a similar need for these types of support from the ideal driver support system, regardless of their background.

Table 7. Influence of driver characteristics on types of driver assistance in ideal system

Type of driver assistance	Driver characteristics of influence
Reduced visibility	Gender
Imminent crash	-
Car following – motorway	-
Regulating speed – motorway	Gender
Congestion driving – motorway	Gender, age, education, average annual mileage, familiarity with ACC
Driver fatigue	-
Regulating speed – rural road	Gender
Car following – rural road	Age, familiarity with ACC
Negotiating non-sign. intersection – rural road	Gender
Negotiating non-sign. intersection – urban road	Gender

Table 7 can be clarified as follows. Gender appeared to have the biggest influence on the types of driver assistance wanted in the ideal driver support system. Men thought the ideal system should mainly support with congestion driving on motorways and with regulating speed on motorways and rural roads. However, women thought the ideal system should mainly support with reduced visibility situations and negotiating non-signalised intersections on rural and urban roads. The results indicated differences between certain age groups, but no 'trend' between young versus old could be found. Especially respondents aged 25-44 years appeared to have a greater need for help with congestion driving on motorways. However, this group seemed to have less need for help with car following on rural roads compared to the other age groups. The results revealed that the higher one's education, the more one indicated a need for support with congestion driving on motorways. Also respondents that drive >20.000 km a year had a great need for this type of support. The results further suggested that the more one was familiar with ACC, the more one had a need for this type of driver assistance in the ideal system as well. However, familiarity with ACC did not show a clear relationship with the need for help with car following on rural roads. Respondents that were not familiar or very familiar with ACC indicated to have a stronger preference for this kind of support in the ideal system than respondents that were somewhat familiar with ACC. The frequency of car driving, years of driving experience and type of car possession did not appear to have an influence on the composition of the ideal system.

Response group

Participants for the survey were invited in two ways, namely via a market agency and via personal and business contacts. Both response groups belonged to the target group and had to fill in the same questions about their needs for driver support. Therefore, it was decided to analyze both groups together. To check whether this had consequences for the results of the survey, statistical analyses were performed.

First, the two groups were compared to each other with respect to the eight driver characteristics (e.g. gender, age) by means of chi-square tests. Results from these tests showed that the groups significantly differed from each other with respect to all of the characteristics, except for average annual mileage and type of car possession ($p<0.05$). For example, the Internet panel group consisted of (1) more female respondents, (2) more older respondents, (3) less highly-educated respondents, (4) more respondents that drove over three times a week, (5) more respondents with over 10 years of driving experience and (6) less respondents that were (very) familiar with ACC.

Second, chi-square tests were performed to see whether the response group had an influence on the ten most popular driver support functions (table 3) and the ten most popular types of driver assistance in the ideal driver support system (table 4). It appeared that respondents had a similar need for the driver support functions, regardless of the way they were gathered for the survey. However, the tests revealed significant results with respect to support from the ideal system with congestion driving on motorways ($p<0.05$). Based on the distribution of response group in the total sample, it was expected that more respondents from the Internet panel group and less respondents from the self-gathered group would have a need for this type of driver assistance. The results indicated the opposite, so it was concluded that this type of driver assistance was more popular among respondents from the self-gathered group. This can possibly be attributed to the different composition of the two groups with respect to gender, age, education and familiarity with ACC. These variables already appeared to have an influence on the perceived needs for this type of driver assistance in the ideal driver support system.

5. Discussion

5.1 Implications for ADAS

The aim of the survey was to reflect the needs of the driver with respect to driver assistance. Generally, it seems that respondents want to be well informed when driving. It was noticed that respondents had a need for a reasonable number of driver support functions. Besides, the ideal system should certainly provide help with more than one driving task or situation. These needs of the driver will have consequences for the possible integration of driver support functions. It was recognized that a shift has to be made from ADAS that only include one kind of support to ADAS that consist of integrated driver assistance. Technical integration should be taken into account, so that different functions can use the same components, such as sensors. Aspects surrounding the Human-Machine-Interface (HMI) are important to prevent the driver from overload and confusion. Different functions should use one interface with information management to give priority to certain information. The HMI should also be easily adjustable, because respondents would like to have the possibility to choose the type of assistance and feedback. Attention should be given to the functional operation of integrated driver assistance as well. ADAS should make use of each other's information, for example by inter-vehicle communication. This applies to functions such as warnings for downstream traffic conditions. Communication between functions within the vehicle needs also consideration. Imagine a driver support system that includes assistance with car following and assistance during reduced visibility. The functions in question should exchange information to extend their individual field of activity, for example, in terms of maintaining an increased headway in reduced visibility situations.

5.2 Contribution to conceptual framework

The conceptual framework (figure 1) related the user needs for driver assistance to characteristics of the driver, the driver assistance and the traffic scene. Below, it is clarified how the results of the user needs survey complemented the conceptual framework.

Driver

The influences of driver characteristics on the most popular driver support functions and the most popular types of driver assistance in the ideal system were studied. Table 8 shows these relationships (see table 5 for abbreviations). The categories mentioned in this table indicated to have a greater need for the specific driver assistance than the other categories.

Table 8. Positive relationships between driver characteristics and driver assistance

Driver assistance with:	gen	age	edu	km	car	acc
Reduced visibility	female					
Imminent crash						
Car following – motorway						
Regulating speed – motorway	male					
Congestion driving – motorway	male	25-44	higher	> 20.000		familiar
Driver fatigue						
Regulating speed – rural road	male					
Car following – rural road		$\leq 24, \geq 45$				
Negotiating non-sign. intersection – rural road	female					
Negotiating non-sign. intersection – urban road	female					
Badly visible objects (presented on windscreen)					business	

Gender revealed to affect the perceived needs the most. Although men and women had equal needs for driver assistance, these needs differed per driving task or situation. For example, women had a greater need for help from the ideal system with reduced visibility situations, while men had a greater need for help with regulating speeds on rural roads. These findings are not consistent with earlier research, which pointed out that women were more positive about ADAS, in particular speed-regulating devices. Driver characteristics did not appear to relate to the needs for support with imminent crash situations. Evidently, all respondents regardless of their background thought this kind of support was important. It must be noted, that the results only focussed on the most favoured driver assistance. It might be possible, that more relations between driver characteristics and perceived needs for driver support appear, when all results are considered.

Driver assistance

Especially the driver support functions that aim to give warnings for downstream traffic conditions and warnings for traffic in blind spots were favoured. The ideal driver support system should, according to the respondents, provide help with (combinations of) reduced visibility, imminent crash and car following on motorways. As in earlier research, lane keeping support was not popular. With respect to level of support, respondents would mainly like their cars to help them by giving information or warnings. Generally, automatic actions from the car were unpopular. Many respondents indicated that they had a desire to stay in full command of the car. This corresponds to findings from literature. However, in some cases respondents did want the car to take over: when they want to maintain a self-chosen speed on motorways or rural roads and when they are driving in traffic jams, irrespective of the road type.

Traffic scene

Also aspects of the traffic scene affected the perceived needs for driver support. According to the results of the survey, respondents thought that their cars should help them in critical situations. For example, warnings for an imminent crash and assistance during reduced visibility supported this view. This is consistent with earlier research. Besides, most respondents indicated that the ideal system should give more support in busy traffic and deviant situations, for example when the weather is bad. In general, the results showed that there was a great need for driver assistance during driving on motorways. However, driver support functions that were more wanted on rural roads than on motorways and urban roads were information on speed limit and warnings for exceeding the speed limit. Some functions were equally wanted, among which warnings for an unsafe speed regarding the actual situation (e.g. fog, curve) on motorways and rural roads.

5.3 Conducting the survey

Drivers can be regarded as ‘hands-on’ experts in car driving. Therefore, it seems relevant to ask them to indicate their needs for driver assistance. However, this methodology can bring along some limitations. A limitation of this user needs survey is the fact that the driver support functions were presented hypothetically in text. To some extent, it is uncertain whether respondents understood everything correctly. Pilot testing was done to diminish the chance of wrong comprehension. Usage of multimedia features (e.g. pictures, movies) can supplement questions or even form the basis of a question. However, the literature we found on using these features in a survey showed contradictory findings. For example, ‘visual language’ could draw attention away from text and alter the meaning of words (Couper, 2001). As a result, respondents may interpret questions in light of accompanying graphics, thus lowering the validity of the answers. Therefore, it was decided not to present pictures of the driver assistance in the survey. Furthermore, respondents may be influenced by their familiarity with forms of driver assistance. In this study, it appeared that familiarity with ACC affected the perceived needs for help with car following on rural roads and congestion driving on motorways. This possibly also explains the great perceived need for support on motorways, because systems already available on the market, such as regular cruise control and ACC, are merely designed to operate on motorways.

In this study, the choice was made to design an Internet questionnaire. In spite of the many benefits, access via the Internet introduces bias, because only Internet users can fill in the questionnaire. This could also be seen from the frequency of Internet usage: more than 97% of the respondents indicated to regularly make use of the Internet. However, it should be kept in mind that the number of current Internet users is high and still growing (CBS, 2004). In 2004, 72% of the Dutch people had ever used the Internet and 80% of the people aged 18-54 years indicated to have used the Internet the past four weeks. Nevertheless, we recognized that the opinions of elderly drivers were to a large extent missing in this user needs survey. Furthermore, it should be asked how respondents (i.e. users of the Internet) were likely to differ from non-respondents. The fact that the respondents were more acquainted with new technology might have affected their views on ADAS. For example, Chalmers (2001) found that those who use new technology as part of their lifestyle did not accept control of the vehicle being taken away from them. Apparently, this group is more concerned about the reliability of a system in terms of technical failure. Another limitation may be the selection of participants. In particular, the invitation of participants via personal and business contacts can lead to inherent bias. Statistical tests revealed that response group (i.e. self-gathered or Internet panel) appeared to have an influence on the perceived needs for certain types of assistance in the ideal driver support system. Probably, this influence can be attributed to the different composition of the two groups with respect to background characteristics, such as gender and age. The total sample appeared not to significantly resemble the target group of Dutch car drivers. However, weighting cases tried to compensate for this bias. It was stated that the results of the sample could be regarded as strongly directional for those of the target group.

6. Conclusions

6.1 Conclusions

The car driver of tomorrow will enjoy an increasing variety of in-vehicle systems that assist him or her in the driving task. This paper has discussed the perceived needs of the driver for driver assistance. By means of a user needs survey, car drivers were asked to indicate their needs for support from their cars during certain driving tasks and situations. It appeared that warnings for downstream traffic conditions and warnings for traffic in blind spots were favoured. Apparently, drivers appreciate being well informed when driving a car. Knowledge about what is happening further down the road (e.g. an accident or road works) can help the driver to accordingly regulate his speed or allows the driver to turn off the road and seek an alternative route to his destination. Being aware of what is happening in the direct vicinity of the car (e.g. another vehicle in the left blind spot or a bicycle in the right blind spot at an intersection) provides the driver with a more accurate idea of the situation, so that dangerous situations can be prevented or at least anticipated. Furthermore, the respondents preferred the ideal system to give support in critical situations, such as an imminent crash and reduced visibility. To fit the needs for driver assistance, it is assumed that ‘stand-alone’ ADAS are not satisfactory. Consequently, integrated ADAS are needed that make use of each other’s information to extend their individual fields of activity. Consider, for example, warnings for imminent crash situations based on sensor data fusion or warnings for downstream traffic conditions based on inter-vehicle communication.

6.2 Future research needs

The user needs survey clarified to which extent drivers have a need for systems that support them with their driving tasks. Because most of these systems do not exist (yet), it is uncertain whether the respondents interpreted the hypothetical driver support functions correctly. Therefore, it would be interesting to investigate whether the opinions ‘on paper’ change after the respondents have gained experience with the driver assistance. In order to verify this, respondents of this survey will participate in a driving simulator experiment in which their driving behaviour and workload as well as their acceptance will be studied.

The survey reflected the needs of the driver with respect to driver assistance. These needs can have implications for the possible integration of driver support functions. In this respect, one could expect that integrated systems would be sensible. However, more research into user needs for integrated systems is advisable. In this questionnaire, the ideal system was not "directly" linked to single functions. For future research, it is recommended to formulate the ideal system in terms of driver support functions.

Selection bias can be regarded as a drawback of Internet questionnaires. Only one population can be researched using the Internet, namely people who (regularly) use the Internet. Up to now, the Internet is hardly accessible for elderly people. Therefore, the opinion of an important group of drivers was missing in this user needs survey. Future research should focus on this group, preferably using other data collection methods (e.g. face-to-face interviews, paper questionnaires).

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