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Ideas and Expectations of Intersection Assistance

Abstract

The objective of this study was to identify aspects of the individual experience and behaviour of drivers in intersection accidents. A total of 40 accident drivers sketched their ideas and expectations relating to intersection assistance using the method of Structure Formation Technique. Using this method prepared content cards and relation cards for a subject matter are formed together in a structure through the application of an explicit set of rules. The structures generated in this process were compared with the structures of 20 control persons who have not recently experienced an accident at intersections. The basis for this comparison was a case-control design with matched samples regarding the variables age, sex, education, occupation, driving experience and annual mileage.

The results of the accident reports indicate that additional assistance is instrumental in the perception of other road users. Generally the interviewed drivers were open-minded towards the use of intersection assistance systems. Drivers who have recently experienced an accident at intersections significantly more often approved of warning assistance in their vehicle than drivers who have not recently experienced an accident. Further accident experienced drivers favoured warning and information via audio warning more frequently. The ideas of the drivers were strongly shaped by the experiences with already available advanced driver assistance systems. Hence acoustic and visual warnings were generally preferred to tactile warnings. The findings also indicate a relationship between the variable age and the acceptance of automatic vehicle intervention, and the suggestion of a head up display as a configuration of a visual warning system.

Introduction

It is the ambition of accident research in vehicle industry to investigate accident events as a whole. For that purpose engineers, physician and psychologists work together interdisciplinarily.

Using the data concerning the vehicle, the injuries of the car occupants, the environmental conditions and the resulting reconstruction of the accident events, it is the objective of accident research to generate information for the technical development of vehicles. Therefore the main focus has traditionally been the development of systems for passive safety. However, in recent years the focus has shifted to concerns of active safety and hence the collection of psychological data relating to the pre-crash phase has become essential. Psychological accident data particularly refer to perception, cognitive procedures, attention as well as risk taking, motives and social interaction of the road users (SCHLAG, 1999). It is of importance to gain expertise about how people experience accidents and how they behave in particular critical situations. Furthermore it is of specific interest which driving tasks demand need for assistance. In order to answer this question it is essential to ask drivers for needs, expectations and ideas concerning advanced driver assistance systems.

In the past decades it was usual in product development that evaluation studies were only applied after products had been introduced onto the market. Such procedures hold the risk of inappropriate developments (HEMMERLING, 1998, SACHSE & HACKER, 1995). Applied in the vehicle industry, inadequate designs of advanced driver assistance systems (ADAS) might lead to so called negative behaviour adaptation (WELLER & SCHLAG, 2004). Hence in the mid-eighties there was a short-term rise in rear end crashes after the introduction of the anti-lock braking system in Germany (REICHLE, 1989). A possible explanation for this phenomenon is a misunderstanding of the drivers of the new system as a brake enhancing system.

It is an underlying assumption that individuals have representations in their mind about why things or systems are existing, how they are operating, what they are doing and what they look like (ROUSE and MORRIS, 1986). Those representations are called mental models. They depend on the experience, goals and tasks of the users of systems as well as the design of the system and the communication of the system function. Mental models are kept in mind by the users of systems as long as they are plausible (KLUWE, 1992; SEEL, 1991; DUTKE, 1994). In conclusion it is important

to involve future system users in the process of product development, especially in designing the human-machine interface, so that negative behavioural adaptations in consequence of inadequate mental models can be avoided (HEMMERLING, 1998).

For this study an intersection assistance system was chosen, in order to show the benefit of interviewing potential system users, because such a system has not been introduced onto the market yet. Besides that, accidents at intersections have a high prevalence (about one third of the accidents in Germany in 2004 happened at intersections) and therefore cause high economic costs. Furthermore, especially elderly drivers have a higher incidence at complex intersections and junctions (ENGELN & SCHLAG, in press), and since the number of elderly drivers is expected to rise in near future, it is important to research intersection assistance systems.

The following questions are to be answered in the course of this paper: What can be learned from reports about accidents at intersections? Is there a general need for intersection assistance? In which situations and on which level do drivers wish for an intersection assistance system? How should an intersection assistance system be designed to effectively assist the driver of a vehicle? Which factors are influencing the ideas and expectations on intersection assistance?

Method

Participants

The sample consisted of 40 drivers who experienced an accident at an intersection in the period from January 2004 to June 2005. 20 of those accidents were investigated by the accident research team of Volkswagen in the region of Wolfsburg and Braunschweig. This part of the sample was compared with a control group of 20 drivers who had not experienced an accident at intersections in recent years. The other 20 accidents were investigated by the accident research team of the Technical University Dresden in and around Dresden. The aim of study this second sample was to confirm the statements deduced in the first part of the research program.

The participation in this study was voluntary and honoured with a small gift at the end of the session.

Apparatus

In order to explore the ideas and expectations of intersection assistance the 40 accident drivers were questioned about their individual accident experience with the help of a structured interview manual. The objective of the interview was to explore details concerning the course of the accident, particularly the moment of perceiving the accident opponent and the consequently following reactions. Also of importance were environmental circumstances. Finally the accident drivers were asked about their opinions towards the avoidability of the accident, in order to find out about the individual view of the mistakes of the driver himself and the mistakes of their opponents, and beyond that, possibly existing mental models of the functionality of advanced driver assistance systems.

The drivers who had not experienced an accident at an intersection were asked about their experiences with accidents in general.

The method chosen to explore the mental models of the participants is called Structure Formation Technique. Under this label different strategies are summarised which support their users in producing structures that illustrate causal and explaining relations between terms of variable contents through the application of an explicit set of rules (SCHEELE & GROEBEN, 1988; BONATO, 1990; FELDMANN, 1979). In the current case the participants of the study were given a set of 46 prepared cards with terms describing and explaining intersection assistance concerning design, functionality and usage settings. They were instructed to take a look at the cards and sort out the terms which they thought of as relevant for their idea of intersection assistance. Additionally they were asked to combine the relevant terms with relation cards containing 5 different possibilities of relations: an arrow to describe chronological and spatial linkages, an equal sign which represents definitions, a card “or” used to indicate relating terms that exclude each other, a card “precondition” to characterize conditional relations and a card with two lines symbolizing hierarchical relationships between the terms. The structures were analyzed through counting frequencies of the used terms and accordingly categories were formulated.

The acquisition of demographic variables was accomplished using a questionnaire answered by the participants at the end of the exploration. The following variables were collected: age, sex,

education, occupation, driving experience in years and annual mileage.

Procedure

The exploration was accomplished at the participants' home, at their work or at another neutral place. After an interview in order to examine the participants' accident experiences, they were given a pack of conceptual cards to look through and sort out and a set of relation cards. The instructor explained the procedure of the structure putting technique by means of the example of a washing machine and guided the participants through the exploration using questions based on the model of ROUSE and MORRIS (1986, see above) concerning the goals, the looks, the functioning and relevant settings of the intersection assistance system. In addition to the given content cards, the participants had the possibility of generating their own cards based on a dialog with the instructor. For the warning strategies they were required to generate their own cards. After the structure was formed, the instructor repeated the ideas in their own words and asked for complementary ideas. There was also time for discussing different aspects of the participant's structures. At the end of the exploration the participants' were asked questions about demographic variables. The whole dialog was recorded with a tape recorder in order to facilitate the analysis of the data. The exploration lasted about 60 to 90 minutes dependent on the interaction styles and the quantity of ideas of the participants.

In order to analyze the data, different strategies were used. Firstly the 20 participants that were involved in accidents investigated in the region Wolfsburg and Braunschweig were compared to the 20 participants without intersection accident experience at intersection in years following a case-control design. A precondition for realizing this design was to match the participants of these two groups concerning the variables age, sex, education, occupation, driving experience and annual mileage. The resulting pairs were analyzed using statistical methods for matched samples such as a binomial test for alternative variable characteristics. Significant results of those analyses are reported respectively. In a second step the accident samples investigated in Wolfsburg/ Braunschweig and Dresden were compared using methods for independent data. The two parts of the accident sample differed rarely concerning reviewed variables. Therefore in the following the reported results concern both parts of the sample.

Results

Structure analysis

In Figure 1 an example of a structure is shown (shortened). The participant who had formed this structure suggested a combination of information and automatic vehicle intervention in case of dangers through other road users. Therefore it is a precondition that other road users and possible dangers can be perceived with the help of sensory systems. An automatic vehicle intervention should be able to apply deceleration and emergency braking depending on the severity of the situation. The participant did not approve of automatic vehicle acceleration. Furthermore he proposed additional information about the automatic intervention of the vehicle either through a visual output like a head up display or through an acoustic output. The main goal of intersection assistance should be the avoidance of accidents. The process of structure forming was accompanied by a dialog between the participant and the instructor.

What can be learned from reports about accidents at intersections?

Drivers with accident experience at intersections either did not see their opponents at all or only just before the crash. Only 2 out of 40 drivers had seen their opponent before they crashed. Both had expected their opponent to stop because he had to wait at the intersection. These findings imply difficulties for the accident drivers concerning information admission. Having been asked about their reactions before the crash, 26 out of the 40 accident drivers answered that they had not been able to react anymore, 12 people were trying to brake. Five drivers tried to steer away from the other vehicle and one driver chose to accelerate. The success of the reaction manoeuvers can only be evaluated using the technical reconstruction data since most of the interviewees could not consciously observe the success of their reaction. Another noticeable finding is that most of the accident drivers describe how they could only react in one way and that it was impossible for them to think about two compensation strategies, for

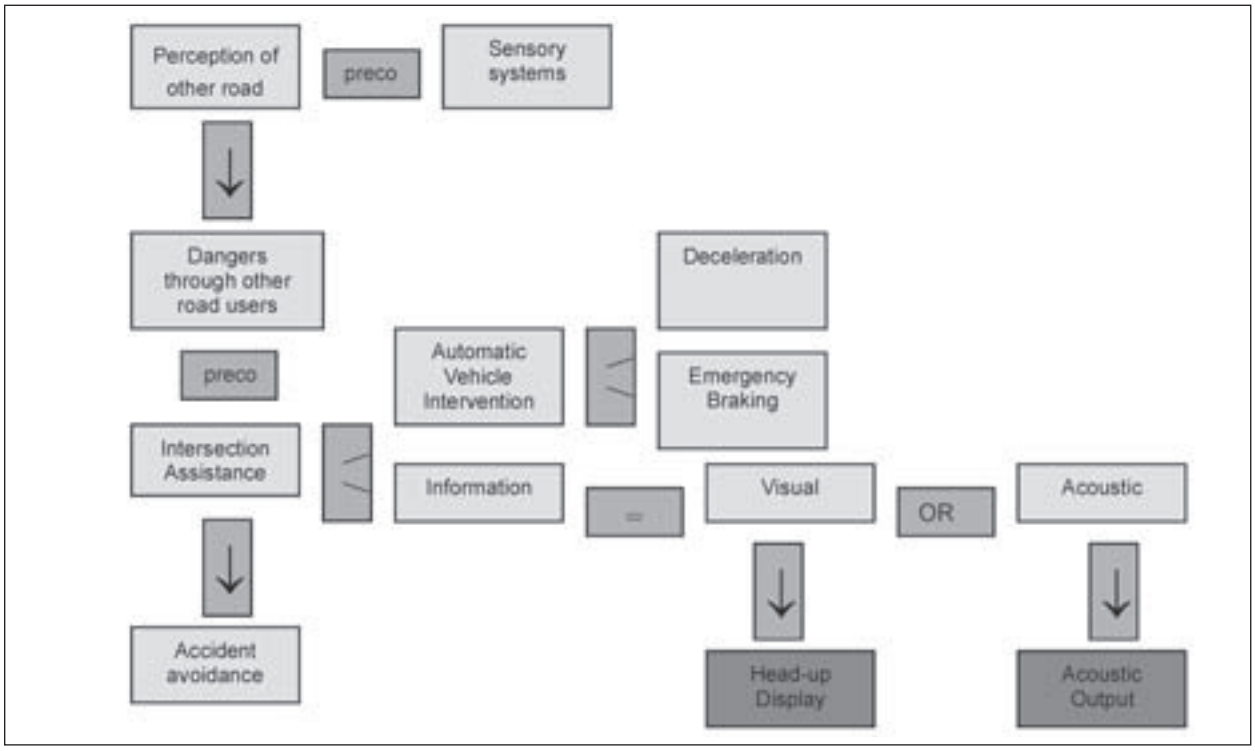

Figure 1: Example of a formed structure

example braking and drawing aside, at the same, very short, time.

Asked about the sight conditions, 12 participants reported obstructions through other vehicles, 6 could not see their opponents because of plants and trees and 4 felt impaired through sun glare. One driver described sight restraints through his own c-pillar.

Table 1 shows frequencies of drivers mentioning strategies of crash avoidance. The findings are shown separately for drivers who caused the accident (24) and for drivers who were involved in the accident (16) according to the accident record of the police. Multiple answers were possible.

One half of the accident originators reported mistakes related to deficiencies providing attention when turning at or crossing the intersections, while three quarters of the accident involved drivers did not see own possibilities of avoiding the accident. Another 12.5% of the originators and 6.25% of the accident involved drivers saw both opponents of capable avoiding the accident. The view of accidents as unavoidable naturalistic events is reflected in the opinions of 25% of the originators and 18.75% of the accident involved drivers. 21% of the accident originators and 31.25% of the accident involved drivers reported that

Avoidance	Originator		Involved Driver	
Only through actions of the opponent	6	25%	12	75%
Through more attention of oneself	12	50%	1	6.25%
Through more attention of both opponents	3	12,5%	1	6.25%
Through advanced assistance systems	1	4,2%	0	0%
Not possible: wrong time, wrong place	6	25%	3	18.75%
Through changes in environment or rules	5	21%	5	31.25%

Table 1: Frequencies of content card usage concerning strategies of crash avoidance

environmental circumstances or inadequate ruling were causal for the accident event. They suggested, for instance, establishing roundabouts. Only one interviewee suggested an advanced driver assistance system could have helped avoiding his accident. This suggestion concerned a “right of way”-display in the vehicle.

Is there a general approval of intersection assistance?

Generally the drivers who participated in the exploration were open-minded towards the use of systems assisting the drivers in turning at and

crossing intersections. Only two out of 40 accident experienced drivers disliked an additional assistance system for intersections. Among the 20 interviewed drivers without accident experience at intersections 3 disliked the idea of an additional assistance system.

In which situations and on which level do drivers wish for an intersection assistance system?

Having been asked about dangerous situations at intersections and approval of assistance all 38 accident-experienced participants of the study who supported the idea of an additional intersection assistance system (95%) were of the opinion that it is reasonable to assist the drivers at intersections in perceiving other road users. Moreover, 37.5% of the accident experienced drivers approved of assistance in detecting road signs and 27.5% accident experienced drivers suggested assistance in recognizing red traffic lights. Multiple answers were possible. It was noticeable that the accident drivers were generally influenced by their own accidents. The drivers who had not experienced an accident at intersections in recent years rated the detection of road signs as relatively more important. 80% of the comments accounted for situations of perceiving other road users, 45% of the comments were related to the detection of road signs and 20% of the comments concerned the recognition of red traffic lights. These results are shown in Table 2. In brackets there are shown the results for the part of the accident sample from Wolfsburg/Braunschweig which were compared to the results of the control group following a matched samples design. There could not be found any significant differences.

The discussion about the levels of assistance revealed a wide spread acceptance of warnings in the vehicle among accident experienced drivers: 85% approved of warnings as an adequate assistance strategy compared to 70% of the drivers without accident experience. This difference was significant (p=0.0315). Information systems were not rated as effective in intersection settings. Only about one third of the accident experienced drivers (30%) as well as the drivers without accident experience favoured information strategies. Surprisingly over one half of the accident experienced drivers (60%) and 65% of the drivers without accident experience suggested automatic intervention of the vehicle especially in emergency situations. Often the participants approved of more than one level of assistance thus suggesting sequential assistance strategies.

	Intersection accident experienced drivers		Drivers without recent intersection accident experience	
Road users	38 (20)	95% (100%)	16	80%
Traffic signs	15 (7)	37.5% (35%)	9	45%
Traffic lights	11 (9)	27.5% (20%)	4	20%

Table 2: Distribution of frequencies of content card usage relating to dangerous situations

	Intersection accident experienced drivers		Drivers without recent intersection accident experience	
Information	12	30%	6	30%
Warning	34	85%	14	70%
Intervention	24	60%	13	65%
Emergency braking	10 (3)	25% (15%)	8	40%
Deceleration	18 (9)	45% (45%)	6	30%
Acceleration	9 (4)	22.5% (20%)	5	25%

Table 3: Frequencies of used concept cards concerning preferred levels of intersection assistance

In a further step the interviewees were asked about their opinion of effective intervention strategies. Multiple answers were possible. Most popular were strategies of deceleration: 25% of the drivers with, and 40% of the drivers without accident experience supported the strategy of emergency braking; 45% of the accident drivers and 30% of the non-accident drivers favoured early deceleration and 22.5% of the accident drivers as well as 25% of non-accident drivers approved of acceleration as an effective strategy of vehicle intervention. There were no noticeable differences between the matched samples. The results of the last two aspects are summarised in Table 3.

How should an intersection assistance system be designed to effectively assist the driver of a vehicle?

In order to answer this question it was discussed which warning strategies would be most effective in signalling the driver of an upcoming crash. The results are presented in Table 4 and 5. The results of the sample from Wolfsburg/Braunschweig are shown in brackets.

Warning/information	Acoustic		Visual		Tactile	
Used in structure	46	76.7%	34	56.7%	18	30%
Not used in structure	14	23.3%	26	43.3%	42	70%

Table 4: Frequencies of content card usage concerning warning strategies overview (n=60)

	Intersection accident experienced drivers		Drivers without recent intersection accident experience	
Audio warning	29 (14)	72.5% (70%)	5	25%
Acoustic output	15 (8)	37.5% (40%)	7	35%
Visual displays (Icons)	15 (10)	37.5% (50%)	7	35%
Head-up Display	8 (5)	20% (25%)	3	15%
Right-of-way-Display	5 (5)	12.5% (25%)	5	25%
Vibration seat/steering wheel	8 (4)	20% (20%)	6	30%
Vibration safety belt	8 (4)	20% (20%)	2	10%

Table 5: Frequencies of content card usage concerning warning strategies detailed

It can be seen that the participants favoured warning media that they had experienced in the vehicle context before. The 76.7% of the drivers who favoured acoustic warnings and information compared the audio warning with an acoustic parking system or the acoustic output with a navigation system. Furthermore 56.7% of the drivers suggested visual displays partly like those they are used to in their cars. In contrast there were only 30% of participants who liked the idea of vibrations for warning, for instance at the steering wheel, the seat or the safety belt. In conclusion audio warning strategies ($c\chi^2$=4.543; p=0.045) as well as visual warning strategies ($c\chi^2$=4.667; p=0.046) were preferred significantly to tactile warning strategies. It is notable that often combined strategies were suggested. So visual warnings were only preferred in combination with acoustic or tactile warnings

It is also evident by the sum of multiple answers given that the interviewees were open for different realizations of warnings in general. An interesting finding is the difference between the opinions of accident experienced drivers (72.5%) and non-accident experienced drivers (25%) concerning the approval of audio-warning strategies. Taking a look at the comparison of the matched samples using a binomial test procedure shows a significant difference between the group of accident experienced drivers and the group of drivers without accident experience in recent years (p=0.012).

Which factors are influencing the ideas and expectations of intersection assistance?

Since a lot of differences could not be found neither between the drivers with and without accident experience at intersections nor between the originators and non-originators of the accident one should look for other possible influencing factors on the structures of intersection assistance. The only variable which had significant effects on the structures of the participants was age and it is therefore discussed in this section.

Age is significantly correlated with the support of automatic vehicle intervention. The mean age of the drivers accepting automatic vehicle intervention is 42.3 years while the mean age of the drivers who disliked the idea of automatic vehicle intervention is 51.7 years (n=60; T=2.145; p=0.036). Age is also closely connected with the approval of the usage of head-up displays for visual warnings. Drivers who supported the idea have a mean age of 33.9 years in contrast to drivers who did not support the idea who were 48.6 years old (n=60; T=3.583; p=0.002).

Discussion

The results of the interviews about the experience of accident situations suggest that there are mainly mistakes of perception leading to crashes. Following the missing information perception the accident drivers did not have the possibility to avoid the accident through their own reaction. So if it was possible to provide an additional system which guides the information perception and focuses on critical situations with other road users, for example through an audio warning, many accidents in complex intersection situations could be prevented. Drivers could brake or steer evasively earlier and gain valuable time. Besides that, automatic systems which intervene immediately and correct could contribute to a reduction of accidents at intersections. When interpreting the open-minded attitude of the study's participants, effects of selective sample drawing of the accident drivers cannot be excluded. The participation in the study was voluntary and there is a possibility that the

positive response behaviour of the accident drivers represents some kind of rehabilitation strategy.

Furthermore the findings indicate that drivers with accident experience at intersections are more convinced of audio warnings in their vehicles. Actually all participants mentioned audio and visual warning strategies more often than tactile warning strategies. This finding can also be interpreted as evidence for acquiring mental models dealing with certain products (KLUWE, 1992). The drivers are in a way already used to audio and visual warnings and have built associations between certain signals and dangers. It has to be evaluated which audio warnings are best for which kind of information. As an alternative to audio warnings some of the drivers preferred an acoustic output. The advantage of an acoustic output is that one does not even have to build associations between signals and dangers. On the other hand it could be easier to miss a warning, for example when talking to passengers of the car. Another argument against an acoustic output is the perception that it is too slow in critical situations. Before implementing new systems, advantages and disadvantages have to be researched carefully in experimental studies.

It is also remarkable that visual displays as a warning were supported only in combination with audio or tactile warnings. These results are probably due to the experience of the drivers, that it can take some time before noticing visual displays.

Warnings through tactile senses like vibration were used by the drivers significantly less in their structures. The reason for this finding could be the lower familiarity of the participants with this medium. An evidence for this statement is shown by the rationales of two young male participants for preferring vibrations at the steering wheel: they stated that they are used to these vibrations by using the game pad of their Play Station. Maybe this is a clue to individualize warning strategies in vehicles. Emergencies in vehicle driving are hopefully very rare. It might be a good solution to use existing stimulus-reaction-associations for a fast and effective warning in critical situations.

Two thirds of the interviewees approved of strategies for automatic vehicle intervention. Among those, some drivers supported sequential strategies of automatic vehicle interventions only after a warning and a chance for the driver to react himself. Others preferred immediate interventions of the vehicle. Often the drivers wished for additional information about the vehicles' actions. The results support the efforts of the automobile manufacturers in research of automatic braking strategies. It is also obvious that drivers feel less comfortable about acceleration strategies. This finding reflects the drivers' aversion to give up control over their vehicle. It is also relevant to the matter of take-over between the driver and the vehicle since acceleration raises the time pressure on the drivers which might lead to an increase of critical situations. These matters have to be researched intensively.

The findings of this study are useful in generating ideas for the development of intersection assistance. They inform about subjective opinions of the interviewed drivers about the effects of future products. Other aspects of the usability of an intersection assistant like interference with the driving task, operating convenience or actual efficiency have to be studied in the progress of the further development of intersection assistance systems (EN ISO 17287).

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