Expert evaluation of driver assistance systems with respect to traffic safety

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1. Introduction

The amount of information which could be offered to the driver grows steadily. All over the world car manufacturers as well as research institutes develop new systems. But, up to now it is not clear or sure, whether additional information is helpful to the driver to perform his most important task: safe driving in the framework of increasing traffic density.

2. Methodology

In the research project KOSIFA, initiated by Bundesanstalt für Straßenwesen (BASt, Germany), information and communication systems in cars, being under development, test or implementation were analysed. Twenty groups of telematic systems were specified. Systems range from ‘autonomous driving’, ‘car dynamics’, ‘distance keeping’, ‘collision avoidance’, ‘reversing aids’, ‘driver alertness monitoring’ and ‘navigation systems’ to ‘telephone’ and ‘television in cars’.

Each group of systems was evaluated by 23 experts, working on traffic safety (11 members of universities and research centres, 10 members of research or development centres of automobile and supplier industry, 2 motor journalists).

To evaluate the expected effects of these telematic systems on traffic safety, four aspects have to be considered:

1. The system can increase traffic safety, due to better information of the driver.
2. Traffic safety can decrease, if the system affects high mental load at the driver: Mental load is high, if one or more of the following conditions exist: an intensive dialogue is needed, the informational content is high, the driver is ‘forced’ to answer the system, the driver cannot interrupt communication.
3. Traffic safety can decrease, if the system causes high sensory distraction of the driver. This happens for example, if the system demands long and often glances, or the driver gets distracted from driving, because he has to handle the system one- or both-handed.
4. A very crucial aspect is safety in the situational context. Here traffic safety of all traffic participants is to consider, not only the safety of the driver and the vehicle. Speeding in turns, for example, not only endangers the driver and his car, but also following or approaching cars and pedestrians.

In a further step the likelihood of activation of a set of telematic systems was analysed in six traffic scenarios. The expert's evaluation and the supposed occurrence of the telematic systems results in an output logic. This logic takes into account time instant and modality of presentation as well as activation mode (driver paced or system paced) and makes proposals for an hierarchy of information presentation on the basis of simply measurable parameters.

3. Representative results and discussion

3.1 Safety ratings

The overview of the results of the experts' rating shows which telematic systems will positively influence traffic safety (see fig. 5).
The 'top group' is represented by four systems: distance keeping, comfortable navigation system, vision enhancement and emergency system.

Distance keeping has got high ratings because of it's safety gain for general traffic safety, combined with low mental load and low sensory distraction for the single driver (see fig. 1). Comfortable navigation systems with turn by turn advises, speech control and destination programming only at standstill will have a positive influence, too. The driver gets more information in combination with low mental workload. Thus safety gain for the whole traffic situation is expected. The same effects can be seen for realisations of vision enhancement, i. e the improvement of roadside vision using automatic

Evaluation of safety gain for distance keeping	no gain	small gain	medium gain	high gain	very high gain
general traffic safety				xxxxxxxxx	
information			xxxxxxxxx		
mental load				xxxxxxxxx	
sensory distraction				xxxxxxxxx	

Fig. 1: Safety gain for distance keeping, experts' rating

Evaluation of safety gain for vision enhancement	no gain	small gain	medium gain	high gain	very high gain
general traffic safety				xxxxxxxxx	
information				xxxxxxxxx	
mental load				xxxxxxxxx	
sensory distraction			xxxxxxxxx		

Fig. 2: Safety gain for vision enhancement, experts' rating

headlamp regulation depending on road geometry, as well as automatic dipping (see fig. 2). Emergency systems are expected to rise general traffic safety.

Figure 5 is mainly self-explaining and there is no need to comment each and any number in this figure. But, some especially remarkable results are highlighted. One concerns the question of driver-initiated versus automatically initiated systems. For parking aids, a driver demanded information system is judged to be better than a system using automatically warning, because it gives more information and its mental load is lower.
Experts scale also driver initiated fleet management to be better than system initiated. System initiated fleet management implicates a high amount of mental load and sensory distraction.

A further interesting result is the evaluation of widely implemented systems. On-board computers and telephones (even the free handed version) got negative rankings due to high mental load and sensory distraction. The same problems are seen for new systems like road pricing and vision enhancement by Head-up display.

From a safety point of view the experts judge the following systems to be quite problematic: television in a vehicle (fig. 4), telephone with hand set (fig. 3), the mobile office and the transfer of private information. They implicate an extremely high mental load and sensory distraction of the driver not improving traffic safety at all. For safety reasons, these telematic systems should not be implemented in vehicles.

Evaluation of safety gain for telephone with hand set	no gain	small gain	medium gain	high gain	very high gain
general traffic safety	xxxxxxxxx				
information		xxxxxxxxx			
mental load	xxxxxxxxx				
sensory distraction	xxxxxxxxx				

Fig. 3: Safety gain for telephone with hand set, experts' rating

Evaluation of safety gain for television	no gain	small gain	medium gain	high gain	very high gain
general traffic safety	xxxxxxxxx				
information	xxxxxxxxx				
mental load	xxxxxxxxx				
sensory distraction	xxxxxxxxx				

Fig. 4: Safety gain for television, experts' rating

system	general traffic safety	informa-tion	mental load	sensory distrac-tion
distance keeping	4	3	4	4
comfortable navigation system, programmable only at standstill	4	4	4	3
vision enhancement	4	4	4	3
emergency system	4	3	3	3
car dynamics, warning	3	4	3	2
car dynamics, system paced	3	2	3	3
collision avoidance, warning	3	3	3	2
collision avoidance, interrupt system	3	2	3	3
fleet management, driver initiated	3	4	3	3
fleet management, system initiated	3	4	2	2
autonomous driving	3	1	3	4
pedestrian and blind corner monitoring	3	4	3	2
parking aids, driver demanded	3	4	4	3
parking aids, automatically warning	2,5	4	3	3
route information system, driver demanded	3	4	3	2
route information system, system paced	2	4	2	2
road pricing, route alternatives & costs	2	3	2	2
road pricing, costs only	2	2	2	2
on-board computer	2	2	2	2
driver alertness monitoring	2	2	3	3
vision enhancement by Head-up display	2	3	2	2
comfortable navigation systems, programmable while driving	2	4	2	1
simple navigation systems, programmable only at standstill	2	3	2	2
simple navigation systems, programmable while driving	1	3	1	1
telephone, free handed	2	2	2	2
telephone with hand set	1	2	1	1
mobile office	1	2	1	1
information, private	1	2	1	1
television	1	1	1	1

Fig. 5: Experts' rating, expected effects on traffic safety:
median 1 or 2: no or small safety gain
median 3: medium safety gain
median 4 or 5: high or very high safety gain

3.2 Development of a model managing telematic systems in vehicles

Due to the experts' evaluation several telematic systems are useful in vehicles. They will be added to the existing instruments like speedometer, revolution meter, fuel gauge, oil temperature and so on. In order to prevent overloading of the driver, the number of information simultaneously presented by these systems, must be restricted.
The best way to do this is the development of an output logic deciding which information is urgent and which can be postponed to a later time instant. Models for information management have been presented elsewhere (see MICHON, 1993). The advantage of the model presented here is the simplicity allowing an implementation in near future without the need of complex additional sensory information.

Activation likelihood in different traffic scenarios:
One step in the model development deals with the possibility of system activation in different traffic environments. Based on the plausible assumption that not all systems will occur in all traffic situations, an analysis was undertaken, which combinations of information will happen in specific traffic scenarios. It was assumed that specific systems will be activated only under specific road conditions. If this is the case, the amount of information possibly presented to the driver at a specific time instant is modulated by the road type.
For six scenarios: motorway, rural roads and urban roads, each of them during daytime and night-time, no important differences could be found concerning the theoretical frequency of systems activation. Since theoretically up to 10 driver information and support systems can be active at the same time, an information manager to control information output is an imperative feature.

Formation of groups:
The development of an output logic has to differentiate between four system categories:
- systems only activated during standstill (e.g. emergency systems),
- systems replacing existing elements (e.g. camera vision instead of rear mirror),
- systems directly influencing the car (e.g. vehicle dynamics like anti-block systems or electronic stability programs),
- self-initiated or driver initiated systems (e.g. navigation systems, telephone etc.).

Matching the systems evaluated by the experts as 'sensible' or 'eventual sensible' to the four categories comes to the following classification:

Systems, activated while vehicle's standstill:
Elements like parking aids and emergency systems are members of this group. The emergency system is only activated while the car is standing; the parking aid works during slow vehicle manoeuvres. In these situations enough spare capacity of the driver can be supposed. There won't be conflicts with other systems. Thus an activation without restrictions is okay („system go").

Systems replacing other elements:
Systems like pedestrian monitoring, blind corner monitoring or vision enhancement must replace actual existing elements: for example, if one wants to monitor the invisible area beside and behind the car, the displays have to be installed instead of the outside mirror or the back view mirror - additional installations have to be avoided!
Pedestrians detected by sensors or cameras must be displayed as an 1:1 picture in the windscreen, e.g. the driver should have the impression to detect them himself, as he

would do, if viewing conditions would be good. Additional information on a whatever kind of display is clearly refused and not covered by the logic.
Vision enhancement, for example by dynamic or curve adapting luminance, has to replace conventional car lighting.
It is very important that conventional systems are replaced by the new ones. We must strictly avoid to 'double the world'. If this is guaranteed the activation of systems belonging to this group is possible without restrictions. It is marked as „system go" in figure 6.

Systems directly influencing the car:
Car dynamics (e.g. like anti-block systems or electronic stability programs), collision avoidance with interrupt systems and distance keeping will directly influence the car. They work automatically, without any need of driver's decision, underlying therefore no restrictions for activation. If one of the systems acts in an emergency situation (e.g. ESP emergency stop ...) they suppress other systems. These pieces of information are postponed until traffic situation has eased.

Systems, working self- or driver initiated:
Comfortable navigation systems, fleet management, route information, and free handed telephone, are principally activated by the driver. But, information will be presented self-paced, either when it is available or necessary from the system's point of view. Information could arrive at any time, independent of driver's workload, independent of special events, independent of traffic situation. If the system works self-paced, we have to check first, if traffic situation is critical. If this is the case, system's output has to wait until traffic situation has eased, even if the driver asked for the specific information. For example, in a critical traffic situation it is not important to receive navigation information right in time. In the worst case, the driver will miss one exit, but the navigation system will bring him back to the right way within a few minutes. Compared to the danger of an accident caused by overload this 'lack of perfection' is acceptable.
If the systems work fully driver initiated, information follows the chronological order, shown in the output logic.

Driving situation:
The crucial question in the last section is of course the definition and measurement of critical driving situations. Different attempts have been made, most of them are high sophisticated and need image processing technology (NAGEL, 1992).
A pragmatic approach could use a few parameters which can be measured with high reliability and little technical expenditure.
Hard acceleration or deceleration manoeuvres (>0.2g) or drastic changes of steering angle are taken as hints for critical driving manoeuvres. For example at a speed of more than 50 km/h drastic changes of steering angle indicates, that the driving manoeuvre should be finished before displaying additional information to the driver. In combination with GPS it is possible to determine whether the car is in an urban or rural area, which gives additional hints for typical manoeuvres on this specific road type.
Of course, some research should be done to get better limits for driving parameters, but the few parameters proposed here can be seen as a good starting point for the evaluation of the driving situation and the management of information.

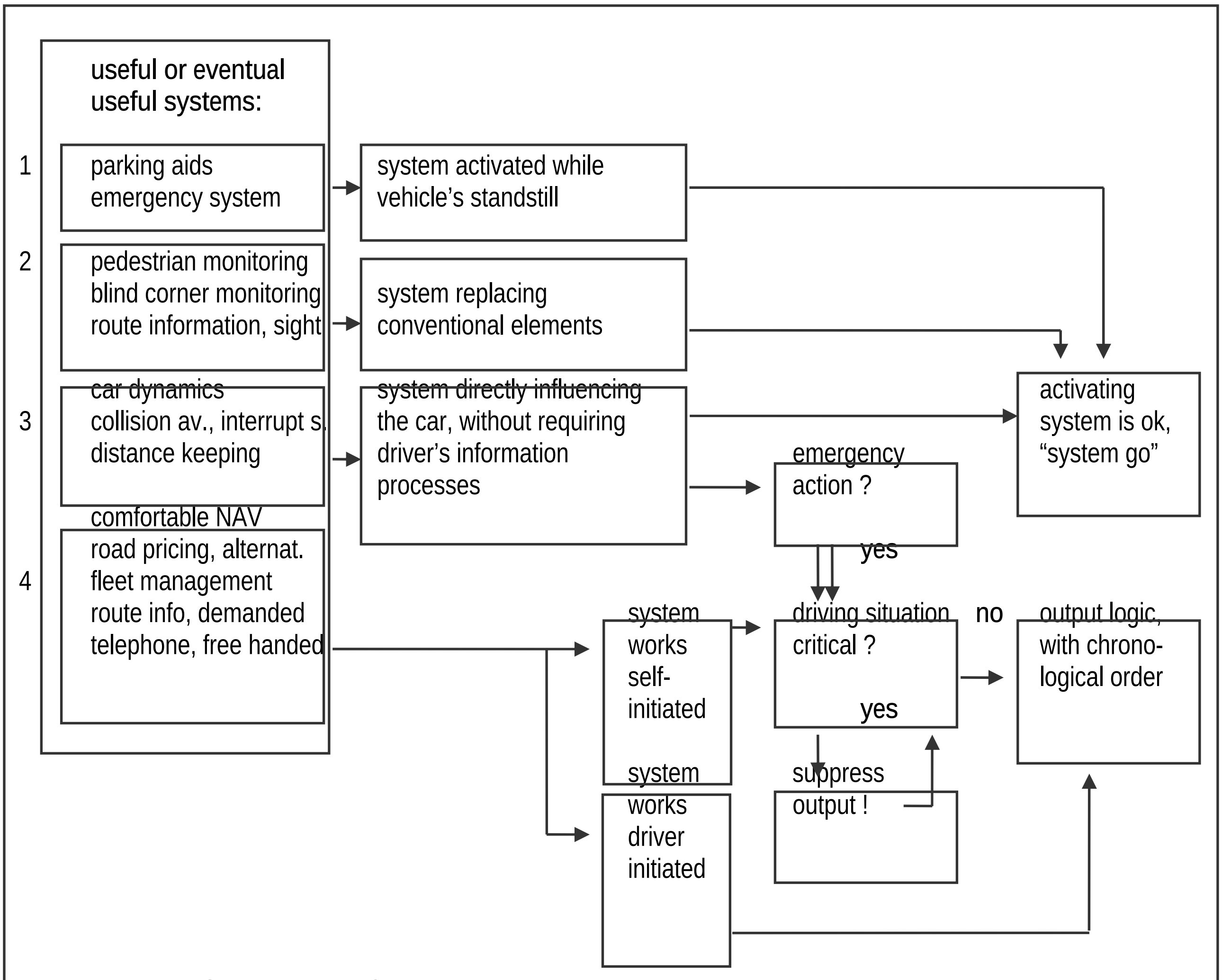

Fig. 6: Output logic for driver assistance systems

Information presentation logic:
The output logic is clearly traffic safety oriented. Of course, other principles can also be realised, like comfort or perfect information of the driver. But, the proposed logic demonstrates that traffic safety and new information technologies can be put together without the loss of comfort or safety.
In detail, the output logic has the following chronological order:

- If an emergency system is working (e.g. collision avoidance, system paced car dynamics like ABS or ESP), other messages are postponed.
- An actual output of the navigation system suppresses systems like road pricing (with route alternatives and costs), fleet management, route information system, telephone and so on.
- The navigation system guides the driver to the point, where he has to decide for the route he wants to use. The decision between alternative routes is strategically and not time-critical and should therefore not interfere with an actual navigation information. If this is the case, the programming of the NAV-system is wrong.
- Actual output of the navigation system has priority over fleet management, because usually fleet management gives long term information, not being time-critical.
- Fleet management has priority over general route information requested by the driver.

- In the standard set-up driver demanded route information has priority over the telephone. Here we recommend the possibility for individual changes, due to the user’s needs.
- The telephone (of course the free handed version!) can only ring, when no other system in figure 6 displays an actual output. Because the normal output times are quite short, this will not severely influence the telephone use (even for business men).
- If the call is accepted, the driver himself has to decide whether to interrupt the conversation or not to, when new information is available.

The decision algorithm, developed on this basis, shows the possibility to realise an output logic for driver information and support systems with acceptable technical effort, balancing the requirements of new technologies and traffic safety.

4. Conclusions

Even the experts belong to different focus and interest groups, the evaluation shows a high consistency for many of the systems. Global reservations exist for the transfer of private information, the telephone with hand set and of course for television in cars. It is interesting to note that also widely implemented systems like trip computers are negatively evaluated concerning their functionality for driving and impact on traffic safety. A comparison between warning and intervention systems shows a clear preference for warning systems. Except for very limited manoeuvres on the control level of driving, the driver should remain responsible for final decisions and actions (especially on the manoeuvrings level).

The model for information presentation, developed on the basis of the expert evaluation seems to be quite restrictive while driving. But it will help to increase traffic safety, preventing information overflow of the driver and providing him with all necessary information from telematic systems.

5. References

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