STRAIGHT INTO CURVES: REFLEKTAS IN DIFFERENT CONTEXTUAL CONDITIONS

Anke Kullack & Frank Eggert
TU Braunschweig, Institute of Psychology, Department of Research Methods and Biopsychology
Spielmannstr. 12 a, 38106 Braunschweig
a.kullack@tu-bs.de, f.eggert@tu-bs.de

ABSTRACT: Up to now there was no rational approach for the development of the HMI (Human Machine Interface) of driver assistance systems. Today's driver assistance systems are mainly developed according to some classical cognitive principles. In order to identify central aspects of the development of HMIs a rational approach was created. Consistent with the new approach an assistance system for critical situations was developed utilizing reflexes in order to elicit the desired steering reaction fast and reliably. The system was tested under several conditions and it could be shown that it prevented departures of critical extents. Therefore the behavioral approach seems to be very useful in the development of driver assistance systems.

1 BEHAVIORAL APPROACH IN THE DEVELOPMENT OF ADVANCED DRIVER ASSISTANCE SYSTEMS

To date there is no reasonable concept for the development of an HMI of driver assistance systems. Rather only two aspects are usually considered: the level of automation and the modality of communication. In the domain of assistance systems for lateral control this approach leads to two main categories of assistance systems: lane departure warning systems (LDWS) and lane keeping assistance systems (LKAS). These systems work quite differently. LDWS use visual, acoustic or haptic advices to warn the driver when he is at risk of leaving the lane. Since the assistant is activated only in dangerous situations, LDWS can be considered as safety assistance systems. In contrast, LKAS primarily enhance driving comfort as they assist the driver during normal driving by reducing the need for frequent minute steering corrections. Any system designed according to these principles is burdened with typical problems. One problem of LDWS is that the association between the signal and the desired reaction has to be learned and thus can be unlearned or reduced by interference with other learning situations. LKAS in turn are designed in a way that the additional steering momentum can be overruled without much effort increasing the risk of lane departures. Furthermore, in case the driver misunderstands an LKAS as a system for automatic driving, he might trust the system inappropriately and thus get out of the loop. According to its principles this classical approach can be considered a cognitive one.

In order to resolve those problems we developed a well-founded behavioral approach for the development of driver assistance systems. First of all this approach requires the analysis of the driver´s behavioral repertoire containing the range of possible responses of the driver. Subsequently the specific reaction, the driver has to perform in the particular situation, is identified in order to finally deduce the stimulus which can elicit the reaction. With the intention of developing a system according to the behavioral approach, the following three questions have to be answered:

What is the behavioral repertoire of the driver?

Which situation-specific reaction should be elicited?

How can the desired reaction be elicited most efficiently?

The aim was the development of an assistance system for critical situations in which the driver is at risk of departing the lane immediately. In those situations there are only a few reactions the driver could possibly perform, for example steering, braking or accelerating. In such situations we want the driver to conduct a steering movement to the middle of the present lane. This reaction can be elicited by a jerk at the steering wheel leading in the same direction in which the vehicle begins to leave the lane.

The introduced approaches are directly linked to two traditions in psychology, cognitive psychology and behavioral psychology. Contrasting these traditions one could say that cognitive psychology focuses on mechanisms of human information processing whereas behavioral psychology focuses on overt behavior. Cognitive systems are based upon the principle of communication using arbitrary signals which have to be interpreted to produce the correct reaction. These systems require a high level of behavioral control (for levels of behavioral control see [1]). In order to control behavior at this level the driver needs to execute complex operations which are characterized by being less stable, more slowly and prone to errors. In contrast, behavioral control mechanisms on lower levels like pre-programmed behavior or reflexes permit simpler reactions but these are more stable, fast and robust in return.

These characteristics of behavioral processes on lower levels are advantageous for assistance systems supporting the driver in critical or emergency situations when a fast and reliable reaction is necessary. Such critical situations mostly occur if the driver is inattentive or distracted.

2 PRINCIPLE OF THE NEW ASSISTANT

Especially when the driver is at risk of leaving the lane, an assistance system ought to elicit the correct steering response fast and reliably. This can be achieved by a new Lane Departure Prevention System (LDPS) called ReflektAS. in ReflektAS an additional momentum is applied to the steering wheel, proceeding into the same direction into which the driver is leaving the lane. By means of that a steering reflex into the opposite direction is elicited. The momentum is triangular and symmetric proceeding strongly and shortly. The principle is illustrated in Fig. 1.

At the moment the driver is going to depart the lane an additional momentum is applied to the steering wheel. Thus the wheel turns very fast clockwise (counterclockwise) when the car is going to leave the lane at the right (left) side of the lane. A steering reflex is elicited letting the driver turn the wheel counterclockwise (clockwise). At the same time an orienting response to the front is evoked and the arousal of the driver is heightened, allowing him to perform any behavior necessary in the critical situation.

Finally the driver just needs to complete the sequence of appropriate steering movements.

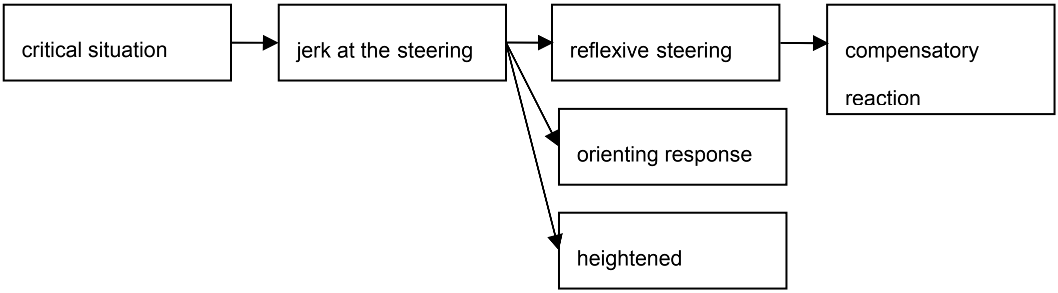

Fig. 1 Principle of ReflektAS

The basic design of this assistant system has been examined in several empirical studies and the general functionality has been proved (e.g. [2]). The research reported in this paper is related to functional aspects under a number of relevant contextual aspects, that is the side of the departure and the course of the track. It is assumed that ReflektAS avoids departures of critical widths and durations even under different contextual conditions.

3 METHOD

In order to analyze the functionality of ReflektAS in the contextual conditions mentioned, a simulator study was conducted. Data of 23 participants (25-61 years old) was analyzed. Their task was to drive on a track with straight parts and curves of different radiuses. Two secondary tasks were used modeling different scenarios of distraction to produce a critical situation in which the driver is going to leave the lane. The first one was designed to model a distraction in the visual field. At pre-defined sectors a ball was projected into the scenery getting smaller or larger (see Fig. 2). The participants´ task was to identify the direction of the resizing ball using buttons on the steering wheel.

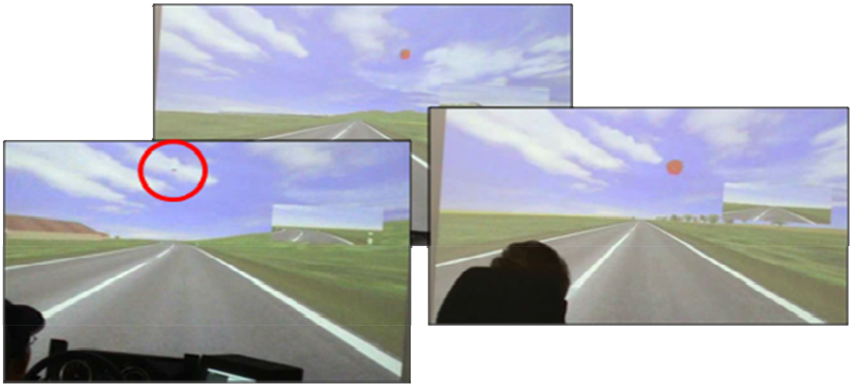

Fig. 2 Secondary task modeling a distraction in the visual field

The second subsidiary task modeled a distraction including a spatial shifting of attention. For this purpose a simple arithmetic problem together with a potential solution was presented on a display attached to the center console. Using (again) buttons on the steering wheel, the participants had to determine if the presented solution was right or wrong (see Fig. 3).

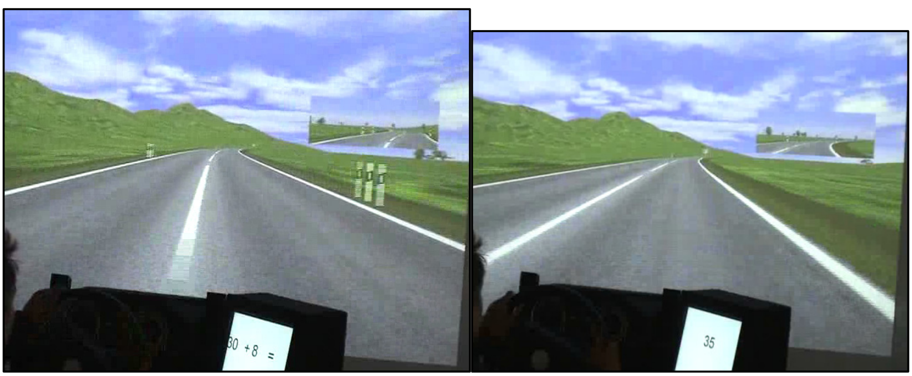

Fig. 2 Secondary task modeling a distraction including a spatial shifting of the attention

During these tasks a virtual crosswind was applied in some cases in order to induce a departure into one direction. Since spontaneous departures were allowed additionally, participants sometimes drifted to one side without recognizing it. At the moment the car reached a defined distance to the lane marking ReflektAS was activated. CAN-bus-data was recorded and subsequently the participants completed a questionnaire concerning the acceptance of the system. Several measures were analyzed of which only the width and the duration of the departures will be presented here. These two measures were chosen as they are correlated positively with the possibility of a collision. The width of a departure will only be critical if the car departs more than 0,45 m from the road. This is due to the fact that German roads are built according to the Guidelines of Road Construction [3] which determine a marginal strip of 0,25 m and a shoulder of at least 0,50 m at rural roads. The first objects a car is able to crash into are the reflector posts being located at 0,50 m aside the road. Thus, if the driver departs 0,50 m from the road he would just fail to touch the reflector post. Considering minor departures from these guidelines departures up to 0,45 m are not critical. A previous analysis showed that in about 70 % of all interventions no departures occurred. In 17 % a departure of less than 0.25 m occurred and in 8 % a departure less than 0.45 m. Thus, only in 5 % of all cases departures of more than 0.45 m occurred [4]. In the present study straight parts and curves were analyzed separately. Examining the straight parts, a t-test was conducted to test a possible difference between departures to the left and to the right. Considering the departures in curves an analysis of variance model was tested including the side of the departure (left vs. right) and the direction of the curve (left vs. right). In this paper only the results concerning the departures caused by the virtual crosswind will be presented.

4 RESULTS AND CONCLUSIONS

Assumptions for the statistical tests were checked and adjustments were made if necessary. Since two secondary tasks were applied, it was primarily tested whether these differed significantly from each other in respect to the examined dependent variables. As this was neither the case for the width of the departures nor for the duration the data of both secondary tasks was analyzed in conjunction. It was shown that departures from straight parts of the road to the left and to the right did not differ significantly with respect to the average width of departures. There were no significant effects for the curves as well. Fig. 4 shows the average widths of departures in the different conditions.

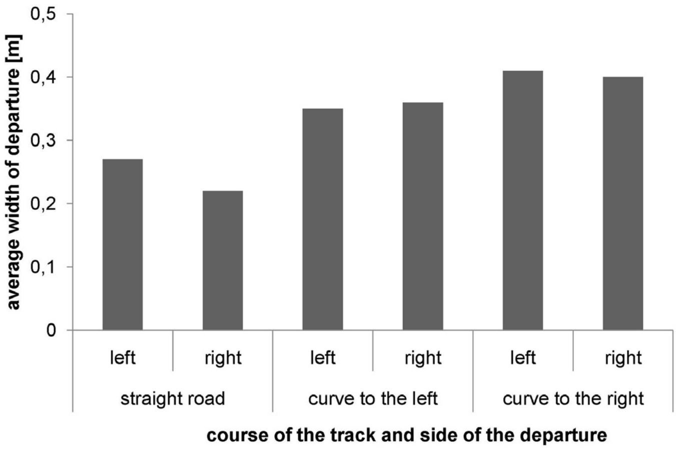

Fig. 4 Average widths of departures in dependence of the course of the track and the side of the departure

There were no significant effects for the duration of departures; neither for the curves nor for the straight parts (see Fig. 5).

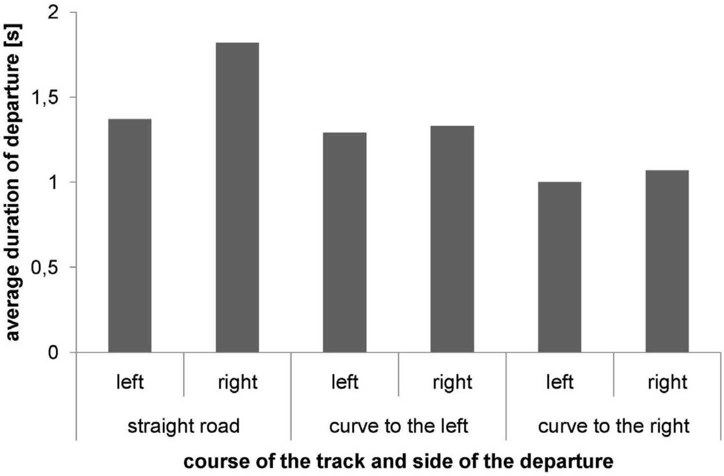

Fig. 5 Average duration of departures in dependence of the course of the track and the side of the departure

As it was assumed, ReflektAS prevented departures of critical extent. The duration of the departures was very short and their average width was less than 0.45 m. As no significant effects were found it could be concluded that neither the side of the departure nor the course of the track (for the curves) are relevant factors for the characteristic of the departure. As only a few departures occurred, the tests are based upon a small sample size and the results have to be interpreted very cautiously. Beyond that, another study revealed that the driving behavior in simulator studies might differ to a great extent from the driving behavior in real traffic [5]. This aspect has to be kept in mind while interpreting the results of simulator studies in general. Thus, a study in a real car should be considered.

Nevertheless the behavioral approach allows for the development of assistance systems that are exactly suitable for the observed situation. This does not imply the replacement of the cognitive approach which uses mainly behaviors on higher levels of control, in the development of driver assistance systems. Instead, it is rather essential to analyze the specific situation in detail and to choose a level of behavioral control as low as possible. This implies if a rather complex reaction is supposed to be elicited behavior on a higher level of control would be suitable.

5 REFERENCES

[1] Konczak, J.: Motorische Kontrolle, in Müsseler, J. (Ed.): Allgemeine Psychologie (Spektrum Akademischer Verlag, 2008), pp. 738-764

[2] Kullack, A., Ehrenpfordt, I., Lemmer, K. and Eggert, F.: ReflektAS: lane departure prevention system based on behavioural control, IET Intelligent Transport Systems, 2008, 2, pp. 285-293

[3] Forschungsgesellschaft für Straßen- und Verkehrswesen (Ed.): Richtlinien für die Anlage von Straßen (Forschungsgesellschaft für Straßen- und Verkehrswesen, 1996)

[4] Kullack, A., Ehrenpfordt, I. and Eggert, F.: ReflektAS – Further tests of a fast and reliable lane departure prevention system for critical situations. 16th World Congress and Exhibition on Intelligent Transport Systems and Services, Stockholm, September 2009.

[5] Kullack, A., Goralzik, A., Ehrenpfordt, I. and Eggert, F.: VIDE – Displaygestaltung nach verhaltenswissenschaftlichen Prinzipien. 11. Braunschweiger Symposium AAET 2010 Automatisierungs-, Assistenzsysteme und eingebettete Systeme für Transportmittel, Braunschweig, February 2010