VIDE – THEORETICALLY GUIDED DEVELOPMENT OF A BEHAVIOURALLY ADAPTED DISPLAY

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ABSTRACT: The research project VIDE aims at developing a new HMI concept which does not modify actual displays but replaces them by just one new display. This system presents information which is directly relevant to the driver's behaviour, meaning that an interpretation of the given information on the status of the vehicle is no longer necessary. Moreover, if the system detects a deviation from the optimal status, the driver is informed of the appropriate behaviour. The amount of relevant information of the environment and the status of the vehicle being integrated varies with the configuration stage of the system. The system was tested on a simplified configuration stage with 26 participants. First results show that when using VIDE, a given speed limit was exceeded to a smaller extent than when using classical cockpit instrumentation. In addition, over 90 % of the participants perceived driving with VIDE as being safer compared to driving with the classical instrumentation.

1 DEVELOPMENT OF A HUMAN MACHINE INTERFACE BASED ON BEHAVIOURAL STRATEGIES

In order to develop a Human Machine Interface providing optimal assistance with the driving task, the Institute of Psychology, Department of Research Methods and Biopsychology at the TU Braunschweig (IPMB) established a behavioural approach in the development of HMIs called "Behaviourally Assisted Car Driver Interaction". This approach mainly comprises three aspects. First of all, the driver's behavioural repertoire containing the range of responses a driver can make has to be analysed. Secondly, the response to be elicited in a given situation has to be defined and identified. In order to elicit this response adequate stimulus configurations have to be found or developed. Furthermore, discriminative stimuli and contextual cues signalling particular situations have to be identified. In case the suitable response is not part of the driver's behavioural repertoire, strategies for its expansion and modification have to be developed. The theoretical background of this approach is based on basic research findings in the behavioural and biological sciences.

The classical approach in the development of HMIs differs from this method. It focuses on the level of automation to be realised and the sensory modality to be used by the car for communication with the driver.

Depending on the chosen approach different HMIs arise. While classical displays primarily transmit information on the status of the car, the behavioural approach concentrates on finding signals which are directly relevant to behaviour. The classical approach further tends to centre on the vehicle. It utilises arbitrary stimulus-response configurations for communication which are presumed to affect human information processing. Summarising, the classical approach can be described as being based on the principle of communication.

In contrast, the Behaviourally Assisted Car Driver Interaction is focused on the driver gearing towards his behavioural repertoire. Pre-programmed and consolidated stimulus-response links are used in order to elicit a specific response. Using these distinct signals, higher order interpretation processes are unnecessary. The behaviour of the driver should therefore be directly affected. Summing up, the paradigm within this approach is the coupling of behaviour.

2 CLASSICAL HMIS IN VEHICLES

The cockpit of a today's vehicle contains several displays, usually one for each piece of information, e. g., speed, the number of revolutions, the amount of fuel, and so on. Especially to new cars supplementary displays are added providing information on the lateral position of the car, the actual speed limit, and several other driving conditions. The driver's task is to perceive the information, to process, and interpret it in order to find out which behaviour is appropriate in a given situation.

Thus, adding new sensors usually means also adding a new display component into the cockpit at the same time. Thus, new developments are integrated only in novel generations of a vehicle. However, vehicles already in use can only be expanded at high costs. Furthermore, current systems do not involve the possibility to adapt to the driver.

3 VIDE

The research project VIDE aims at developing a new HMI concept which does not modify actual displays but replaces them by a universal interface. Based on data integration from different sources, it includes re-organised information on standard dashboard features as well as several driving assistance functions. The information presented is directly relevant to the driver's behaviour, meaning that an interpretation of the information on the status of the vehicle is no longer necessary. If the system detects a deviation from the optimal status, the driver is informed of the appropriate behaviour in the given situation (see Fig. 1). Driving speed may, for example, be appropriate with respect to the actual speed limit but inappropriate with respect to the actual weather conditions (e. g., snow or fog). The amount of relevant information from the environment and the status of the vehicle being integrated varies with the configuration stage of the system. As an example of a low configuration stage, a driver who exceeds a given speed limit is informed by VIDE to slow down in order to comply with this speed limit. Likewise, the driver is advised to accelerate the vehicle when becoming too slow. The recommendation regarding the reduction or increase of the driving speed is presented by the vertical position of a car symbol on the display (see Fig. 1b). Likewise, lane keeping and obstacle alerts are administered in critical situations according to the side of the vehicle involved (see Fig. 1c and d). On a more complex stage, not only information regarding speed limit and nearby obstacles is processed, but information about the condition of the road surface is integrated into the calculation of the appropriate response in the given situation, as well. In the long run, it is intended to develop a perfect calculation integrating all information relevant to driving. Thus, the driver will not need to gather all the relevant information himself; instead the system will execute this task. With future enhancements of sensor technique, it will be possible to integrate additional information in the existing system; a replacement of the whole system will not be necessary. The way information is presented remains the same, only the amount of information being integrated increases. If particular functions of the vehicle achieve a critical status, e. g., if the level of oil is far too low, VIDE will be able to give short commands as "Please pull over to the side of the road and stop the engine". VIDE permits combining driver behaviour with the car using an adequate HMI. In order to efficiently and differentially modifying driving behaviour, several assistance functions can be integrated depending on the characteristics of the situation. That is, functions which are not inherently executed by VIDE (e. g., an active intervention) can be incorporated additionally. The concept takes advantage of easily adding new information as well as new output modalities to the existing system. Additional displays are not required; rather, new information is used for a more exact calculation of the appropriate driving behaviour. Furthermore, there is the option to adapt the system to the driver so that his behaviour can be influenced towards a safer driving manner. Hence, VIDE is a core assistance system not only for speed control but for all functions necessary for driving safely and comfortable.

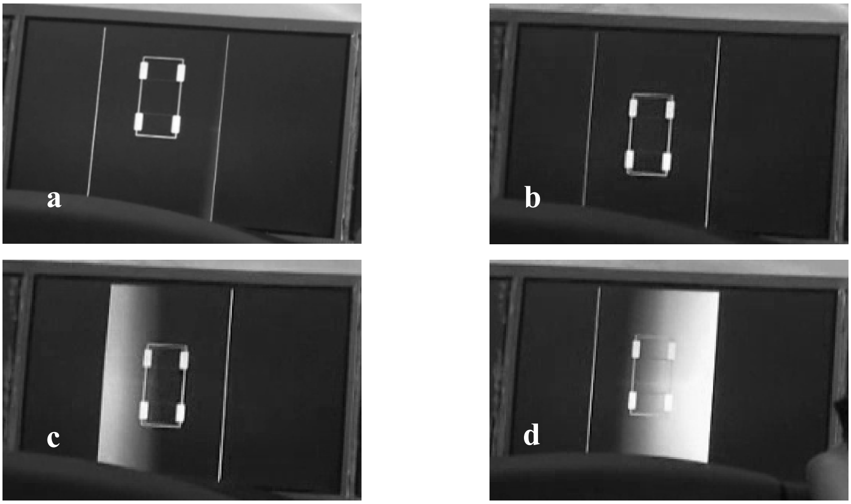

Fig. 1. Appearance of VIDE as a function of different driving behaviour: (a) velocity appropriate, (b) velocity too high regarding the traffic situation, (c) distance to the left lane marking too small (yellow colour gradient from the left), (d) distance to the right vehicle/an obstacle right to the vehicle too small (red colour gradient from the right)

4 METHOD

VIDE was first tested at a low configuration stage displaying driving speed and the vehicle's position towards obstacles. It was assessed how appropriate driving using this system is depending on the given speed limit, course of track, and the distance to lane markings or obstacles. Driving behaviour in terms of driving speed using VIDE was compared to driving using classical cockpit instrumentation (i. e., analogue display of velocity and number of revolutions) in order to find out whether VIDE leads to an increase of traffic safety by inducing a minor violation of speed limit and a more appropriate distance to the lane markings or other cars.

The experiment was realised at the HMI-Lab of the German Aerospace Center in Braunschweig. 26 participants (Mdn=38 years, Range=24-59 years) with a minimum of five years of driving practice (Mdn=22 years, Range=7-42 years) completed a standardised circular track fitted with different characteristics (see Table 1) in a fixed-base driving simulator. The study used a within-subjects design with repeated measures. Each participant drove the track using both VIDE and the classical instrumentation. In order to prevent sequence effects, the levels of the independent variable were counterbalanced resulting in two sequences (A: VIDE – classical display – VIDE – classical display; B: classical display – VIDE – classical display – VIDE). Participants were instructed to drive in the same manner as in usual traffic. Speed limits were presented on road signs; otherwise the recommended speed limit of 130 km/h on German motorways applied. Irrespective of traffic volume on real roads, the rural parts of the track did not include other cars on the same lane apart from the own vehicle allowing for unbiased speed control.

Table 1. Characteristics of the track

Speed limit [km/h]	Course of track			
	Rural road			Motorway
	Straight	Curve to the left	Curve to the right	
60	+	+	+	
80	+	+	+	+
100	+			+
120				+
130				+

Note. + = Configuration of the track realised in the present study

In addition to the objective CAN-bus-data, subjective data was collected after the test drive. Participants were asked to complete a questionnaire on how they evaluated VIDE in comparison to the classical system. The questionnaire contained questions about the subjective perception of safety, comprehensibility, comfort, usefulness, perceived control, perceived degree of efficiency, irritability, conformity with expectancies, appropriateness of driving behaviour, as well as specific intentions to use the system and possible requests for modifications concerning the design of VIDE.

5 DATA ANALYSIS

In order to compare the extent of speeding while driving with VIDE and the classical instrumentation, the integral of the actual velocity [m/s] as a function of simulator runtime [s] was calculated when the given speed limit had been exceeded. According to this, larger integrals imply a larger extent of speeding. Data was aggregated in such a way that eventually one integral was available for each of the eleven characteristics of the track (cf. Table 1), for each participant, and for both VIDE and the classical instrumentation, respectively. These integrals were the basis for comparing both systems. It was hypothesized that driving with VIDE on average results in smaller integrals of speeding for each characteristic of the track than driving with the classical instrumentation. This assumption was statistically tested with permutation tests for dependent samples (α=0.05).

Analyses of data concerning the distance to obstacles and the lateral position are currently under way.

Questionnaire data was analyzed by means of medians and frequencies. Requests to modify VIDE and additional remarks were collected, counted and summarised in superior categories.

6 RESULTS

The results of the permutation tests for the rural parts of the track are presented below. Statistical analyses showed that the extent of speeding at the straight rural parts with a speed limit of 80 km/h ($t(25) = -5.36$, $p = .00$) and 100 km/h ($t(25) = -2.74$, $p = .00$) was significantly smaller using VIDE than using the classical instrumentation. The same effect was observed in curves to the left ($t(25) = -3.64$, $p = .00$) and curves to the right ($t(25) = -3.98$, $p = .00$), given a speed limit of 80 km/h. No statistically significant effects were found regarding the remaining configurations of the track.

The analysis of the questionnaire data showed that as for comprehensibility, irritability, conformity with expectancies, perceived control, and perceived degree of efficiency, VIDE and the classical instrumentation were equally rated. In contrast, participants tended to impute characteristics of comfort (easy overview of traffic and possibility of an early reaction) to VIDE. Table 2 presents a comparison of VIDE and the classical instrumentation with reference to the subjective perception of safety, usefulness, perceived degree of efficiency, appropriateness of driving behaviour, and an estimation of the total contribution of VIDE to traffic safety. VIDE is preferred as to all of the listed aspects. It stands out that over 90 % of the participants perceived driving as being safer with VIDE than with the classical instrumentation.

Table 2. Preferences of VIDE in comparison to the classical instrumentation

Item	%	
	„Classical display“	„New display“[a]
The information of which display made you feel safer?	30.8	69.2
Which display do you deem more reasonable?	38.5	61.5
Which display influenced you more while driving?	23.1	76.9
Which display made you drive more appropriately?[b]	11.5	84.6
	„No“	„Yes“
Do you believe that the new display[a] allows for safer driving?	7.7	92.3

Note. [a]The notation ”New display“ corresponds to VIDE. [b]Missing values cause the categories not to sum up to 100 per cent.

Furthermore, the lateral warnings administered by VIDE were deemed helpful and comfortable. However, participants asked for an improved perceptibility of the dynamic display of driving speed and the additional integration of a numerical display of driving speed.

Using VIDE, driving behaviour was experienced as being better adjusted to the traffic flow and thus being safer than using the classical instrumentation.

7 CONCLUSIONS AND OUTLOOK

VIDE as an HMI based on the Behaviourally Assisted Car Driver Interaction was implemented and experimentally tested in a driving simulator for the first time. The focus of interest was to find out whether VIDE increases traffic safety in comparison to classical cockpit instrumentation. Analyses of the driving data showed that driving with VIDE caused less speeding in some of the configurations of the track when compared to the classical instrumentation. This finding is strongly supported by the participants' subjective report of increased driving safety. The congruence of objective driving data and subjective experience not only exemplifies a good functionality of VIDE but also gives rise to optimism with respect to its prospective use.

Anyhow, a decrease in speeding could not be proved for every configuration of the track examined in the study. The hypothesis of a decrease in speeding using VIDE had to be refused for all parts of the rural road (straight parts, curves to the left, curves to the right) with speed limits of 60 km/h. This finding might be explained by the sameness of the road conditions in all configurations of the track, thus not leading to a decrease of speeding at the lowest speed limit of 60 km/h. It seems likely that participants adjusted their driving behaviour not according to the recommendations of VIDE but instead according to their own assessment of the situation, which eventually might have led to speeding. Since the test track did not differ between the two systems, this consideration applies to driving with the classical instrumentation, as well. Such a “preferred velocity” could be attributed to the programming of the track in the driving simulator with participants choosing the velocity which allows for the most comfortable drive through the different parts of the track. In line with such a preferred velocity in the driving simulator, it might be asked to what extent real driving behaviour can be reproduced in a driving simulator at all. Considering a possible restriction of the internal validity of experiments in driving simulators, further research addressing this issue is needed.

Nevertheless, these first results present a promising starting point for future research regarding behaviourally based HMIs in general and further developments of VIDE in particular. The data of the present study is currently being analysed in more detail in order to supply information on the lateral position and the distance to other vehicles, as well. Additional components will subsequently be implemented with a view to testing VIDE in a real car under real driving conditions.

8 ACKNOWLEDGMENTS

We would like to thank Marco Hannibal, Timo Krehle, and Mark Schröder for their excellent technical support. VIDE will be further developed in the project FAMOS which is partly funded by the BMWi.