Measurement of Driver's Distraction for an Early Prove of Concepts in Automotive Industry at the Example of the Development of a Haptic Touchpad

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Abstract. This contribution shows how it is possible to integrate the user's behavior in the development process in a very early stage of concept. Therefore innovative applied methodologies for objectifying human behavior such as eye tracking or video observation like the Dikablis/ DLab environment in the Audi driving simulator are necessary. A demonstrative example therefore is the predevelopment of a touchpad with an adjustable haptic surface as a concept idea for infotainment interaction with the Audi MMI. First an overview of the idea of capturing human behavior for evaluating concept ideas in a very early stage of the development process is given and how it is realized with the Dikablis and DLab environment. Furthermore the paper describes the concept idea of the innovative control element of the haptic touchpad as well as the accompanied upcoming demands for research and how these questions were clarified. At the end some example results are given.

Keywords: Eye Tracking, haptic feedback, touchpad, interaction, driving simulator.

1 Introduction

In future, successful products have to focus on ergonomics, usability and joy of use in order to differentiate from their competitors. Nowadays, this is one of the automobile manufacturer's biggest challenges considering the development of infotainment features. But those key factors cannot be tested quickly at the end of the development process to check if they are fulfilled. They need to be considered carefully from the very beginning of the concept idea along the whole development process. This assumes an integration of theoretical ergonomic product design as well as a consideration of human skills, behavior and user's opinion. Especially for the last point lots of methodologies such as e.g. focus groups or standardized questionnaires do exist.

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For a complete user centered product design objective behavioral data are also necessary. Reasons for that are documents like the AAM [1] for example, which contain specific criteria of driving behavior and gaze distraction for safety reasons which have to be fulfilled before entering the market.

Furthermore at the very beginning of the development process prototypes are on a lower level than the latest products in market concerning design and functionality, which have a massive impact on subjective justification. Bringing design and functionality issues to perfection is very costly. Behavioral strategies like e.g. driving performance or gaze distribution should be unaffected by design issues.

The following chapter gives an overview about the basic ISO standards for capturing the required gaze metrics as well as how this is implemented in the Dikablis DLab environment for an efficient and effective evaluating process.

Afterwards the idea of developing a touchpad with an adjustable haptic surface for in-vehicle infotainment control for the Audi MMI is presented. This example shows the evaluation of an ergonomic concept for the decision making of a further complex technical development.

2 Behavioral Research According to ISO - Standards

The synchronous recording and analyzing of data is always a challenge in experiments. This is especially the case when eye-tracking and data of additional data streams such as e.g. external videos shall be recorded together with driving relevant data. One requirement for a successful test is the planning part at the beginning. To face this challenge, the D-Lab environment [2] is used in the Audi driving simulator. D-Lab enables synchronous recording and common analysis of several data streams such as eye-tracking data, several video streams, audio, driving dynamics data, physiological data and workload measurement. Furthermore D-Lab contains a build-in planning, measure and analyzing process according to the process described in ISO/TS 15007-2:2001 [3] which guides the experimenter through the experimental process. Below these three steps are described shortly.

2.1 Planning an Experiment

ISO/TS 15007-2:2001 [3] describes how behavioral experiments shall be planned. The idea is to think about the tasks, which will be given to the subject during the experiment and to cut major tasks further down. The highest level is the so called condition (e.g. a new navigation system). This condition can contain tasks (e.g. enter navigation destination) and those tasks can contain subtasks (e.g. enter town, street and house number). Figure 1 on the left shows the suggestion of ISO/TS 15007-2:2001 and Figure 1 on the right shows how one can set up this experimental plan in D-Lab according to the suggestion of ISO/TS 15007-2:2001.

2.2 Synchronous Measurement with D-Lab

The core when performing an experiment is D-Lab. D-Lab allows to control the experiment and to record all data synchronously. In order to control the experiment

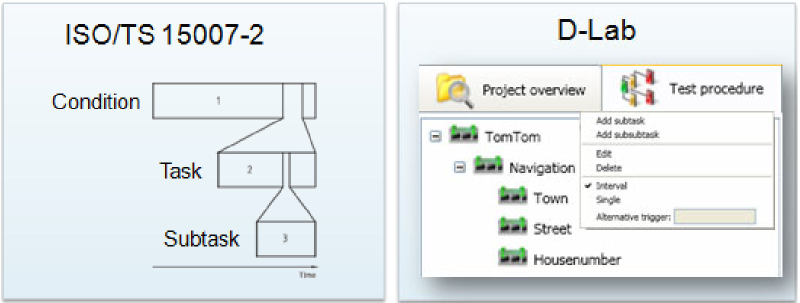

Fig. 1. Left: Experimental plan according to ISO/TS 15007-2:2001; Right: Planning module in D-Lab

D-Lab visualizes the experimental plan as clickable buttons. These buttons can be clicked to mark beginning and end of task intervals. Clicking of those buttons can be done with the mouse as well as by network events.

When the recording has been started D-Lab records synchronously all connected measurement devices like in this case glance behavior via Dikablis, driving performance data from the Audi driving simulator, video data from 4 cameras and subject's comments via a microphone. The interconnection is shown in Figure 2.

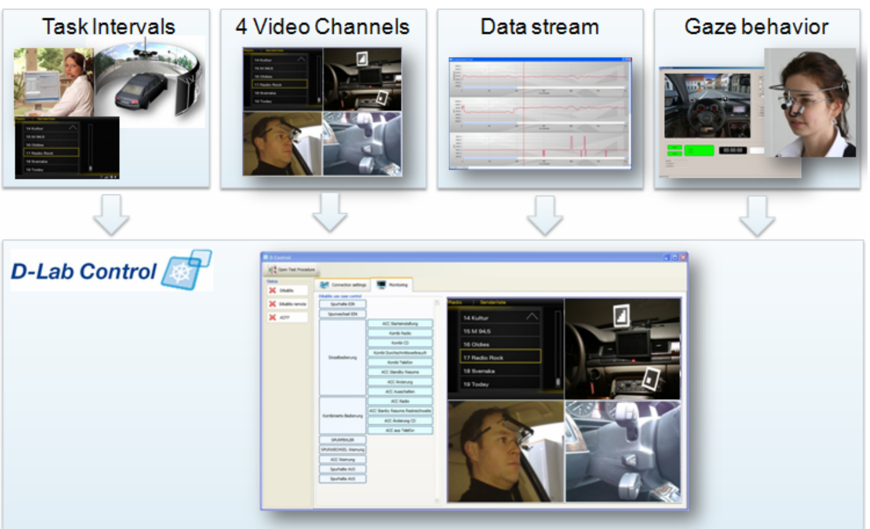

Fig. 2. Experimental control and synchronous data measurement with D-Lab

The great advantage of the D-Lab research environment is that all data is recorded synchronously and already contains the intervals of all performed tasks. This simplifies and shortens the data analysis after the experiment extremely. Figure 3 shows the common replay of gaze data, driving dynamics data and the 4 recorded videos in D-Lab.

2.3 Common Data Analysis in D-Lab

All synchronously recorded data of the whole project can be imported and analyzed with D-Lab. After all recorded data is imported one can replay the whole dataset synchronously and analyze it step by step (see Figure 3). The analysis process is described below using the example of analyzing eye-tracking data. The data analysis of all other measured data follows exactly this analysis process.

For the analysis of the eye-tracking data, D-Lab offers the possibility for the free definition of areas of interest (AOIs), for which the glance durations are calculated automatically and conforming to the eye-tracking standard ISO/TS 15007-2. The glance durations are shown as timeline bars synchronously to the progress bar of the gaze movie respectively to the progress bar of the player for the four recorded video channels (see Figure 3). The vertical line under the gaze movie player shows exactly the progress of the gaze movie or the four external videos in the timeline bars of the glance durations to the AOIs.

With the help of the integrated statistics functionality can be defined, which glance metrics shall be calculated for which AOIs during which task. An example for such a calculation would be: Calculate the glance metrics "total glance time", "total glance time as a percentage" and "number of glances” to the AOI display of the navigation system while entering the navigation destination. D-Lab calculates these metrics automatically and visualizes the result in a table for all subjects of an experiment. This automated calculation can be done for all defined AOIs, all experimental conditions, tasks and subtasks as well as for all glance metrics. The calculated result which is visualized in a table can be exported to a .csv file which can be imported to SPSS or MS Excel.

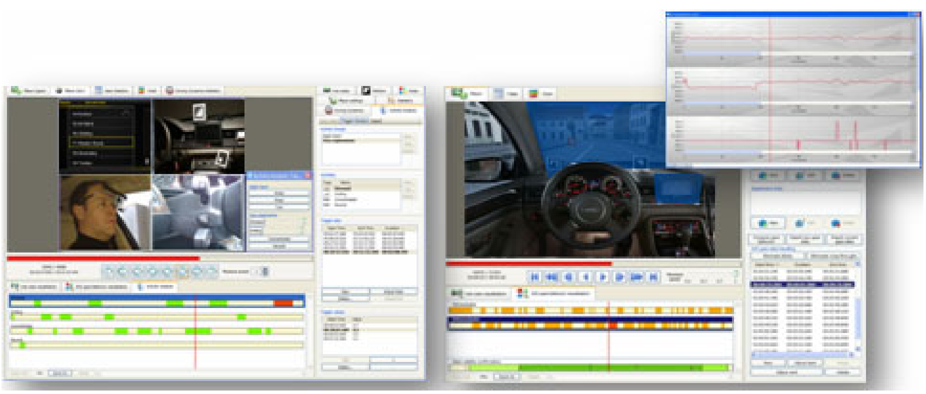

Fig. 3. Synchronous replay and common analysis of all data in D-Lab

3 Haptic Touchpad for Infotainment Interaction

The following chapter contains the concept idea of the Haptic Touchpad for infotainment interaction. The technical realization for an automotive application of such a device is very costly and complicated. The idea was to search for a technology which enables the functionality independently from a later technical realization in a car application. The goal for such a prototype was to evaluate the theoretical hypothesis and prove the estimated benefit of such a control device.

3.1 Concept Idea and Technical Realization of a Haptic Touchpad

A challenge for car manufacturers today is the increasing amount of comfort functions in modern vehicles e.g. navigation, media and communication systems and soon internet services. To keep all these systems controllable while driving, car producers have integrated these functions in menu-based central infotainment systems which are mostly controlled by one multifunctional input device. Currently, many different solutions of such control devices are available on the market. These solutions can be divided into two different groups: First, an integrating approach represented by touchscreens and second an approach separating display and control element, e.g. turning knobs or joysticks in the center console. The latest concept with an additional touchpad for character input is delivered by Audi [4]. According to Hamberger [5] an in-car-touchpad offers several potentials. It is familiar to the users because of the accustomed usage with computer touchpads and enables handwriting recognition. Furthermore a touchpad is a multipurpose control element, which perpetuates the possibility of splitting up display and controls. Thus the display remains in the ideal field of vision and the touchpad can be positioned in the ideal reaching distance. Robustness, optics and the ease of use are additional positive arguments. The results of an experiment in a driving simulator occupy, that a touchpad reduces track deviation compared to a rotary push button and a touchscreen. Within the task of a text entry a touchpad decreases gaze diversion times in comparison to a rotary push button. In addition to the mentioned results customers prefer the usage of a touchpad compared to a touchscreen [5].

In order to enable the control of the whole infotainment menu with one single touchpad, the idea is to give an additional haptic structure onto the surface for orientation. A prototype of a touchpad with such an adjustable haptic structured surface has been built up for evaluation purposes [6] [7]. In order to realize the haptic surface the technology of hyper braille is used [8]. The touchpad surface can be adjusted to the displayed content on the middle screen, so that the user can feel and press every elevated element on the touchpad which is shown on the display (see Figure 4).

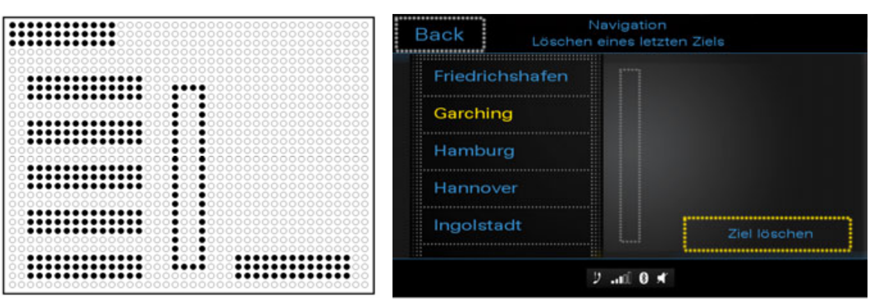

Fig. 4. Left: Elevated elements on the touchpad; Right: Displayed content on the middle screen with highlighted graphical widget

An additional visual feedback by highlighting the current touched graphical widget on the screen shows the user the finger position on the touchpad (see Figure 4). This guarantees an absolute compatible interface design between display and control device because of direct manipulation.

Moreover new interaction concepts, like it is suggested by Broy [9] for example, are possible by using a two dimensional touch device. A touchpad enables a separation of display and control, what means that the position of the control element is independent from the display position. Hence infotainment information can also be provided in the Head-Up Display [10] or further innovative interaction concepts as it is proposed by Spies et al. [11] are thinkable.

3.2 Need for Research

In case of menu operation while driving it is about a dual task situation which can cause interferences between the two parallel tasks. This means that menu control leads to driver distraction from the driving task. The major goal of an ergonomic interface design is to avoid distraction from driving because of controlling a secondary task like e.g. a navigation system. The ultimate benefit of the haptic structured touchpad surface is to give the user additional orientation via the haptic channel by elevating different kinds of shapes on the touchpad surface. Thus the haptic structure is not only for finding elements but also for getting the content of the element. A reduced number of glances away from the driving scene to the screen are expected.

In terms of an automotive capable realization the highest costs are produced by the realization of a technology for the haptic structured surface. To clarify if this is really worth it and if there is a real benefit given by the haptic structure, two questions should be answered:

1. Is there a real benefit given by the haptic structure compared to a usual flat touchpad?
2. Is a cursor for giving an optical feedback of the current finger position comparable to a laptop application enough?

3.3 Simulator Tests for Capturing Human Driving and Gaze Behavior

How to clarify the mentioned questions in a very early stage of concept development is shown with the results of a usability test in a static driving simulator at Audi [12]. The driving task consisted of following a vehicle in a constant distance. The test persons had to fulfill different menu tasks with the navigation system while driving. The navigation system had to be controlled via four different touchpad solutions:

1. Haptic Touchpad with cursor Feedback (HTP + Cursor)
2. Haptic Touchpad without Feedback (HTP without Cursor)
3. Flat Touchpad with Cursor (TP + Cursor)
4. Flat Touchpad without Cursor (TP without Cursor)

The gaze behavior was measured with Dikablis and was synchronously stored with driving performance data via DLab Control. Figure 5 shows the results for the gaze behavior as well as the driving performance.

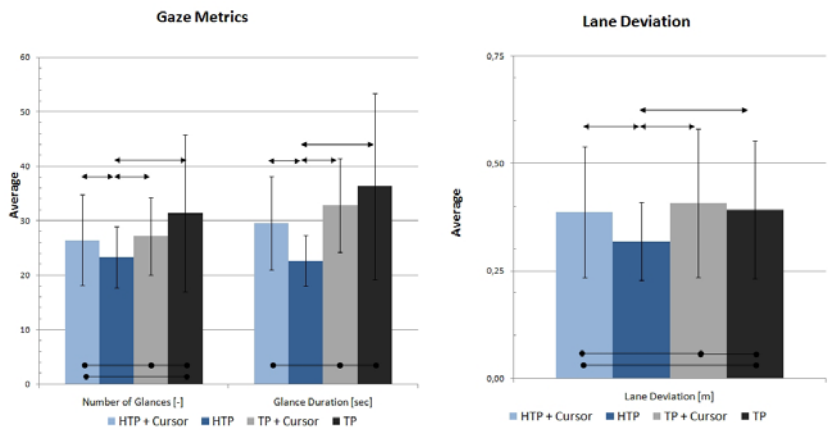

Fig. 5. Left: Number of gazes and gaze duration to the display while controlling a secondary task with different touchpad solutions; right: Lane deviation while controlling a secondary task with different touchpad solutions

The results show that the haptic structured surface improves the control performance with the touchpad significantly. The number of gazes as well as the gaze duration can be decreased by providing additional orientation feedback via the haptic channel. This also leads to an in improvement of the lane deviation what comes along with safer driving performance.

The theoretical assumption would have been that an additional optical cursor feedback leads to a further improvement of driving safety and gaze distraction. The results show that this assumption cannot be verified via the objective behavioral data. Moreover the optical cursor feedback even works like an eye catcher that causes additional gaze distraction from driving.

4 Conclusion

In conclusion the example of evaluating the concept idea of the haptic touchpad in a realistic environment in a very early stage of development shows, how on the one hand theoretical ideas can be proven if they work under realistic conditions like it has been done with the haptic surface. In this case the haptic structure leads to a massive benefit what legitimates a further effort in development of the technical realization. If the result would have been, that there is no difference between haptic and flat touchpad surface the technical development could have been stopped at this point what would have avoided the wastage of a high amount of development budget. The example with the optical feedback shows how the measurement of objective behavioral data can avoid wrong concepts given by theoretical assumptions.

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