How Do Different Vehicle Interior Concepts Influence Work and Entertainment Experience During Automated Driving?

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Abstract. The goal of the research project RUMBA, which is funded by the German Federal Ministry for Economic Affairs and Climate Action, is to redesign the user experience for occupants during a highly automated drive (SAE level 4 [1]) by developing innovative interior and interaction concepts. As part of the second iteration of the user-centered, iterative development process, a laboratory study is conducted. It aims to evaluate a simulated prototype of an innovative vehicle interior concept for work and entertainment during automated driving as well as to identify design suggestions for its further development. The vehicle interior concept to be evaluated is compared with a classic vehicle interior in an experimental research setting. Test subjects experience the two vehicle interior prototypes during two simulated automated test drives of approximately 15 min each. In the first ride, one subject performs work tasks while the other watches a movie; in the second ride vice versa. Besides others, user experience, system trust, and subjective road safety of the occupants are measured. Data collection for the study is completed by the end of March 2023. Therefore, this short paper focuses on the method and does not yet include results. The HCII conference poster in July 2023 reports both, the methodology and the results of the evaluation study.

Keywords: Automated Driving · Vehicle Interior · User Experience · Work · Entertainment

1 Introduction

Since this paper is related to the same research project (RUMBA) as [2], the introductions of both papers are identical and their structures are similar. However, they are two different short papers reporting on different studies with independent results. This short paper reports on a laboratory study in a driving simulator on the topic of work and entertainment during automated driving, while [2] reports on a field study in a real vehicle on social interaction during automated driving.

1.1 Research Project RUMBA and User-Centered Development

This contribution results from the publicly funded joint research project RUMBA (German acronym for "Achieving a positive user experience through user-friendly design of

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the vehicle interior for automated driving functions"), which is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a resolution of the German Bundestag (funding code 19A20007D).

The user-centered development process of DIN EN ISO 9241–210:2020–03 [3] (see Fig. 1) pursued in the RUMBA research project by the Stuttgart Media University is explained in detail below.

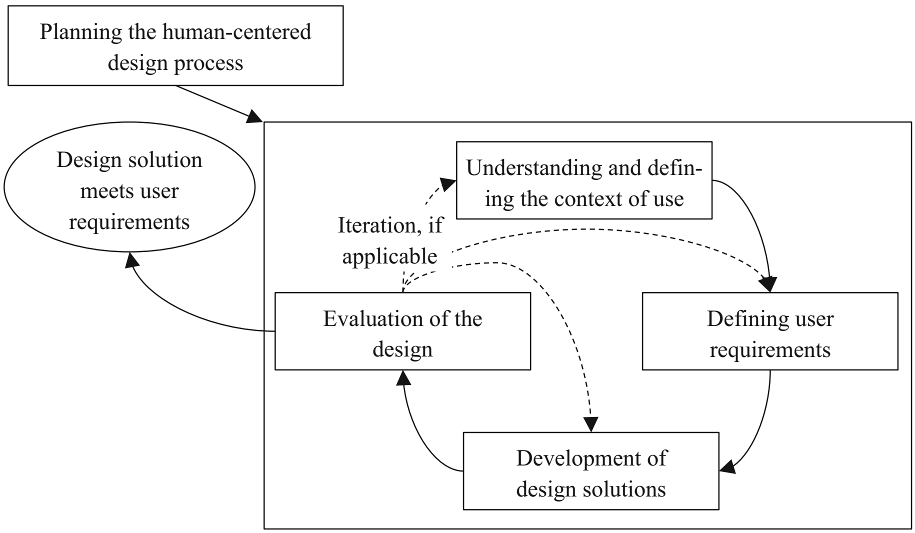

Fig. 1. User-centered development process of DIN EN ISO 9241–210:2020-03 [3]

Based on the planning step ("Planning the human-centered design process"), in which the project goal and approach were conceived, the requirements and needs for SAE Level 4 automated driving were empirically investigated from the user's perspective ("Understanding and defining the context of use"). The authors conducted a simulator and a diary study to investigate user requirements for the vehicle interior and for displays and controls in fully automated driving [4, 5]. In the next step ("Defining user requirements"), the research results on user requirements were compiled, key learnings were extracted, and design spaces were derived. This was done in a synthesis workshop. In the subsequent step ("Development of design solutions"), ideas and initial prototypes for the vehicle interior, displays and controls were generated. This was done in a design thinking workshop. There, various alternative concept ideas were generated and concretized in low-fidelity prototypes. On this basis, the authors developed five user narratives [6], which describe the innovative concept ideas integrated there in the form of a usage story. These user narratives were evaluated with users in a first iteration as part of the evaluation step ("Evaluation of the design"). The goal of the evaluation was to gather user feedback on innovation ideas and concept concretization and to identify design cues for their further development.

In the second iteration, based on this initial user feedback, the authors developed the low-fidelity prototypes into mid-fidelity prototypes: A simulation prototype for working and watching movies during an automated ride was created in a laboratory setting. This prototype was then evaluated in a laboratory study as part of the second evaluation iteration. The prototype and the methodology of this study are described in detail in this short paper. The results of the evaluation study are reported on the HCII poster.

1.2 Objectives

The objectives of the laboratory study were:

1. To quantitatively compare a classic interior concept (Classic Mode) and an innovative interior concept (Individual Occupation Mode) for work and entertainment during automated driving.
2. To obtain qualitative design information for the further development of the equipment elements of the interior concept.

2 Methods

2.1 Participants

Two test subjects participated in each experiment simultaneously. A total of 26 females and 22 males participated in the study. The mean age of the participants was 23.25 years ($SD = 3.68$) and the age range was 18 to 31 years.

2.2 Experimental Design

In the experimental two-factor within-subjects research design, the two-level independent variables *interior concept* (Classic Mode vs. Individual Occupation Mode) and *non-driving activity* (completing work tasks vs. watching a movie) were purposefully manipulated. To avoid sequence effects due to the within-subject design, the experimental conditions were counterbalanced.

Interior Concept. The *Classic Mode* bases on the familiar interior concept of today's vehicles. The *Individual Occupation Mode* is designed to support work and movie watching during automated driving by means of innovative equipment elements. Figure 2 shows the two interior concepts set up in a laboratory driving simulation.

Non-Driving Activity. To simulate the *work tasks*, two comparable task sets were created, each with four task types (text input, addition, proofreading, and creative thinking) [7–9]. The tasks were designed to take a total of 15 min. To simulate the *movie* entertainment, Interstellar was chosen, based on a preliminary study. The first and the subsequent 15 min of the movie were shown during the study.

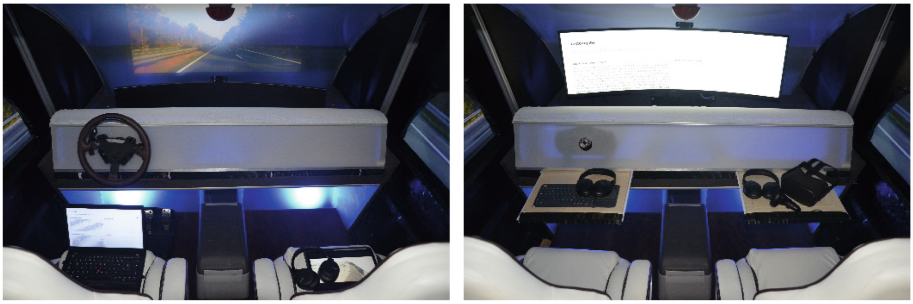

Fig. 2. Interior concept[1] (left: Classic Mode, right: Individual Occupation Mode)

Table 1 below lists the equipment elements per interior concept and non-driving activity.

Table 1. Equipment elements per interior concept and non-driving activity

	Classic Mode	Individual Occupation Mode
Work tasks	– With steering wheel and pedals on driver's side – Laptop – Front view through (transparent) windshield	– Without steering wheel and pedals on driver's side – Extendible screen – Visibility to the front not given due to milky windshield – Extendible table top – Integrated keyboard – Noise-canceling headphones
Movie	– Steering wheel and pedals on driver's side – Tablet – Headphones	– Without steering wheel and pedals on driver's side – VR glasses (simulating a cinema environment) – Noise-canceling headphones – Extendable table top – Controller for the VR glasses

The following additional equipment elements were included in both interior concepts: flexible seats, an emergency button, a refrigerator, and storage compartments.

2.3 Procedure

The study took place from December 2022 to March 2023 at the Stuttgart Media University. The test procedure includes three parts. These are described below.

Introduction and Pre-Questionnaire. The study began with a welcome and an introduction to the study. This was followed by a pre-survey via a questionnaire on personal

[1] Vehicle interior mockup by Fraunhofer IAO.

details (e.g. gender, age, and driving performance) and affinity for technology. The participants were then instructed in the use of the driving simulator.

Four Experimental Test Drives Followed by Interim Questionnaires. Prior to each test drive, participants were instructed on the non-driving activity to be performed and the available equipment elements.

All participants experienced each of the two interior concepts during two simulated, automated drives of approximately 15 min each. This resulted in a total of 4 test drives for each participant. Each subject performed work tasks in each of the two interior concepts once and watched a movie once, while the second subject simultaneously carried out the other non-driving activity during the respective test drives. The subjects always took the same seat in the driving simulator (driver seat or passenger seat) during all four drives. During the test drives, the participants were observed by four cameras installed in the driving simulator.

After each of the four test drives, the participants completed a questionnaire on simulator sickness, user experience, system trust, subjective traffic safety, and intention to use. The participant who had completed work tasks additionally answered questions about flow, subjective work performance, distraction, and subjective work ability. The participant who watched a movie additionally answered a questionnaire about the film immersion experience.

Final Questionnaire, Interview, and Conclusion. After the fourth test drive and interim questionnaire, participants answered questions about system trust, ranked the equipment elements they experienced, and selected their preferred interior concept. This was followed by an interview about their experiences with the interior concepts and the equipment elements included. Finally, the incentives were handed out (3 h of test person time or 30 euros per person).

2.4 Measurement Methods

Table 2 below provides an overview of the measurement instruments used to collect the measurement variables.

Table 2. Measurement variables and instruments

Variable	Instrument	Measuring point in time
Personal information	Closed and open questions	1
Technology affinity	Interactional Technology Affinity Questionnaire (ATI) [10]	1
Objective work performance	Speed and accuracy on four different task types adapted from [7–9]	2a
Simulator sickness	Simulator Sickness Questionnaire (SSQ) [11] (translation from [12])	2b
User experience	User Experience Questionnaire-Short (UEQ-S) [13]	2b
	Facets of user experience [14]	2b
System trust	Trust in Automation (TiA) [15]	2b, 3
Subjective traffic safety	Single-items on risk and safety [16]	2b
Intention to use	Intention to use adapted from [17]	2b
Flow	Flow Short Scale (FSS) [18]	2b
Subjective work performance	Subjective work performance [19, 20] (own translation)	2b
Distraction	Distraction [19] (own translation)	2b
Subjective work ability	Single item on work ability adapted from [7] (own translation)	2b
Film immersion experience	Immersive Experience Questionnaire for Film and TV (Film IEQ) [21] (own translation verified via back translation by state-certified translator)	2b
Evaluation of equipment elements	Ranking of equipment elements with regard to ownership preference (scenario: equipment of own vehicle)	3
Acceptance of the interior concepts	Selection of an interior concept with regard to usage preference (scenario: driving from Stuttgart to Frankfurt)	3
Design information	Open questions about the experience (oral)	3

Note. 1 = Pre-questionnaire, 2a = During test drive, 2b = Interim questionnaire, 3 = Final questionnaire

3 Results (Preview)

As the data collection is scheduled to be completed by end of March 2023, the results cannot be presented in this short paper. At HCII in July 2023, initial insights are provided into how vehicle interior concepts influence the work and entertainment experience of automated driving.

4 Discussion

Compared to low-fidelity prototypes, creating a mid-fidelity prototype requires more effort to illustrate concept ideas. However, a simulation prototype in a driving simulator allows for greater immersion and interaction of users. For example, equipment elements can be directly interacted with and the spatial experience is more realistic. Therefore, more detailed hints for interaction concepts and real behavioral data can be generated.

Compared to field research, laboratory research has lower external validity. However, advantages of laboratory research are that confounding variables can be controlled better and innovations can be tested already, before complex traffic safety solutions have to be developed (e.g. crash safety of equipment elements).

The quantitative evaluation and qualitative user feedback serve to identify the strengths and weaknesses of the concept, thus avoiding greater development effort to realize a high-fidelity prototype in a potentially inappropriate direction.

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