Research Article

Carolin Wienrich* and Kristina Schindler

Challenges and Requirements of Immersive Media in Autonomous Car: Exploring the Feasibility of Virtual Entertainment Applications

https://doi.org/10.1515/icom-2018-0030

Abstract: This paper investigated the influence of VR-entertainment systems on passenger and entertainment experience in vehicles with smooth movements. To simulate an autonomous driving scenario, a tablet and a mobile VR-HMD were evaluated in a dynamic driving simulator. Passenger, user and entertainment experience were measured through questionnaires based on comfort/discomfort, application perception, presence, and simulator sickness. In two experiments, two film sequences with varying formats (2D versus 3D) were presented. In Experiment 1, the established entertainment system (tablet + 2D) was tested against a possible future one (HMD + 3D). The results indicated a significantly more favorable experience for the VR-HMD application in the dimensions of user experience (UX) and presence, as well as low simulator sickness values. In Experiment 2, the film format was held constant (2D), and only the device (tablet versus HMD) was varied. There was a significant difference in all constructs, which points to a positive reception of the HMD. Additional analyses of the HMD device data for both experiments showed that the device and not the film format contributed to the favorable experience with the HMD. Additionally, the framework to evaluate the new application context of VR as an entertainment system in autonomous vehicles was discussed.

Keywords: immersive media, VR, autonomous driving, driver experiences

***Corresponding author: Carolin Wienrich,**
Julius-Maximilians-Universität Würzburg, Human Technique Systems, Oswald-Külpe-Weg 82, 97274 Würzburg, Germany, e-mail: carolin.wienrich@uni-wuerzburg.de
Kristina Schindler, Berlin, Germany, e-mail: kristinafschindler@gmail.com

1 Introduction

Since the launch of recent virtual reality (VR) displays such as the Oculus Rift [49] and the HTC VIVE [30], VR applications created keen interest in media and commerce. In particular, applications for smartphones provide a promising potential for mobile use cases in busses, trains and planes. The advancing development especially in the field of autonomous vehicles reveal a change from the construct of driving experience to that of passenger and entertainment experiences. In particular, the experience for the driver will radically change. The interaction with devices and the content of different media will play a major role when drivers evaluate their experience during an autonomous ride. Different experiences (e. g., passenger experience, user experience, entertainment experience) are becoming important considerations while traveling by car. Hence, different constructs from different research fields (e. g., passenger research, human-computer-interaction, and media psychology) might contribute to a holistic framework of this new driver experience. First, the present article presents requirements and challenges providing immersive media in autonomous driving scenarios. Second, two studies explore the feasibility of a virtual reality entertainment applications in a simulated driving scenario. To extend findings from previous pilot studies (see below), the exposure time (to the devices and the content) was extended to evaluate the experience during a smooth ride in a driving simulator (simulation of autonomous driving context). The experiments tested the impact of a conventional entertainment system (tablet device + 2D film format) and a new VR head mounted display system (HMD device + 2D film format and HMD device + 3D film format) on passenger, user and entertainment experience. Thus, the change of understanding of the driver's experiences in the autonomous driving context was incorporated by an evaluation framework, which was chosen from different research fields (passenger research, human-computer-interaction, and media psychology). The content shown on these devices was selected based on a consumer survey.

2 Related Work

2.1 Relations between General Passenger Experience, UX and VR Entertainment Experiences

Future ideas regarding autonomous driving reveal a change from the construct of driving experience to that of passenger and entertainment experiences (e. g., IAA presentations of the Audi Aicon or Renault Symbioz, see Grünweg, [23]). In particular, the experience for the driver will radically change. The interaction with devices, and the content of different media will play a major role when drivers evaluate their experience during an autonomous ride. Hence, constructs from different fields (e. g., passenger research, human-computer-interaction, and media psychology) might contribute to a holistic framework of this new driver experience.

2.1.1 General Passenger Experience

Passenger experience includes the journey experience (e. g., purchasing tickets in public transportation) and the experience in the transport system itself (e. g., Jabalpurwala [31]; Myant & Abraham, [47]). The present two studies focused on the latter, and operationalized the experience with the constructs of comfort and discomfort. Comfort and discomfort are essential aspects of passenger experience [1, 50]. Zhang, Helander, and Drury [73] presumed that the perception of comfort and discomfort are two independent constructs. In their model, the authors assumed that discomfort is influenced by biomechanical design aspects, such as pressure points, and therefore more relevant to the ergonomic side of design. These design aspects can induce painful, sore or numb sensations. Comfort is not solely the absence of discomfort, but rather a multi-dimensional feeling of being relaxed and well, which can be improved with an appealing aesthetic design. The more psychological aspect includes, for example, positive or negative feelings (e. g., Richards, Jacobson, & Kuhlthau [54]). The absence of discomfort might make it possible to feel comfort, but the two are not mutually exclusive. Slater [60] defines comfort as a state between humans and the environment that is harmonious in a physiological, psychological and physical way. Later, a social component (such as balancing privacy with facilitating social interactions) was also suggested (e. g., Ahmadpour et al., [1]; Kolcaba [37]). While Lewis [40] showed that VR-entertainment could distract from physical sources of discomfort (e. g. restricted legroom), the present study took a closer look to the feelings of comfort and discomfort arising from the whole device (e. g., pressure from the HMD), from the display (e. g., eye strain) and from the content format (e. g., headache). Of course, comfort and discomfort might also derive from the interaction between the driver and the technical system and media during an autonomous ride. In that context, constructs from the field of human-computer-interaction (e. g., UX) might offer a broader approach to assessing the driver experience.

2.1.2 User Experience

UX concerns the behavior and the perception when interacting with products or technical systems (ISO-Norm BS EN ISO 9241-210:2010, [11]). When characterizing UX, the functionality of a product, the use context, and the user's emotion and perception of the product must be considered (e. g., Hassenzahl & Tractinsky [26]; Law, Roto, Hassenzahl, Vermeeren, & Kort, [39]; McCarthy & Wright [44]; Thüring & Mahlke [66]). The hedonic/pragmatic model of UX by Hassenzahl [24] differentiates between the objective qualities of a product and the perception of those qualities from the user's perspective. While the pragmatic qualities focus more on the usability aspects of the product, such as its functions or design, the hedonic qualities emphasize non-functional aspects, such as beauty or originality. Taken together, they form a more general rating of the product, which is called attractiveness [25]. The corresponding questionnaire *AttrakDiff2* focused on the assessment of both qualities, and is one of the most and commonly used UX questionnaires. The Components of User Experience model (CUE-model, Thüring & Mahlke [66]) is a similar framework, which distinguishes between instrumental and non-instrumental qualities. In contrast to the AttrakDiff2, the *meCUE* questionnaire (modular evaluation of key Components of User Experience; Minge, Riedel, & Thüring [46]) provides a modular assessment of the product perception (instrumental, non-instrumental), emotions (positive and negative), consequences (product loyalty and intention to use), and a global UX evaluation. This modularity enables a targeted assessment of different UX aspects. Due to the innovative character of VR entertainment in the driving context, the motivations, wishes, and intentions of future users were of particular interest to the present research. However, pragmatic and instrumental issues were also included by assessing the handling and functionality of the device. Since, the effect of media content might play a bigger role for drivers in an autonomous driving context than for drivers who must control the car themselves, the aspect of entertainment of the presented applications also requires a closer look at the effect of media on recipients. Researchers in the field of media psychology agree that entertainment is a non-professional leisure activity with the primary goal that the person feels good [71]. Traditional process theories of the reception of entertaining media (e. g., the affect disposition theory by Zillmann [74] or the simulation theory by Oatley [48]) have been conceptualized extensive emotional component of positive and negative affect. Emotion as an effect of media exposure, as well as the impact of emotions on the reception of media content is well investigated in this field (for a review see Wirth & Schramm [71]). The emotional component is also linked with the hedonic and non-instrumental quality of user experience. In other words, the affective impact of a new VR entertainment system is related to both UX components and entertaining media reception. In the present study, the emotional impact was measured in this broad sense of positive and negative affect and the hedonic quality as conceptualized in the AttrakDiff2.

2.1.3 VR Entertainment Experience

Another important indicator for being entertained is the feeling of presence. Klimmt and Vorderer [35] linked emotions and other essential states and theories of media psychology with the feeling of presence. Also in the human-computer-interaction research, the concept of presence is intensively discussed. In this field, a controversial debate exists about the definition and distinction of immersion and presence (e. g., Slater [61]; Usoh, Catena, Arman, & Slater, [68]). The present research followed the opinion of Slater and Wilbur [62] who defined immersion as the degree to which a person can be engrossed in a virtual world, based on objective and quantifiable multisensory stimuli. Hence, immersion describes the extent to which the technological features of the device and the setting are capable of offering the user the illusion of reality. In contrast, presence can be seen as a multi-dimensional psychological construct. Presence occurs when a mental model is constructed, and attention is allocated to a virtual environment. This leads to the feeling of being a part of this environment, and the sense that one's actions take place there [59, 62]. According to Schubert et al. [59], the construct of presence has three main components: realism, involvement and spatial presence. Realism is defined as the user's evaluation of how convincing the virtual environment is. Involvement is defined as a facet of presence based on attention. Spatial presence is defined as a facet of spatial-construction. Apparently, the degree of immersion (features of the system such as a wide field of view, or an accurate and active head tracking) influences the feeling of presence. The higher the degree of immersion, the higher the potential feeling of presence (e. g., Dörner, Broll, Grimm, & Jung, [15]).

In the context investigated by the present study, the feeling of being engrossed (high feeling of presence) might be a very important issue for the VR entertainment experience. During traveling, even in cars, passengers are exposed to attentional distraction, and current displays (e. g., tablets) do not allow much privacy because other passengers could look at the display. In contrast to that, HMDs offer a higher degree of immersion (with an enclosed display) and thus carry a high potential to decrease attentional distraction and increase privacy. The research regarding the impact of different displays on presence supports this assumption and shows mostly a stronger feeling of presence for HMDs compared to other displays (e. g., Baños, Botella, Alcañiz, Liaño, Guerrero, & Rey, [5]; Fonseca & Kraus [20]). However, an additional increase of presence caused by a stereoscopic format (3D) is still controversial (pro: e. g., Freeman, Avons, Davidoff, & Pearson, [21]; contra: e. g., Baños, Botella, Rubió, Quero, García-Palacios, & Alcañiz, [6]). The present study investigated the impact of the device (tablet versus HMD) and format (2D versus 3D) on the feeling of presence. In accordance with Stanney, Mollaghasemi, Reeves, Breaux, & Graeber [65] who developed a structured approach to assess multiple criteria for the usability of virtual environments (MAUVE: Multi-criteria Assessment of Usability for Virtual Environments), presence was here further taken as an indicator for good UX and successful entertainment of the new entertainment system.

Besides presence and immersion, sickness was also considered to directly affect the usability of VR applications [65]. The phenomenon of simulator sickness is not yet fully explained. However, one frequently cited theory is the sensory conflict theory by Reason and Brand [53], which proposes that simulator sickness is triggered if the perception of movement by different senses (mainly that of the visual and that of the vestibular systems) varies. Concerning immersive media in autonomous driving scenarios, the motion of the car and the induced visual movement perceived on screens could trigger the symptoms. The sensory conflict could arise when the movement of the car does not correspond to the movement of the VR content. As previously mentioned, simulator sickness has been increased when the VR content and the car was moving in the study of McGill et al. [45]. Furthermore, the entertainment format also influences simulator sickness symptoms [63]. Visually induced simulator sickness can be triggered by viewing 2D and (more severely) stereoscopic 3D content on displays [38, 63, 67]. Referring to the sensory conflict theory, an intense visual self-motion signal is induced, while the signals from the vestibular system remain weak. That might occur in 2D and 3D content. In current 3D technologies, simulator sickness might also occur when monocular depth cues and stereo depth cues are differing [29]. In addition, environmental and individual factors influence the severity of simulator sickness [41]. Visually induced motion sickness symptoms could get worse over a longer exposure time or in a moving context [9]. Further, inexperienced users are more likely to get sick (e. g., Bles & Wertheim [10]). Considering a VR entertainment system during a longer journey, and an inexperienced user group due to the innovative character of this kind of entertainment, simulator sickness is an essential factor, which might have an impact on the travel experience of passengers. Hence, it was also incorporated into the present studies.

According to the theory, the *Simulator Sickness Questionnaire* (*SSQ*; Kennedy et al. [33]) assesses simulator sickness. The symptoms of simulator sickness are mapped in the SSQ with three subscales: nausea, oculomotor and disorientation during an experience. Another simulator sickness scale is the one-item *Fast Motion Sickness Scale* (*FMS*; Keshavarz & Hecht [34]), which can be used as a direct measure (on a scale from 0 to 20) for a global motion sickness as well as nausea.

In summary, the evaluation of experiences in transport systems (e. g., during autonomous driving scenarios) might include more global concepts of passenger experience such as comfort and discomfort, aspects of user experiences from the field of human-computer-interaction, and also more specific aspects of an entertaining system like presence, and simulator sickness in the case of a VR application. Only a few studies investigated the impact of VR entertainment in transport systems from some of these perspectives to this date. The next section presents an overview of these studies.

2.2 The Impact of VR Applications in Transport Systems

For the first time in 2015, Quantas Airlines [51] offered VR applications to passengers traveling first class, which were 360° videos about potential destinations as well as current movies. Those applications were presented on a mobile HMD device. Unfortunately, the airline did not report how the users evaluated this offer. More scientifically, the project VR-Hyperspace [69] aimed to improve passenger experience on long distance flights. Lewis [40] investigated if a simulated tropical islands VR environment could be used to distract passengers from sources of discomfort, both auditory (e. g., crying infants) and physical (e. g., restricted legroom). The results showed that the VR application successfully distracted from the restricted legroom, but did not decrease the perception of crying infants. Further, an auditory distractor (birds chirping) helped to reduce the impact of noise, but the combination of both auditory and visual VR distractions was the most effective. However, the study was conducted in a CAVE system, and the simulation lasted roughly 15 minutes. Hence, the impact of VR-HMD applications on passenger experience during a longer journey remained unclear. Another study in the same project examined the influence of physical in-flight motion (three ten-second intervals of turbulence) on motion sickness and presence while passengers were wearing a HMD in a motion simulator [64]. The authors created two virtual environments (a virtual airplane, and a magic carpet ride) and varied the extent to which the physical motion matched the motion in the virtual world. Severe motion sickness was not found, and the scores for motion sickness and presence seemed to be slightly more positive when the physical motion matched the motion in the virtual world. However, these effects were very small and the exposure time was even shorter than in Lewis [40]. The authors suggested increasing the exposure time to investigate the effects on motion sickness, presence, and passenger wellbeing. More recently, Hock, Benedikter, Gugenheimer, and Rukzio [28] examined the influence of compatible movements in a VR game on simulator sickness, enjoyment, and engagement in two conditions (one moving and one stationary). The game was presented on a mobile HMD (Samsung GearVR) in a driving car while the player in the game was seated in a virtual helicopter. The movements of this helicopter were generated based on the movements of the real car, which was driven by a person outside of the game. The results showed significantly higher scores for player experience in the moving condition, but no difference in simulator sickness values between the two conditions. One reason for the latter result might be the predictability of the flight bends, because they were visible to the players on a map. This result supports the findings of Lin, Abi-Rached, and Lahav [42], who showed that a guiding avatar predicting the direction of in-game movements reduced simulator sickness. Although a real transport system (a driving car) was used, the exposure time was still very short. McGill, Ng, and Brewster [45] presented 360° VR videos on a HMD (Samsung Gear VR) to participants (passengers in a driving car), and examined simulator sickness as well as presence. Expanding on Hock et al. [28], the authors not only matched movements between the transport system and the VR content, but they also used different approaches to compensate for movements of the transport system on a HMD. The methods used compensated either head rotations, vehicle rotations or vehicle rotations with motion cues of the car shown on the HMD display. In comparison to a baseline, simulator sickness scores increased when participants watched a VR video in a moving car. However, the compensating method itself had no different impact on simulator sickness. The feeling of presence was also not affected by the conditions. Another interesting result was that different people preferred different compensating methods. Due to short exposure times, the impact of VR applications on passenger and entertainment experience during long distance traveling still remained unclear in those recent studies. Moreover, strong movements of the transport system were induced and therefore a significant level of simulator sickness. Yet despite that, the tested compensation methods yielded no different impact on the reduction of simulator sickness.

Wienrich et al. [4] chose a setting with smoother movements of the transport system and compared the impact of the motion induced by the VR content to that of the transport system on passenger experience. Similar to McGill et al. [45], 360° videos were presented on a mobile HMD (Samsung Gear VR). 40 participants watched two videos (dynamic camera work vs. stationary camera work), one in a moving car and the other in a resting car. In line with previously reported results, simulator sickness was slightly increased when the car was moving, and the VR scene was dynamic. However, the standard deviation of the original values remained well below 15, which was proposed as significant variation of simulator sickness [33]. The results also revealed that there was neither an influence of car motion nor video dynamic on the other measurements of the participant‘s experience (e. g., affect, presence). Overall, the experience of the VR entertainment system was found to be very positive throughout the experiment, and the majority of participants indicated the intention to use such a system again and a willingness to pay about 18€ on average.

The studies described above investigated different aspects of various experiences (e. g. general passenger experiences such as comfort, user experiences such as positive affect, or VR entertainment experiences such as presence). However, the content of these VR applications shown was mostly five to ten minutes long, which is too short for the intended context of use (long distance journeys). The devices used are usually only HMDs, and no comparison to the already established way of watching films in a moving context, a tablet, was made so far. Lastly, the content used in those studies is not necessarily content passengers would choose to be exposed to for a more extended period.

3 Outline of the Present Research

In the present studies, the exposure time to the content was increased to a more realistic one, ideally the standard length of many TV series (e. g., sitcoms). In addition to the previous studies, the exposure material was selected based on the opinions of potential users, who were asked about their content preferences for entertainment purposes during a long distance journey in a pre-study. The experience of a conventional form of entertainment in a long distance travel context, and the experience of a new one, which might be part of entertainment packages in the future, was evaluated. In the first experiment, the impact of the conventional entertainment device (tablet) and format (2D film) on the experience was compared to a new entertainment device (HMD) and format (3D film). In other words, the impact of the *kind of application* (*old* versus *new*) was investigated in a first step. In order to investigate the impact of the device independently on the format, the content format remained constant (2D film) between the *device*-conditions (*tablet* versus *HMD*) in Experiment 2. Therefore, the impact of the *device* was investigated in a second step. An additional analysis allowed examining the additional impact of the *3D film format* compared to the *2D film format* when participants watched the film on the HMD device. Therefore, the impact of *format* was examined in a third step.

As described above, the experience was examined by the constructs of general passenger experience (comfort / discomfort), UX (user experience; of the overall experience, the device and the film format), and VR entertainment experiences (presence and simulator sickness).

The travel context was also located in a future use case. An autonomous driving scenario was mimicked by using a functional driving simulator. Even though participants were seated in the driver seat, the simulator was driving autonomously. The preset route in a simulator environment eliminated any unplanned maneuvers due to traffic, which in turn allowed for standardized driving conditions as well as removing the influence of human driving behavior.

3.1 Hypotheses Experiment 1: The impact of the kind of Application (Old versus New)

Previous studies presented reasons to recommend the new kind of VR entertaining applications during travel. However, there are still many concerns that might make a launch difficult, which is also reflected by the following hypotheses. A confirmation of hypotheses 1 to 3 would support a positive experience through the VR entertaining application (HMD device + 3D film format) compared to the old one (tablet device + 2D film format). A confirmation of Hypotheses 4 and 5 would underline the concerns (see Table 1).

Table 1: Hypotheses comparing the experience through the whole immersive media application (HMD device + 3D film format) compared to the old one (tablet device + 2D film format) (Study 1).

Positive experience through immersive media
H1: user experience 1 (meCUE): The combination of HMD device + 3D film format (new) receives higher UX ratings than the combination of tablet device + 2D film format (old).
H2: user experience 2 (AttrakDiff2): The HMD device + 3D film format condition (new) receives higher UX ratings than the tablet device + 2D film format condition (old).
H3: presence: The combination of HMD device + 3D film format (new) receives higher presence ratings than the combination of tablet device + 2D film format (old).
Negative experience through immersive media
H4: comfort / discomfort of the devices: The tablet device + 2D film format condition (old) is expected to receive higher comfort and lower discomfort ratings than the HMD device + 3D film format condition (new).
H5: simulator sickness: It is expected that simulator sickness scores are higher for the HMD device + 3D film format condition (*new*) than for the tablet device + 2D film format condition (*old*).

3.2 Hypotheses Experiment 2: The impact of Device (Tablet versus HMD)

Similar to Experiment 1, the confirmation of hypotheses 6 to 8 would support a positive experience through the HMD device compared to the tablet device. A confirmation of hypotheses 9 and 10 would underline the concerns (see Table 2).

Table 2: Hypotheses comparing the experience through the HMD compared to tablet device (Study 2).

Positive experience through immersive media
H6: user experience 1 (meCUE): The combination of HMD device + 2D film format (HMD) receives higher UX ratings than the combination of tablet device + 2D film format (tablet).
H7: user experience 2 (AttrakDiff2): The HMD device + 2D film format (HMD) receives higher UX ratings than the tablet device + 2D film format condition (tablet).
H8: presence: The combination of HMD device + 2D film format (HMD) receives higher presence ratings than the combination of tablet device + 2D film format (tablet).
Negative experience through immersive media
H9: comfort/discomfort of the devices: The tablet device + 2D film format condition (tablet) is expected to receive higher comfort as well as lower discomfort ratings than the HMD device + 2D film format condition (HMD).
H10: simulator sickness: It is expected that simulator sickness scores are higher for the HMD device + 2D film format condition (HMD) than for the tablet device + 2D film format condition (tablet).

3.3 Hypotheses of the Additional Analysis: The Impact of Film Format (2D versus 3D)

Similar to the hypotheses of Experiment 1 and 2, a confirmation of hypotheses 11 to 13 would support a positive experience through the 3D format compared to the 2D format. A confirmation of hypotheses 14 and 15 would underline the concerns (see Table 3).

Table 3: Hypotheses comparing the experience through the format 3D compared to the format 2D (additional analyses).

Positive experience through immersive media
H11: user experience 1 (meCUE): The combination of HMD device + 3D film format (3D) receives higher UX ratings than the combination of HMD device + 2D film format (2D).
H12: user experience 2 (AttrakDiff2): The combination of HMD device + 3D film format (3D) receives higher UX ratings than the combination of HMD device + 2D film format (2D).
H13: presence: The combination of HMD device + 3D film format (3D) receives higher presence ratings than the combination of HMD device + 2D film format (2D).
Negative experience through immersive media
H14: comfort/discomfort of the devices: The HMD device + 2D film format condition (2D) is expected to receive higher comfort as well as lower discomfort ratings than the HMD device + 3D film format condition (3D).
H15: simulator sickness: It is expected that simulator sickness scores are higher for the HMD device + 3D film format condition (3D) than for the HMD device + 2D film format condition (2D).

4 Pre-Study

In order to choose the exposure material for the main experiments, the opinions of potential users were asked in a pre-study. Participants were recruited via SurveyCircle, a German language survey platform for research surveys, and social media. In total $n = 56$ participants ($n = 35$ female) took part in the survey. The mean age was 27.4 years ($sd = 7.1$ years). When asked about their experience with VR devices, the majority ($n = 31$) claimed to have never used any VR devices. A further $n = 16$ participants had used some VR devices before and five participants used VR devices at least once every six months. The remaining four participants said that they used VR devices at least on a monthly basis. When asked about VR or simulator sickness, the majority of the participants ($n = 35$) answered *unsure*. Seven people had experienced simulator sickness before, and $n = 14$ had not. For the user study, a questionnaire was designed. The questions were based on the different activities people can undertake with a mobile HMD during long-distance travel. The items (questionnaire choices) were generated based on the best-selling genres of games and films in Germany [22, 8]. The questionnaire contained two parts. The first part concerned demographics: age, gender, and experience with VR and simulator sickness. The second part began with the question: *If I could use a mobile VR system during a long distance trip, I would use it the following way…*. Participants could select *watching 2D videos or films*, *watching 3D videos or films*, *watching 360° videos*, *playing 2D games*, *playing 3D games* and *working in a desktop environment*. Selecting more than one option was possible. Depending on which options were selected, further questions were presented (e. g., specific film genres for the questions concerning film formats). The descriptive results showed that during a long distance journey, watching films (in 2D, 3D or 360° formats) was the most popular choice, with 3D being the most popular format, and documentary and action being the most popular genres. As a consequence, a 3D film which combines the characteristics of those two genres was selected for the experiments. The film will show characteristics of a documentary, such as a natural setting and an extensive use of light and shade effects [58] as well as incorporate aspects of a typical action film, such as quicker camera shot changes and frequent movement [52]. On the basis of these results, sequences of the *The Jungle Book* [18] were presented to participants in the main experiments.

5 Experiment 1 – Impact of the Kind of Application

The main goal of Experiment 1 was to investigate the impact of a new entertainment application in a transport context simulating an autonomous driving situation. In comparison to previous studies in this field, the exposure-time to the content was increased to the length of a typical TV episode. Furthermore, the experience during the exposure was evaluated by different constructs regarding passenger experience, UX, and VR entertainment experience. Further, in addition to previous studies, the exposure material was selected by opinions of potential users who were asked in a pre-study.

5.1 Method

5.1.1 Participants

In Experiment 1, 20 volunteers from the TU Berlin ($n = 10$ female; mean age 29.3 years; $sd = 5.7$ years) with normal or corrected to normal vision participated. No participants reported any health problems such as epilepsy or migraines. Participants were equally distributed into the order conditions by their answers to individual predisposition to motion sickness of a screening questionnaire, which the participants were asked to complete as a part of the registering process for the experiment.

5.1.2 Materials

Participants filled out the questionnaires on an iPad Air 2 (9.7 inch). The tablet was a desktop computer monitor by Faytech (10 inches) with touch screen function, which was part of the functional driving simulator located at the Digital Cube Test Center (DCTC) at the TU Berlin. The Functional Driving Simulator of the Digital Cube Test Center (DCTC) of the Institute of Information Technology was used, which was a custom built system situated in a 3×3 m interaction space (a 360° CAVE). Four 3.1 m × 3.1 m screens surrounded the driving simulator. The (passenger) seat of the driving simulator could be moved through a pneumatic hexapod system, which enabled driving simulations with six degrees of freedom, such as tilting the seat to mimic acceleration, deceleration and torsion movements during bends in the simulated route. The hexapod could simulate minimal lateral and longitudinal movements [55]. The tablet was fixed on the driving console of the driving simulator (placed centrally in front of the driving seat, where the steering wheel would be). The resolution of the tablet was of a maximum of 1920 × 1200 pixels. The HMD used was the VR Gear by Oculus and a Samsung Galaxy S7. The headphones were Sennheiser. For the data gathering and processing LimeSurvey (Version 2.06+ Build 160129) and R (version 3.2.2) were used.

On the basis of the pre-study results, two comparable 24 minutes long film sequences (a typical length of a TV episode) from *The Jungle Book* [18] were presented, one sequence on a tablet device with a 2D film format and the other on a HMD device with a 3D film format (i. e. independent variable: *kind of application*; *old* versus *new*).

The constructs described above were operationalized by the following questionnaires (dependent variables). Comfort/discomfort (general passenger experience) of the device was assessed using the translated and adapted version of the *comfort/discomfort scales* based on Zhang et al. [73] (see also Helander & Zhang [27]). The following items of the comfort scale were adapted: *the chair feels soft* became *the device feels good* (*Das Medium fühlt sich gut an.*); *the chair is spacious* was turned into *the device feels comfortable* (*Das Medium sitzt bequem.*); *the chair looks nice* was changed into *the device looks nice* (*Das Medium sieht gut aus.*), and *I like the chair* was altered to *I like the device* (*Ich mag das Medium.*). Three items of the discomfort scale were adapted as follows: *I have sore muscles* became *I have sore eyes* (*Meine Augen tun weh.*), *I have heavy legs* was changed to *I have a heavy head* (*Ich habe einen schweren Kopf.*) and *I feel uneven pressure* was turned into *I feel uneven pressure on my head or on my face* (*Ich fühle einen gleichmäßigen Druck am Kopf oder im Gesicht.*). One item of the comfort scale (*I feel restful*) and two of the discomfort scale (*I feel numb; I feel cramped*) were not used because it was thought that they either were already covered by other items through the translation or just would not apply to the use case of the VR-HMD.

In order to assess one part of UX (*user experience 1*), the *meCUE* questionnaire for user experience [46] was selected. The module III Emotions of Users was used for the users' (positive and negative) emotions about the overall experience (film format and device), and module IV Consequences of Use was chosen to determine if users would use the combination of film format and device again (product loyalty and intention of further use). The whole experience was rated using the module VI but split into three questions inquiring about the overall experience, the film format and the device with one question respectively. In addition to the meCUE questionnaire, UX (*user experience 2*) was also assessed through the questionnaire *AttrakDiff2* [25]. The AttrakDiff2 consists of the three dimensions pragmatic quality, hedonic quality and attractiveness. *Presence* was assessed by the German version of the *iGroup Presence Questionnaire* (*iPQ*; Schubert et al., [59]). For *simulator sickness*, the *Simulator Sickness Questionnaire* (*SSQ*; Kennedy et al. [33]) as well as the *Fast Motion Sickness Scale* (*FMS*; Keshavarz & Hecht [34]) were used to compare sickness levels after each trial to sickness levels prior to the experiment. The SSQ consists of the three dimensions nausea, oculomotor and disorientation. The total score was omitted because of different ways of calculating it and because the scores in the subdimensions were of interest.

Additionally, participants were asked some exploratory questions, which were based on Wienrich et al. [4]: *How much did you like the experience* (on a five-point scale with the anchors *not at all* and *very good*)? Please estimate: *how much time did you just spend in the driving simulator? Would you use the system you just tried on a long distance journey, when given a chance* (on a five-point scale from *no* to *yes*)? *How much money would you be willing to spend on such an application* (in €)?

All questionnaires that did not have a German version (i. e., FMS) were translated or used the translation of Wienrich et al. [4]. In general, higher scores would indicate increased (passenger, user, or entertainment) experience, except in the subscales of negative emotions (meCUE module III), discomfort (comfort/discomfort), and all SSQ and FMS scales.

5.1.3 Procedure

Prior to the experiment, the participants were greeted, and they were asked to read and sign the general information about the experiment, and the form of consent. Next, the pre-experiment questionnaires (SSQ and FMS) were presented on a tablet. After that, the participants sat down in the driving simulator for trial 1 and watched the first film sequence in the condition they were allocated. After that, they answered the questionnaires before moving on to trial 2. In trial 2, they were watching the second film sequence in the driving simulator using the kind of application, which was not used in trial 1. After completing the questionnaires of trial 2, the experiment was over, and the participants left the DCTC. All subjects participated in trial 1 and 2 (within-subject design). Table 4 shows the procedure and the questionnaires used in Experiment 1.

Table 4: Overview of procedure and questionnaires used in Experiment 1.

Experiment	Pre-Trial	Trial 1 (24 min.)	Test 1	Trial 2 (24 min.)	Test 2
1	SSQ FMS	tablet + 2D (old)	Presence (IPQ)	HMD + 3D (old)	Presence (IPQ)
		or	User Experience 1 (meCUE Modules 2-4)	or	User Experience 1 (meCUE Modules 2-4)
		HMD + 3D (new)	User Experience 2 (AttrakDiff2)	tablet + 2D (new)	User Experience 2 (AttrakDiff2)
			Comfort/Discomfort		Comfort/Discomfort
			Exploratory Questions		Exploratory Questions
			Simulator Sickness (SSQ and FMS)		Simulator Sickness (SSQ and FMS)

5.1.4 Data Analysis

In order to prepare the data for the statistical analysis, all questionnaire scores (meCUE, AttrakDiff2, iPQ, Comfort/Discomfort, SSQ, and FMS) were aggregated according to their manuals. Explorative questions were analyzed descriptively. After aggregating the data, difference variables were built. For the SSQ and the FMS values, the values of the pre-experiment values were subtracted from the tablet-condition and HMD-condition values, respectively. Although, the relative differences between the factor levels would remain the same without building pre-post differences, the building difference score ensure that the precondition of participants will not shadow the an overall change through the experimental conditions. After that, the resulting values were subtracted from each other (HMD 3D – tablet 2D). For all other questionnaires, the tablet condition values were deducted from the HMD condition values. Positive values present higher scores in the new kind of application (HMD + 3D) compared to the old kind (tablet + 2D).

Each construct will be analyzed with multivariate methods for normally distributed data leading to five analysis (one for user experience 1; one for user experience 2; one for presence; one for comfort and discomfort; and one for simulator sickness). Hence, the assumptions of the Hotelling's T^2 test were tested. For the multivariate normality, the Shapiro Test for multivariate distributions was used. The results indicate a violation of multivariate normality in all constructs. However, the Hotelling's T^2-tests were used to test the hypotheses, since it displayed some robustness towards violations of multivariate normality [19]. For the assumption of homogeneity of covariances, no test was used, because the balanced design of the experiment with equally sized groups should counter differences in variances [19]. The alpha level was set at 0.05. The significant test results were followed up by t-tests with Bonferroni corrected *p*-values. For the post-hoc t-tests, the effect size *r* will be calculated for each experiment. Cohen [14, 13]; (see also Field et al. [19]) classified effects in small, medium and large: if the effect is $r = .10$, it is considered a small effect, which explains about 1 % of variance, $r = .30$ a medium one, explaining about 9 % of variance and a large one would be $r = .50$, explaining about 25 % of variance [19].

5.2 Results

For the statistical analysis, no participant was excluded. Table 5 shows the descriptive data (means and standard deviations), Table 6 results of the T^2-test and Table 7 displays the results of the post-hoc analyses. Figures 1 and 2 display the results regarding UX and presence.

It was expected for the HMD + 3D combination to receive higher average scores for *user experience 1* (*meCUE*) compared to the tablet + 2D one. However, no significant difference between the conditions was found, leading to the rejection of H1. Nevertheless, the HMD + 3D condition was descriptively rated more positively than the tablet + 2D condition in all dimensions (*positive emotions, negative emotions, product loyalty, intention of further use, general experience, film format and device*).

As expected, the *user experience 2* (*AttrakDiff2*) in the HMD + 3D condition was rated significantly more positively on average than in the tablet + 2D condition. As a result, H2 can be accepted. One-sided post-hoc t-tests (with Bonferroni corrected p-values; $\alpha_{UX2(AttrakDiff2)} = 0.02$) revealed that there was no significant difference between

Table 5: Descriptive data of Experiment 1.

Dependent Variables	Experimental Condition			
	Tablet + 2D		HMD + 3D	
	m	*sd*	*m*	*sd*
UX 1 (meCUE)				
Positive Emotions	4.17	1.06	4.31	1.06
Negative Emotions	3.12	1.03	3.20	1.03
Intention of Use	3.50	1.27	4.12	1.27
Product Loyalty	2.83	1.14	3.58	1.14
General Experience	7.00	2.22	8.05	2.22
Film Format	6.60	1.95	8.00	1.95
Device	7.20	1.62	8.20	1.62
UX 2 (AttrakDiff2)				
Pragmatic Quality	5.23	0.58	4.45	0.58
Hedonic Quality	3.87	0.79	5.25	0.79
Attractiveness	4.66	0.89	5.01	0.89
Presence				
General	2.20	0.93	4.35	0.93
Spatial Presence	2.14	0.57	3.53	0.57
Involvement	2.38	0.57	3.13	0.57
Realism	1.85	0.89	3.20	0.89
Comfort/Discomfort				
Comfort	2.13	1.13	3.06	1.13
Discomfort	5.35	1.42	4.94	1.42
Simulator Sickness				
FMS	1.55	1.09	2.60	2.25
Nausea	79.66	13.64	80.61	11.29
Oculomotor	75.42	14.39	80.73	15.53
Disorientation	116.23	17.25	132.94	26.52

the conditions in the dimensions *pragmatic quality* (where tablet + 2D was rated more positively) and *attractiveness* (where HMD + 3D was rated slightly better), countering the expectations. The ratings in the *hedonic quality* were significantly higher in the HMD + 3D condition and therefore confirming the expectations.

Further in line with the expectations, H3 can be accepted because *presence* received significantly higher average scores in the HMD + 3D condition compared to the Tablet + 2D one. Further one-sided post-hoc t-Tests

Table 6: Main results of Experiment 1.

Dependent Variables	One-sample Hotelling's T² Test				
	df_1	df_2	T^2	F	p
UX 1 (meCUE)	7	13	20.57	2.01	0.13
UX 2 (AttrakDiff2)	3	17	70.05	20.89	<0.01
Presence	4	16	84.71	17.83	<0.01
Comfort/Discomfort	2	18	7.11	3.37	0.06
Simulator Sickness	4	16	8.49	1.79	0.18

Table 7: Post-hoc results of Experiment 1.

Dependent Variables	Post-hoc one-sided t-Tests with Bonferroni correction				
	$\alpha_{corrected}$	df	t	p	r
UX 2 (AttrakDiff2)	0.02				
Pragmatic Quality		19	−4.24	1.00	0.70
Hedonic Quality		19	5.57	<0.01	0.79
Attractiveness		19	1.219	0.36	0.269
Presence	0.01				
General Presence		19	7.35	<0.01	0.86
Spatial Presence		19	7.68	<0.01	0.87
Involvement		19	4.16	<0.01	0.69
Realism		19	4.81	<0.01	0.74

with Bonferroni-corrected p-values ($\alpha_{Presence} = 0.01$) also showed significantly higher ratings in the HMD + 3D condition in all dimensions (*general, spatial presence, involvement, and experienced realism*).

The mean scores of the *Comfort/Discomfort* scales revealed slightly more favorable ratings for the HMD + 3D condition than the tablet + 2D condition, therefore countering the expectations and leading to the rejection of H4.

Also against the expectations, the HMD + 3D condition did not elicit significantly higher *simulator sickness* values compared to the tablet + 2D one. Therefore, H5 cannot be accepted.

5.2.1 Exploratory Results Experiment 1

Participants rated the overall experience on a scale from 1 = *not at all* to 5 = *very much*. Due to technological problems, only half of the participants were able to answer that question for each condition. The *sd*s in both conditions are identical since the within-subjects *sd*s are reported here. The tablet + 2D condition was rated with 4.0 (*sd* = 0.8) and the HMD + 3D condition received an average score 3.2 of (*sd* = 0.6). The time spent in the driving simulator was estimated on average as 25.0 min in the tablet + 2D condition and as 22.6 min (*sd* = 4.8 min) in the HMD + 3D condition. Next, participants were asked if they would use the systems they used in the experiment again on a five-point scale ranging from 1 = *no* to 5 = *yes*. The tablet + 2D was rated with 3.9 on average and the HMD + 3D condition with 3.5 (*sd* = 1.3). On average, participants would spend 65.0 € on the tablet + 2D combination and 79.5 € on the HMD + 3D one (*sd* = 33.7 €).

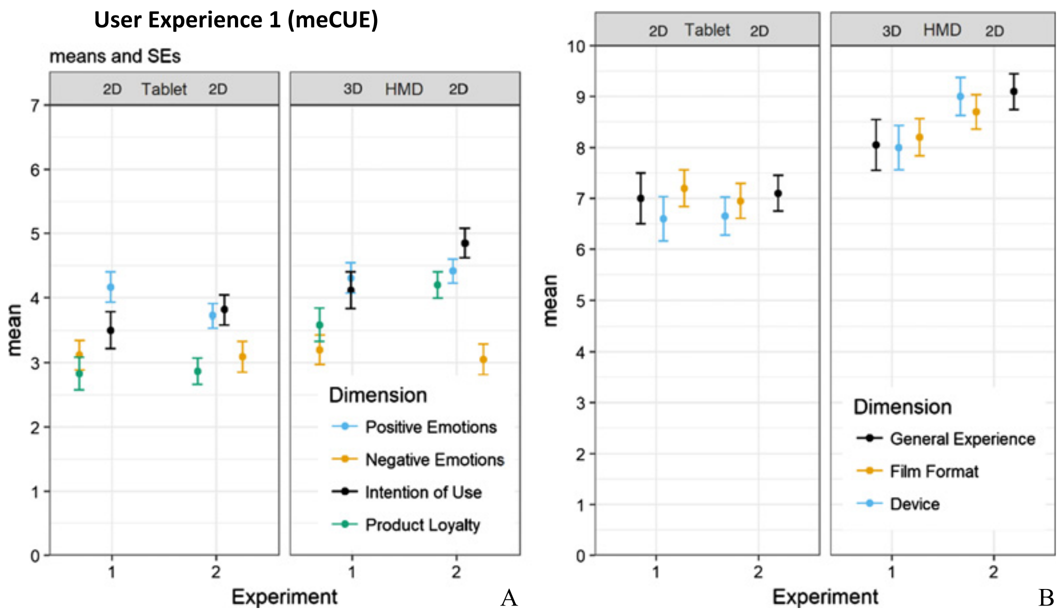

Figure 1: It shows the results of the dependent variables assessed user experience 1 (meCue). On the left side (A) the subdimensions of positive and negative emotions, intension of use, and product loyalty are shown. On the right side (B) the overall estimations are presented. Each figure depicts results in dependence of the experiment (x-axis), device (left panels: tablet, right panels: HMD), and format (within right panels).

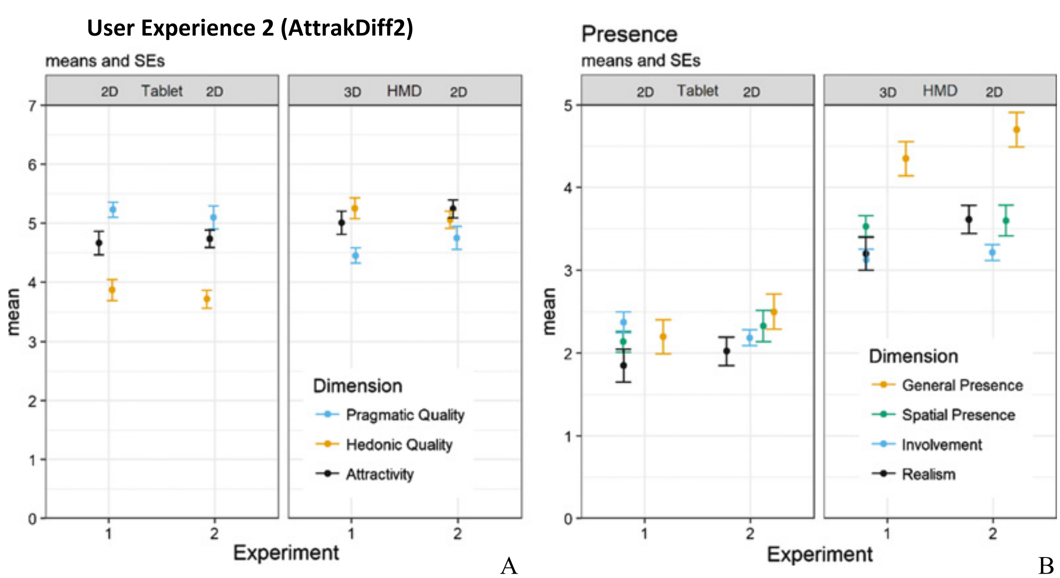

Figure 2: It shows the results of the dependent variables assessed user experience 2 (AttrakDiff2) on the left side (A) and variables assessed presence on the right side (B). Each figure depicts results in dependence of the experiment (x-axis), device (left panels: tablet, right panels: HMD), and format (within right panels).

6 Experiment 2 – Impact of Device

Participants (20 volunteers with normal or corrected to normal vision from the TU Berlin ($n = 10$ female; mean age 26.1 years; $sd = 3.9$ years)) passed through a similar procedure than the participants of Experiment 1 (compare Table 8) with the exception of the independent variables uses in trial 1 and 2. No participants reported any health problems such as epilepsy or migraines. All participants participated in trial 1 and 2 (within-subject design).

Table 8: Overview of procedure and questionnaires used in Experiment 2.

Experiment	Pre-Trial	Trial 1 (24 min.)	Test 1	Trial 2 (24 min.)	Test 2
2		tablet + 2D (tablet)	Presence (IPQ)	HMD + 2D (tablet)	Presence (IPQ)
		or	User Experience 1 (meCUE Modules 2-4)	or	User Experience 1 (meCUE Modules 2-4)
		HMD + 2D (HMD)	User Experience 2 (AttrakDiff2)	tablet + 2D (HMD)	User Experience 2 (AttrakDiff2)
			Comfort/Discomfort		Comfort/Discomfort
			Simulator Sickness (SSQ and FMS)		Exploratory Questions
					Simulator Sickness (SSQ and FMS)

6.1 Data Analyses

Data were analyzed as in Experiment 1. Positive values present here higher scores in the HMD device (HMD + 2D) compared to the tablet device (tablet + 2D).

6.2 Results

For the statistical analysis, no one was excluded. Table 9 shows the descriptive data of the experiment (means and standard deviations). Table 10 shows the results of the T^2-test, and the results of the post-hoc analyses can be found in Table 11. Figures 1 and 2 display the results regarding UX and presence.

In line with the expectations, the HMD + 2D combination received significantly higher average *user experience 1* (*meCUE*) values than the tablet + 2D condition, resulting in the confirmation of H6. A further investigation of the results with one-sided post-hoc t-tests with Bonferroni-corrected p-values ($\alpha_{UX1(meCUE)} = 0.01$) showed that the dimensions *positive emotions*, as well as *negative emotions* in the HMD + 2D condition, were not significantly different to the tablet + 2D condition, therefore countering the expectations. All other dimensions *of user experience 1* (*meCUE*: *intention of use, product loyalty, general experience, film format and device*) received significantly more positive scores in the HMD + 2D condition, confirming the expectations.

Further in line with the expectations regarding the *user experience 2* (*AttrakDiff2*), the 2D film format in the HMD condition was rated significantly more positive on average than the 2D film format in the tablet condition, leading to the confirmation of H7. One-sided post-hoc t-tests with Bonferroni-corrected p-values ($\alpha_{UX2(AttrakDiff2)} = 0.02$) also showed significantly higher average ratings of the HMD + 2D condition in the dimension *hedonic quality*, which supported the expectations. However, contrary to the expectations, the differences between the two conditions in the dimensions *pragmatic quality* (tablet + 2D was rated descriptively higher) and *attractiveness* (HMD + 2D received descriptively higher scores) were not significant.

Table 9: Descriptive Data of Experiment 2.

Dependent Variables	Experimental Condition			
	Tablet + 2D		HMD + 2D	
	m	*sd*	*m*	*sd*
UX 1 (meCUE)				
Positive Emotions	3.73	0.84	4.41	0.84
Negative Emotions	3.09	1.07	3.05	1.07
Intention of Use	3.82	1.03	4.85	1.03
Product Loyalty	2.87	0.92	4.20	0.92
General Experience	7.10	1.57	9.10	1.57
Film Format	6.65	1.67	9.00	1.67
Device	6.95	1.52	8.70	1.52
UX 2 (AttrakDiff2)				
Pragmatic Quality	5.10	0.87	4.75	0.87
Hedonic Quality	3.72	0.65	5.06	0.65
Attractiveness	4.74	0.66	5.24	0.66
Presence				
General	2.50	0.93	4.70	0.93
Spatial Presence	2.33	0.84	3.60	0.84
Involvement	2.19	0.43	3.21	0.43
Realism	2.03	0.76	3.61	0.76
Comfort/Discomfort				
Comfort	2.01	0.76	2.88	0.76
Discomfort	5.14	1.25	5.31	1.25
Simulator Sickness				
FMS	1.20	1.06	1.55	1.26
Nausea	77.27	9.55	79.18	12.19
Oculomotor	76.18	10.00	86.41	11.25
Disorientation	113.45	13.18	128.06	15.37

Table 10: Main results of Experiment 2.

Dependent Variables	One-sample Hotelling's T² Test				
	df_1	df_2	T^2	F	p
UX 1 (meCUE)	7	13	114.19	11.16	<0.01
UX 2 (AttrakDiff2)	3	17	47.26	14.10	<0.01
Presence	4	16	87.13	18.34	<0.01
Comfort/Discomfort	2	18	18.20	8.62	<0.01
Simulator Sickness	4	16	19.47	4.10	0.02

Table 11: Post-hoc results of Experiment 2.

Dependent Variables	Post-hoc one-sided t-Tests with Bonferroni correction				
	$\alpha_{corrected}$	df	t	p	r
UX 1 (meCUE)	0.01				
Positive Emotions		19	2.61	0.06	0.51
Negative Emotions		19	−0.12	1.00	0.03
Intention of Use		19	3.18	0.01	0.59
Product loyalty		19	4.56	<0.01	0.72
General Experience		19	4.02	<0.01	0.68
Film Format		19	3.64	0.01	0.64
Device		19	4.44	<0.01	0.71
UX 2 (AttrakDiff2)	0.02				
Pragmatic Quality		19	−1.27	0.66	0.28
Hedonic Quality		19	6.52	<0.01	0.83
Attractiveness		19	2.42	0.08	0.49
Presence	0.01				
General Presence		19	7.44	<0.01	0.86
Spatial Presence		19	4.76	<0.01	0.74
Involvement		19	7.49	<0.01	0.86
Realism		19	6.57	<0.01	0.83
Comfort/ Discomfort	0.03				
Comfort		19	3.61	1.00	0.64
Discomfort		19	0.45	1.00	0.10
Simulator Sickness	0.01				
Nausea		19	0.61	1.00	0.14
Oculomotor		19	3.70	<0.01	0.65
Disorientation		19	3.12	0.01	0.58
FMS		19	1.10	0.57	0.24

As expected, *presence* received significantly higher average ratings in the HMD + 2D condition, thereby confirming H8. Additional one-sided post-hoc t-tests with Bonferroni-corrected p-values ($\alpha_{presence} = 0.01$) also revealed significantly higher average scores in the HMD + 2D condition compared to the tablet + 2D one in all dimensions of *presence* (*general, spatial presence, involvement, and experienced realism*).

Countering the expectations, the HMD + 2D condition received significantly higher *Comfort*/*Discomfort* ratings than the tablet + 2D condition. Therefore, H9 has to be rejected. Further investigation of the results with one-sided post-hoc t-tests with Bonferroni-corrected p-values ($\alpha_{Comfort\text{-}Discomfort} = 0.03$) showed no significant difference in both dimensions (*comfort* and *discomfort*). Nevertheless, the HMD + 2D condition was rated higher in the *comfort* dimension, whereas the tablet + 2D condition received smaller *discomfort* scores.

As expected in H10, *simulator sickness* scores were significantly higher in the HMD + 2D condition compared to the tablet + 2D one, confirming H10. The results of the one-sided post-hoc t-tests with Bonferroni-corrected ($\alpha_{Simulator\ Sickness} = 0.01$) p-values are in line with the expectations (HMD + 2D receives higher averages) in the dimensions *disorientation* and *oculomotor*. There was no significant difference in the scores of the dimensions *nausea* nor those of the *FMS* in the HMD + 2D condition compared to the tablet + 2D one, although the HMD + 2D consistently had higher values.

6.2.1 Exploratory Results Experiment 2

Participants were asked how much they liked the overall experience on a five-point scale ranging from 1 = *not at all* to 5 = *very much*. On average, the tablet + 2D condition was rated with 3.6 and the HMD + 2D system with 4.2 (*sd* = 0.9). When estimating the time spent in the driving simulator, participants thought that the tablet + 2D condition lasted on average 25.5 min and the HMD + 2D one 25.0 min (*sd* = 5.8 min). Participants were also asked if they would use the entertainment systems of the experiment again if given a chance to, on a five-point scale ranging from 1 = *no* to 5 = *yes*. The tablet + 2D condition was rated with 4.4, and the HMD + 2D condition received 4.0 on average (*sd* = 0.8), which points to a high intention of using both systems again in a long-distance traveling context. On average, participants would be willing to pay 26.2 € for the tablet + 2D entertainment system and 36.5 € for the HMD + 2D one (*sd* = 23.3 €).

6.3 Discussion of Experiment 2

All positive-connoted hypotheses were confirmed. The HMD device led to higher feelings of UX (especially intention of use and hedonic quality) and presence. As in Experiment 1, comfort scores were descriptively better for the HMD device whereas for discomfort there was hardly any difference found between the HMD device and the tablet for discomfort. Even though two SSQ scales scored worse in the HMD condition, the nausea-related scale and the FMS were not affected by the device. Again, participants descriptively showed the intention to spend more money on the HMD than the tablet. Overall, the HMD device seems to be safe concerning the health of users. In addition to Experiment 1, an increment value was revealed by the new HMD device in comparison to a more conventional device regarding the experience. Together with the results of Experiment 1, the assumption arises that the HMD device and not the 3D format makes the difference in the experience. This assumption was tested in the following additional analysis.

7 Results of Between-Comparison of Experiment 1 and Experiment 2—the Impact of Format

The results of Experiment 1 and 2 indicated that the device leads to a greater extent to a different experience during the simulated autonomous journey than the presented format. In Experiment 1, the combination of a HMD device and a 3D film format was presented. In Experiment 2, the combination of a HMD device and a 2D film format was presented. That offered the possibility of a between-subject comparison in order to investigate the impact of format independently on the device. Furthermore, the comparison between the same tablet device + 2D film format condition enabled controlling effects of the experiment (e. g., more enthusiasm sample in one of the studies) and check for the impact of the device again.

The results of both experiments were tested with T^2-tests for each construct. Only the HMD conditions (HMD + 3D and HMD + 2D) were considered in order to determine if the film format or the device itself is the reason for the evaluation pattern. Results are shown in Figures 1 and 2. The results of the T^2-tests indicate that there is no significant difference between the HMD + 3D and the HMD + 2D conditions. The results can be found in Table 12.

However, additionally calculated MANOVAS over the two experiments and all conditions (not reported here), revealed no main effect for experiment suggesting that the two samples of Experiment 1 and 2 are comparable. The MANOVAS also revealed a significant main effect for device (tablet versus. HMD) for all constructs (UX overall impression, UX film format, presence, comfort/discomfort, simulator sickness). These results corroborate the assumption that the device and not the film format made the essential

Table 12: Main results of between Comparison of the HMD conditions of Experiment 1 and Experiment 2.

Dependent Variables	Two sample Hotelling's T^2-Test			
	df_1	df_2	T^2	p
UX 1 (meCUE)	7	32	10.29	0.31
UX 2 (AttrakDiff2)	3	36	3.27	0.39
Presence	4	35	1.96	0.77
Comfort/Discomfort	2	37	0.55	0.77
Simulator Sickness	4	35	2.97	0.61

difference in the experience. In line with the results of Experiment 2, the format did not show any additional impact on the investigated experience. It also did not cause more concerns regarding simulator sickness or discomfort.

8 General Discussion

An analysis of Deutsche Bank claimed an estimated turnover of up to seven billion Euro for the German virtual reality market by 2020 [7]. In this vastly growing sector, companies developing HMD content primarily for entertainment are emerging rapidly [12]. With regard to the quick change of our mobility (e. g., advancing automation), the entertainment of the driver is becoming an essential aspect of this market. The interaction with devices, and the content of different media will play a major role when drivers evaluate their experience during an autonomous ride. Hence, constructs from different fields (e. g., passenger experiences, human-computer-interaction, or media psychology) might contribute to a holistic framework of this new driver experience.

In the present studies, entertainment packages of the future (2D and 3D on a VR-HMD) were compared to experiences of a conventional and already established form of entertainment (2D on a tablet) in a long distance travel context. As travel context, an autonomous driving scenario was mimicked by the use of a functional driving simulator. A few studies already investigated the impact of VR entertainment in transport systems, but those only showed very short VR sequences and therefore missed the intended context of use (long distance travel) (e. g., Hock et al. [28]; Lewis [40]; McGill et al. [45]; Soyka et al. [64]; Wienrich et al. [4]). So far, neither the beneficial nor the detrimental impact on the experience of passengers was addressed in previous research. In the present studies, the exposure to the content was increased to a more realistic one, the length of a standard TV episode (e. g., sitcoms). Furthermore, the exposure material was selected based on the opinions of potential users consulted in a pre-study. In addition, a broader assessment framework of the driver experience (including constructs from different fields of research) was considered. In Experiment 1, the impact of the conventional entertainment device (tablet) and format (2D film) on passenger, user and entertainment experience was compared to a new entertainment device (HMD) and format (3D film). In order to investigate the impact of the device independently of the format, the content format was held constant (2D film) between the device-conditions (tablet versus HMD) in Experiment 2. An additional analysis allowed examining the additional impact of the 3D film format compared to the 2D film format when participants watched the film on the HMD device. The scientific evaluation of the experiences included more general concepts of passenger experience like comfort and discomfort, aspects of user experiences from the field of human-computer-interaction, and also more specific aspects of the VR entertaining system like presence and simulator sickness.

Overall, the data revealed a positive result pattern regarding the immersive media application promising new possibilities of entertaining, while concerns mainly with regard to the health of users could not be confirmed by the present research.

8.1 General Passenger Experience

Surprisingly, discomfort was not affected differently by the experimental conditions. Discomfort aiming at symptoms like pressure points or eye strain. This was not expected, because the HMD is heavy (weighing 312 g), and since it has direct skin contact with the head and face, it creates design-based pressure points, especially on the nose bridge. Additionally, the display resolution of the main display of 2560 × 1440 (Quad HD) [57] is not very high once it is split into two screens, which can lead to eye strain [29]. Similar symptoms were also assessed by the oculomotor related subscale of the SSQ. Regarding that measurement, the symptoms were more pronounced in the HMD condition, but only in Experiment 2 (2D format). Lewis [40] showed that consuming relaxing VR content distracted from physical discomfort. The 3D format might be more exciting and thus distracted to a greater extend from some sources of discomfort in the HMD conditions. However, the comparison between the 2D and 3D format did not reveal any differences that support this assumption.

Even more surprisingly was that participants reported more comfort in the HMD conditions. Many researchers emphasized that comfort can be more than the absence of discomfort – it is instead a multi-dimensional feeling of being relaxed and well, which can be improved through appealing aesthetic design. Hence, they underlined the psychological aspect of comfort (e. g., Richards et al. [54]). The exciting new VR-HMD applications probably meet this aspect better than the tablet applications. In line with the results regarding presence (discussion below), the 3D film format did not have a further positive impact. In other words, the HMD itself might facilitate the psychological feeling of comfort. Another reason could be a low feeling of comfort regarding the tablet application, which is discussed in greater detail in the next section (user experience). Independently of the tablet, VR HMD application appeared as a comfortable new form of entertainment application. In addition, the device (HMD) is the significant factor and not the format (3D). However, the slight negative symptoms observed in the present study might become more pronounced with longer exposure times. Thus, a certain amount of physiological discomfort generated by the HMD might not be ruled out. Another component of comfort was not evaluated in the present study but should be considered in the future. Social aspects (e. g., Ahmadpour et al., [1]; Kolcaba [37]) concerning privacy, social interactions, or social norms are important topics with regard to the social acceptance of new applications in (public) transport systems. In summary, it is clear that the constructs of comfort and discomfort will change in the context of autonomous driving. They might focus more on the interaction between the driver and technical systems and media. Comfort and discomfort measures usually used to assess passenger experiences and that has been assessed in similar studies has been used in the present study. Anyways, the used term "Medium" in the German translation might be less clear than we would have use the term "Gerät" (device), because medium might be the HDM or the film. On the other side, if we used the term device, participation might be unsure if they should evaluate the driving simulator or the HDM. Further, the content of items ("comfortable") allows more associations to medium as "device" than as "film". For future studies, different measures assessing comfort/discomfort should be assessed (e. g., the scale from Knight and Baber [36] assessing comfort of the wearable computers).

8.2 User Experience

The results regarding the user experience measurements gave a positive impression of the VR-HMD applications. In both experiments, the hedonic quality received higher scores in the HMD condition. In Experiment 2 (2D format), the dimension attractiveness was also increased in the HMD condition, suggesting that participants enjoyed watching the film on a VR-HMD more than on a tablet. The dimension intention of use confirmed the assumption that this new mobile entertaining format might be an attractive offer for future passenger entertainment. At this stage, it remains to be seen if the evaluations will be equally positive when the innovative effect of VR fades. The present results showed that users were still not familiar with the handling of those mobile VR applications. The pragmatic quality was evaluated poorer for the VR-HMD applications compared to the tablet systems (in Experiment 1 significantly). We observed similar results in another study, which investigated the usability of 3D user interfaces in comparison to 2D user interfaces in a VR environment. The participants found the 3D interaction more attractive but needed more time to successfully control it [3].

The tablet was fixed on the driving console of the driving simulator (placed centrally in front of the driving seat, where the steering wheel would be), which was ergonomically speaking not the optimal place, since the angle of the display could not be manipulated (unlike in planes). Additionally, the distance of the tablet to the passenger was determined by the distance of the seat to the driving console, meaning that the optimal distance to the tablet could not always be adjusted for. Another issue was the resolution of the tablet of a maximum of 1920 × 1200 pixels (the smart phone's resolution was 2560×1440 pixel, but split into two screens), which was not very high, and might have affected the experience of users who in turn might have given lower UX ratings.

Thus, the usability aspect (pragmatic quality by Hassenzahl et al. [25] or instrumental quality by Thüring & Mahlke [66]) should be improved for future applications, both old and new.

Positive and negative emotions were not affected differently by the conditions. The affective aspects are connected with the entertaining aspect of the presented applications. Traditional process theories of entertaining media reception (e. g., the affect disposition theory by Zillmann [74] or the simulation theory by Oatley [48]) demonstrate the importance of the user's affect. Even though the VR-HMD applications did not lead to more positive feelings, the affective ratings were consistently favorable across both experiments. Assuming that the feeling of being well entertained is highly correlated with positive emotional ratings, we can conclude that the new applications entertain participants (e. g., Wirth & Schramm [71]; Zillmann & Vorderer [75]). However, especially emotional aspects in the understanding of media reception should get more attention in future studies. In the present study, affective aspects seemed more related to the usability of the device that was particularly apparent in the open comment section at the end of each experiment. There, the participants mentioned roughly twice as many negative feelings than positive ones towards the HMD, whereas the tablet was hardly mentioned. However, the negative comments were mostly about the lack of usability of the HMD itself and some technological aspects (e. g. pressure points due to the weight or eyestrain because of the resolution). At the same time, some excitement about the device was mentioned, which was dampened a bit because of those problems. Some participants expressed the willingness to use HMDs in the future once the technical issues have been adequately addressed. Especially well reviewed was the consequence of use (e. g. intention of use) regarding the VR-HMD application. In addition, the motivations, wishes, and intentions of future potential users were addressed in a pre-study. Thus, the present research gave some scientific evidence that new mobile applications carry a high potential for entertaining passengers in public transport systems and autonomously driving vehicles. For the future, it would be interesting to take into account different user groups and to observe how wishes will change with the level of experience and the travel context.

8.3 VR Entertainment Experience

Wienrich et al. [4] already reported high values of presence caused by a mobile VR application in a real car setting. In addition to these results, the present experiments revealed that the VR-HMD applications led to higher feelings of presence (in all subscales) than the conventional tablet based systems. Hence, the present results were in line with previous findings demonstrating that the degree of immersion (i. e. features of the system) have an impact on the feeling of presence (e. g. Dörner et al., [15]) as well as with research regarding the impact of different displays on presence (e. g. Baños et al., [5]; Fonseca & Kraus [20]). In addition, the impact of the HMD device on presence was independently of the film format (2D or 3D). In other words, the stereoscopic format did not lead to participants allocating more attention to the film. In this aspect, the present results corroborated the part of research, which did not find an additional increase of presence caused by the stereoscopic viewing condition (e. g., Baños et al., [6]). However, other researchers found higher feelings of presence for 3D compared to 2D formats (e. g. Baños et al., [5]; Fonseca & Kraus [20]). When participants of both experiments were asked how much time they spent in the simulator, the estimated times were quite similar in the 2D format conditions (tablet: 25.5 minutes and HMD: 25.0 minutes). However, participants felt that less time had passed when the format was 3D (HMD: 22.6 minutes). These findings suggest a higher psychological involvement in stereoscopic viewing conditions.

A highly immersive application and a strong feeling of presence are desirable for entertainment. However, an intense absorption might entail the risk of a reduced situation awareness (e. g., Kass, Cole, Stanny [32]; Ma & Kaber [43]; Young, Salmon, & Cornelissen [72]). Situation awareness involves being aware of what is happening in the environment. Endsley [17] suggested that situational awareness, "provides the primary basis for subsequent decision making and performance in the operation of complex, dynamic systems" (p. 65). In line with this definition, many studies concerned with understanding of the environment critical to decision-makers in complex, and dynamic areas like the driving context (e. g., Endsley [16]; Kass et al. [32]). Even in autonomous driving situations, drivers have to be aware of the environment (e. g., Walch, Mühl, Kraus, Stoll, Baumann, Weber, [70]). Also in other traveling contexts (e. g. train), people should know what is happening around them (e. g. being aware of the nearest exit). In the open comment section at the end of each experiment, the participants mentioned the HMDs more frequently than they commented on the tablet. They also mentioned that they were more immersed and forgot about their real environment more frequently in the HMDs conditions in general (four comments in total) and especially in the HMD + 3D condition (three out of the four comments). Thus, future studies should consider the trade-off between the feeling of presence and the need of being informed about the environment.

In summary, in the context of traveling, passengers are exposed to attentional distraction, and current display technologies (e. g., tablets) do not allow for privacy because other passengers can look at nearby displays. The present study showed that VR-HMD entertainment applications also offer a higher degree of immersion (e. g., enclosed display) in this specific context and thus reveal a high potential to decrease attentional distraction and increase privacy. However, there also might be a trade-off with regard to reduced situational awareness.

Furthermore, the VR applications did not induce higher values of nausea (SSQ and FMS) in comparison to the tablet applications. These results seemed somewhat surprising, but other studies investigating VR applications during driving report similar results (Hock et al. [28]; Lewis [40]; McGill et al. [45]; Soyka et al. [64]; Wienrich et al., [4]). Even though higher values of simulator sickness were reported previously, a dramatic amount of nausea was not found.

Besides nausea, the SSQ also contains subscales related to disorientation and oculomotor and those two consequently used as indicators for simulator sickness, too. Both were negatively affected by the VR-HMD application (only significant in Experiment 2 – 2D format). In particular oculomotor related symptoms might be more important for comfort and discomfort, which has already been discussed above. However, several reasons might be responsible for the small overall values of simulator sickness, such as viewing perspective, experience with or enthusiasm for the VR devices. In the present studies, participants watched a film from a third person perspective and were not involved as an actor in the VR scene. In such passive viewing conditions the sensory conflict is not as severe as in VR scenes were participants take the first person perspective [41]. Second, some participants also had experience with video games and VR. It is known that inexperienced users are more likely to get sick (e. g. Bles & Wertheim [10]). Furthermore, a sample with considerably high interest in technology was investigated. Users who are more enthusiastic about technology are probably more involved and therefore show a higher tolerance to simulator sickness. Hence, less experienced and less enthusiastic future users might be more vulnerable to simulator sickness in this context. Another important aspect is the exposure time. Even though the VR exposure time was the longest presented in a driving context so far, it was still too short for an entertaining program during a real long distance journey. In order to mimic an autonomous driving context, the car simulator drove very smoothly. However, visually induced simulator sickness symptoms could get worse over a longer exposure time or in a moving context [9]. Hence, it remains unclear if those VR applications are safe for an extended use case or in a transport system with more intense and more irregular movements.

9 Future Studies

Several open questions were mentioned above.

1. Which fields of research might contribute to the evaluation of the experience concerning new entertaining applications (e. g. VR) and new concepts of mobility (e. g. autonomous driving)?
   Similar to Wienrich et al. [4], the present studies used measures from the field of passenger comfort, human-computer-interaction, media psychology, and VR experience. Some conventional overlaps were presented, but also some gaps mentioned.

2. How much motion is possible without any compensating method in order to offer a safe VR-HMD application?
   Using immersive media in autonomous driving cars, three levels of motion impact on the user: the motion of the car, the motion of the screen content as well as the motion of the user itself. Different sensorial conflicts, especially between the motion of the car and the motion of the media content might occur. Intelligent compensation methods are necessary to ensure a safe and healthy ride (compare [2]).
3. How can we balance the trade-off between being fully present and being situationally aware?
   In an ongoing project, the authors investigate the impact of different virtual and augmented reality applications on the trade-off between the entertainment goal of being fully present and the need of passengers, especially of drivers, to be situationally aware. Different travel use cases are considered.
4. How is the social acceptance of VR-HMD applications in an autonomous driving context and public transport systems?
   In an ongoing project, the authors investigate the impact of social norms and reaction on the acceptance of different VR and AR application in an autonomous driving context and public transport systems.
5. To what extent are the present results generalizable to inexperienced and technology-averse future users?
6. What constructs and modifications are needed to evaluate other use cases, such as gaming or working contexts? Do the needs and wishes of users change with the context, or are the other important aspects, which were not considered here?
   Starting with the use case already investigated in this study, a diverse film selection across different genres would render this use case more realistic. In addition, the presentation time should be further increased in future studies.

10 Conclusion

Lewis [40] demonstrated that showing VR content decreases passenger discomfort on a simulated flight. Focusing more on positive aspects of passenger and entertainment experience, Wienrich et al. [4] showed that (dynamic) VR content could be presented on mobile VR HMDs without movement compensations during a car journey with smooth movements. The studies presented here extended the existing research by showing that more prolonged exposure to content on VR-HMDs is safe to use in a simulated long-distance journey. New mobile entertaining applications can influence passenger, user and entertainment experience positively, especially regarding presence and joy of use. Participants also expressed the intention to use the VR system in the future, and a willingness to hire it when given a chance. In order to enforce a change of understanding of the driver's experiences in the autonomous driving context, an evaluation framework was chosen from different research fields (passenger research, human-computer-interaction, and media psychology). Overlaps and gaps were discussed intensively.

References

[1] Ahmadpour, N., Lindgaard, G., Robert, J.-M., & Pownall, B. (2014). The thematic structure of passenger comfort experience and its relationship to the context features in the aircraft cabin. *Ergonomics*, *57*(6), 801–815.

[2] Wienrich, C., Weidner, C., Schatto, C., Obremski, D., & Israel, H.J. (2018). A virtual nose as a rest-frame - the impact on simulator sickness and game experience. In IEEE (Ed.), Proceedings of the 10th IEEE International Conference on Virtual Worlds for Serious Applications (VS-Games). IEEE.

[3] Wienrich, C., Noller, F., & Thüring, M. (2017). Design Principles for VR Interaction Models: An empirical Pilot Study. In R. Dörner, R. Kruse, B. Mohler, and R. Weller (Hrsg.). *Virtuelle und erweiterte Realitäten. 14*. Workshop der GI-Fachgruppe VR/AR (pp. 162–171).

[4] Wienrich, C., Zachoszcz, M., Schlippe, M. v., & Packhäuser, R. (2017). Pilotstudie: Einsatz von mobilen VR-Anwendungen in gleichmäßig und ruhig bewegten Transportsystemen. In M. Burghardt, R. Wimmer, C. Wolff, & C. Womser-Hacker, (Hrsg.), *Mensch und Computer 2017 - Workshopband*. Regensburg: Gesellschaft für Informatik e.V.

[5] Baños, R., Botella, C., Alcañiz, M., Liaño, V., Guerrero, B., & Rey, B. (2005). Immersion and Emotion: Their Impact on the Sense of Presence. *Cyberpsychology & Behavior: The Impact of the Internet, Multimedia and Virtual Reality on Behavior and Society*, *7*, 734–741. https://doi.org/10.1089/cpb.2004.7.734.

[6] Baños, R. M., Botella, C., Rubió, I., Quero, S., García-Palacios, A., & Alcañiz, M. (2008). Presence and emotions in virtual environments: The influence of stereoscopy. *CyberPsychology & Behavior*, *11*(1), 1–8.

[7] Bastian, M. (2015). *Deutsche Bank: Virtual Reality bis 2020 ein Milliardenmarkt*. Retrieved from https://vrodo.de/deutsche-bank-virtual-reality-bis-2020-ein-milliardenmarkt/.

[8] Bitkom: Bitkom Research. (2015). *Welche Arten von Games spielen Sie?* Retrieved from https://de.statista.com/statistik/daten/studie/315938/umfrage/umfrage-zu-den-bevorzugten-gaming-genres-in-deutschland/.

[9] Bles, W., Bos, J. E., de Graaf, B., Groen, E., & Wertheim, A. H. (1998). Motion sickness: only one provocative conflict? *Brain Research Bulletin*, *47*(5), 481–487.

[10] Bles, W., & Wertheim, A. H. (2001). Appropriate use of virtual environments to minimise motion sickness.

[11] British Standards Institution. (2010). BS EN ISO 9241-210:2010: Ergonomics of human-system interaction. Human-centred design for interactive systems.
[12] CeBIT. (2017). *Immer mehr Entwickler drängen auf den VR-Markt*. Retrieved from http://www.cebit.de/de/news/artikel/immer-mehr-entwickler-draengen-auf-den-vr-markt-48585.xhtml.
[13] Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155.
[14] Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hoboken: Taylor and Francis. Retrieved from http://gbv.eblib.com/patron/FullRecord.aspx?p=1192162.
[15] Dörner, R., Broll, W., Grimm, P., & Jung, B. (2013). *Virtual und Augmented Reality*. Springer Verlag: Heidelberg.
[16] Endsley, M. R. (2016). *Designing for Situation Awareness: An Approach to User-Centered Design*, Second edition. CRC Press.
[17] Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, *37*(1), 32–64.
[18] Favreau, J. (2016). *The Jungle Book: The Jungle Book*. (Disney, Ed.).
[19] Field, A., Miles, J., & Field, Z. (2013). *Discovering statistics using R (Reprint)*. Los Angeles, Calif.: Sage.
[20] Fonseca, D., & Kraus, M. (2016). A Comparison of Head-mounted and Hand-held Displays for 360° Videos with Focus on Attitude and Behavior Change. In *Proceedings of the 20th International Academic Mindtrek Conference* (pp. 287–296). New York, NY, USA: ACM. https://doi.org/10.1145/2994310.2994334.
[21] Freeman, J., Avons, S. E., Davidoff, J., & Pearson, D. E. (1997). Effects of stereo and motion manipulations on measured presence in stereoscopic displays. *Perception*, *26*(1_suppl), 144.
[22] Gesellschaft für Konsumforschung. (2016). *Genres nach unterschiedlichen Formaten: Der Home Video Markt 2015*. Retrieved from http://www.bvv-medien.org/fileadmin/user_upload/businessreports/JWB2015.pdf.
[23] Grünweg, T. (2017). *Audi Aicon und Renault Symbioz: Aus Freude am Rumlümmeln*. Retrieved January 30th 2019 from https://www.spiegel.de/auto/aktuell/audi-aicon-und-renault-symbioz-aus-freude-am-rumluemmeln-a-1167503.html.
[24] Hassenzahl, M. (2007). The hedonic/pragmatic model of user experience. In E. Law, A. Vermeeren, M. Hassenzahl, & M. Blythe (Eds.), *Towards a UX Manifesto - Proceedings of a cost294-affiliated workshop on HCI 2008* (pp. 10–14).
[25] Hassenzahl, M., Burmester, M., & Koller, F. (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In G. Szwillus & J. Ziegler (Eds.), *Mensch & Computer 2003* (Vol. 57, pp. 187–196). Wiesbaden: Vieweg+Teubner Verlag.
[26] Hassenzahl, M., & Tractinsky, N. (2006). User experience - a research agenda. *Behaviour & Information Technology*, *25*(2), 91–97. https://doi.org/10.1080/01449290500330331.
[27] Helander, M. G., & Zhang, L. (1997). Field studies of comfort and discomfort in sitting. *Ergonomics*, *40*(9), 895–915.
[28] Hock, P., Benedikter, S., Gugenheimer, J., & Rukzio, E. (2017, May). CarVR: Enabling In-Car Virtual Reality Entertainment. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 4034–4044). ACM.
[29] Hwang, A. D., & Peli, E. (2014). Instability of the perceived world while watching 3D stereoscopic imagery: A likely source of motion sickness symptoms. *I-Perception*, *5*(6), 515–535. https://doi.org/10.1068/i0647.
[30] HTC VIVE (2016). Abgerufen a, 23. März, 2017, unter https://www.vive.com/us/summit/.
[31] Jabalpurwala, N. (2011). *Passenger Experience for Airlines: Evaluating experience drivers for Airline Passengers*. Retrieved 5th May, 2014, from http://www.slideshare.net/najmuddin24/passenger-experience-for-airlines.
[32] Kass, S. J., Cole, K. S., & Stanny, C. J. (2007). Effects of distraction and experience on situation awareness and simulated driving. Transportation Research Part F: *Traffic Psychology and Behaviour*, *10*(4), 321–329.
[33] Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, *3*(3), 203–220. https://doi.org/10.1207/s15327108ijap0303_3.
[34] Keshavarz, B., & Hecht, H. (2011). Validating an efficient method to quantify motion sickness. *Human Factors*, *53*(4), 415–426. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/0018720811403736.
[35] Klimmt, C., & Vorderer, P. (2006). Media psychology "is not yet there": Introducing theories on media entertainment to the presence debate. *Media Psychology*, *12*(4).
[36] Knight, J. F., & Baber, C. (2005). A Tool to Assess the Comfort of Wearable Computers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *47*(1), 77–91. https://doi.org/10.1518/0018720053653875.
[37] Kolcaba, K. (1992). Holistic comfort: Operationalizing the construct as a nursesensitive outcome. *Advances in Nursing Science*, *15*(1), 1–10.
[38] Kuze, J., & Ukai, K. (2008). Subjective evaluation of visual fatigue caused by motion images. *Displays*, *29*(2), 159–166. https://doi.org/10.1016/j.displa.2007.09.007.
[39] Law, E. L.-C., Roto, V., Hassenzahl, M., Vermeeren, A. P. O. S., & Kort, J. (2009). Understanding, scoping and defining user experience. In D. R. Olsen, R. B. Arthur, K. Hinckley, M. R. Morris, S. Hudson, & S. Greenberg (Eds.), *the SIGCHI Conference*. https://doi.org/10.1145/1518701.1518813.
[40] Lewis, L. (2015, July 16). Investigating the ways in which virtual environments could influence aircraft passengers' comfort and experiences. (doctoral dissertation, University of Nottingham). Retrieved September 20, 2017, from http://eprints.nottingham.ac.uk/31358/.
[41] Lewis-Evans, B. (2015). Designing to minimize simulator sickness in VR. *Game Developer Conference Europe*. Cologne (August, 2015). http://www.gdcvault.com/play/1022772/Designing-to-Minimize-Simulation-Sickness.
[42] Lin, J. J., Abi-Rached, H., & Lahav, M. (2004). Virtual guiding avatar: An effective procedure to reduce simulator sickness in virtual environments (pp. 719–726). ACM.
[43] Ma, R., & Kaber, D. B. (2005). Situation awareness and workload in driving while using adaptive cruise control and a cell phone. *International Journal of Industrial Ergonomics*, *35*(10), 939–953.
[44] McCarthy, J. C., & Wright, P. C. (2004). *Technology as experience*. Cambridge, Mass: MIT Press.

[45] McGill, M., Ng, A., & Brewster, S. (2017). I Am The Passenger. In G. Mark, S. Fussell, C. Lampe, M. Schraefel, J. P. Hourcade, C. Appert, & D. Wigdor (Eds.), *The 2017 CHI Conference* (pp. 5655–5668). https://doi.org/10.1145/3025453.3026046.

[46] Minge, M., Riedel, L., & Thüring, M. (2013). Und ob du wirklich richtig stehst . . . Zur diskriminativen Validität des User Experience Fragebogens "meCUE". In S. Boll-Westermann, S. Maaß, & R. Malaka (Eds.), *Mensch & Computer 2013 – Workshopband* (Vol. 2013, pp. 137–144). München: Oldenbourg.

[47] Myant, P., Abraham, R., & House, A. C. (2009). Research on the air-passenger experience at Heathrow, Gatwick, Stansted and Manchester airports. *O. International* (Ed.), pp. 1–53.

[48] Oatley, K. (1995). A taxonomy of the emotions of literary response and a theory of identification in fictional narrative. *Poetics*, *23*(1-2), 53–74.

[49] Oculus VR (2015). Oculus Runtime for Windows. Abgerufen am 03. November, 2016, unter https://developer3.oculus.com/downloads/pc/0.8.0.0-beta/Oculus_Runtime_for_Windows/.

[50] Patel, H., Lewis, L., Cobb, S., D'Cruz, M., Tedone,D., & Hakulinen, J. (2012). *VRHYPERSPACE deliverable D1.1 Report of current scenarios& case definition*. http://www.vr-hyperspace.eu/about-vrhyperspace/publicdocuments/deliverables/84-d1-1.

[51] Quantas Airways. (2015). Visit Hamilton Island in 360° Virtual Reality with Qantas. Retrieved from http://www.youtube.com/watch?v=lJype_TafRk.

[52] Rasheed, Z., & Shah, M. (2002). Movie genre classification by exploiting audio-visual features of previews (Vol. 2, pp. 1086–1089). IEEE. Retrieved from http://ieeexplore.ieee.org/abstract/document/1048494/.

[53] Reason, J. T., & Brand, J. J. (1975). Motion sickness. London: Acad. Press.

[54] Richards, L. G., Jacobson, I. D., & Kuhlthau, A. R. (1978). What the passenger contributes to passenger comfort. *Applied Ergonomics*, *9*(3), 137–142. doi: 10.1016/0003-6870(78)90003-0.

[55] Richter, J. (2014). *Motion Cueing Algorithmen für die Absicherung von Fahrerassistenzsystemen* (nicht veröffentlichte Bachelorarbeit). TU Berlin, Berlin.

[56] Salas, E., and Dietz, A.S. (2011). *Situational Awareness*. Burlington, VT: Ashgate.

[57] Samsung. (2017). *Galaxy S7*. Retrieved from http://www.samsung.com/us/explore/galaxy-s7/.

[58] Sapino, R., & Hoenisch, M. (2011). *What is a Documentary Film: Discussion of the Genre* (Seminarbericht). Freie Universität Berlin, Berlin.

[59] Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The Experience of Presence: Factor Analytic Insights. *Presence: Teleoperators and Virtual Environments*, *10*(3), 266–281.

[60] Slater, K. (1985). *Human comfort*. Springfield, Ill., U.S.A.: C.C. Thomas.

[61] Slater, M. (1999). Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, *8*(5), 560–565.

[62] Slater, M., & Wilbur, S. (1997). A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments. *Presence: Teleoperators and Virtual Environments*, *6*(6), 603–616. https://doi.org/10.1162/pres.1997.6.6.603, http://www.spiegel.de/auto/aktuell/audi-aicon-und-renault-symbioz-aus-freude-am-rumluemmeln-a-1167503.html retrieved at September 20, 2017.

[63] Solimini, A. G. (2013). Are there side effects to watching 3D movies? A prospective crossover observational study on visually induced motion sickness. *PloS One*, *8*(2), e56160. https://doi.org/10.1371/journal.pone.0056160.

[64] Soyka, F., Kokkinara, E., Leyrer, M., Buelthoff, H., Slater, M., & Mohler, B. (2015). Turbulent motions cannot shake VR. In *2015 IEEE Virtual Reality (VR)* (pp. 33–40). https://doi.org/10.1109/VR.2015.7223321.

[65] Stanney, K. M., Mollaghasemi, M., Reeves, L., Breaux, R., & Graeber, D. A. (2003). Usability engineering of virtual environments (VEs): identifying multiple criteria that drive effective VE system design. *International Journal of Human-Computer Studies*, *58*(4), 447–481.

[66] Thüring, M., & Mahlke, S. (2007). Usability, aesthetics and emotions in human–technology interaction. *International Journal of Psychology*, *42*(4), 253–264.

[67] Ujike, H., & Watanabe, H. (2011). Effects of stereoscopic presentation on visually induced motion sickness. In A. J. Woods, N. S. Holliman, & N. A. Dodgson (Eds.), *IS&T/SPIE Electronic Imaging* (p. 786314). SPIE. https://doi.org.

[68] Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using Presence Questionnaires in Reality. *Presence: Teleoperators and Virtual Environments*, *9*(5), 497–503.

[69] VR-Hyperspace. (2011). Retrieved from http://www.vr-hyperspace.eu/.

[70] Walch, M., Mühl, K., Kraus, J., Stoll, T., Baumann, M., & Weber, M. (2017). From Car-Driver-Handovers to Cooperative Interfaces: Visions for Driver–Vehicle Interaction in Automated Driving. In *Automotive User Interfaces* (pp. 273–294). Springer, Cham.

[71] Wirth, W., & Schramm, H. (2005). Media and emotions. *Communication Research Trends*, *24*(3).

[72] Young, K. L., Salmon, P. M., & Cornelissen, M. (2013). Missing links? The effects of distraction on driver situation awareness. *Safety Science*, *56*, 36–43.

[73] Zhang, L., Helander, M. G., & Drury, C. G. (1996). Identifying factors of comfort and discomfort in sitting. *Human Factors*, *38*(3), 377–389.

[74] Zillmann, D. (1995). Mechanisms of emotional involvement with drama. *Poetics*, *23*(1-2), 33–51.

[75] Zillmann, D., & Vorderer, P. (Eds.). (2000). Media entertainment: *The psychology of its appeal*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bionotes

Carolin Wienrich
Julius-Maximilians-Universität Würzburg,
Human Technique Systems,
Oswald-Külpe-Weg 82, 97274 Würzburg,
Germany
carolin.wienrich@uni-wuerzburg.de

Carolin Wienrich is Juniorprofessor for Human-Technique-Systems at the University of Wurzburg. She graduated in psychology at the University of Halle/Wittenberg. In 2015, she finished her PHD at the TU-Berlin. Her research interests focus on human-computer-interaction. Particularly, she is interested in the impact of technology on users' perceptions, reactions, and social interactions. Furthermore, she also asks for the human impact on technology and how the cognitive, emotional, and social human nature influences technology development. Currently, she is fascinated by immersive technologies like virtual and augmented reality as well as devices like speech assistance systems which could be regarded as embodied artificial intelligence.

Kristina Schindler
Berlin, Germany
kristinafschindler@gmail.com

Kristina studied Psychology and Human Factors at the Technische Universitat in Berlin, Germany. During her studies, she worked on diverse research projects (e.g. medical, immersive VR and social psychology). In 2018 she moved her focus to IT and currently works in the finance sector. She also takes part in machine learning projects in the fields of finance and autonomous driving.