Investigation of Implicit Interactions for Entertainment Features in Autonomous Vehicles

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The trend towards connectivity and digitalization has strongly influenced the automotive industry in recent years. At the same time, the degree of automation of vehicles is constantly being improved. For many companies, the question arises of how the newly gained time in autonomous vehicles could be used. Some companies, startups and universities are researching and planning on new extended reality (XR) concepts that will be integrated into vehicles. In this paper, we propose a new interaction concept for an immersive entertainment feature which could be part of an autonomous vehicle in the future. For this purpose, we developed an implicit interaction design that follows the attention of the passenger and suggests suitable interactions based on contextual information. For comparison, we created an explicit interaction design. In a qualitative study with N = 7 subjects, we evaluated the designs to identify strengths and weaknesses of both interaction types. The findings show that both the sense of control and the sense of presence influence the user experience (UX). Nevertheless, explicit interactions, that led to a stronger sense of control, are preferred over implicit interactions, that are perceived as more immersive. In terms of pragmatic UX, it was shown that implicit interactions were perceived as more inventive and more leading edge. This raises the question of whether users will demand novel forms of interaction in the future.

CCS Concepts: • **Human-centered computing → User studies**.

Additional Key Words and Phrases: implicit interactions, car entertainment features, autonomous driving, user experience, feeling of control, feeling of presence

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1 INTRODUCTION

In the context of autonomous driving, companies are introducing new concepts with visions about what cars could look like in the future. Some of them consider that entertainment experiences will be an important aspect of future mobility [2]. However, the concepts also bring new requirements. For example, the *VISION AVTR* by *Mercedes-Benz* focuses on intuitive controls and a completely new idea of how passengers interact and communicate with cars [16]. Furthermore, the vehicle should become an immersive experience space.

The purpose of this work is to develop such a novel and intuitive form of interaction to control an immersive XR experience. We investigate what the limitations of this form of interaction are and which influences on the UX, the sense of control and the sense of presence occur.

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2 RELATED WORK

2.1 User Experience

UX is the holistic experience with a product [9]. Not only interactions are taken into account, but also subjective impressions that arise before, during and after use [5]. Consequently, UX also includes expectations for a product and reflections after using it. The focus is not on the individual product but also on everything related to it. Experiences are perceived differently. Using the example of an immersive entertainment feature in an autonomous car, a positive experience could be created for passengers who want to be diverted from traffic. Conversely, for passengers who want to observe the traffic, it potentially creates a negative experience. It becomes clear that the UX depends on the subjectively perceived quality, which determines whether a product will be used in the future or not [9].

2.1.1 The Model of Pragmatic and Hedonic Qualities. Usability is the part of UX that focuses on interacting with a product. It describes the effective and efficient achievement of quantified objectives [3]. For good usability, interactions should be practical, predictable and clear [9]. The ability of a product to achieve quantified goals intuitively is referred as pragmatic quality.

UX is about creating short-term positive experiences, pursuing long-term meaningful objectives and developing capabilities [4]. Positive experiences are driven by positive emotions and occur when psychological needs are fulfilled. Psychological needs are present in varying intensities in every person, regardless of culture. They express requirements and desires [7]. When needs are fulfilled by a product, the potential to create positive experiences arises [8]. This ability of a product is referred as hedonic quality.

2.1.2 Sense of Control. The sense of control defines the subjective awareness of self-determination over an event [14]. This can be the control over an interaction. In this context, perceived control plays an important role in emotional reactions [14]. As already mentioned, positive emotions arise from the fulfillment of psychological needs, which cause a positive UX [7]. The relationship between control and UX could be confirmed by Schneider et al. through a positive correlation between the variables [21]. According to this, negative emotions caused by indistinct or frustrating interactions should be avoided and positive emotions should be reinforced [14].

Apple anchors the principle of user control in their *Human Developer Guidelines*. These suggest that users can be empowered with a sense of control through interactive elements, predictable actions, and cancellation of undesired actions [1]. A product should balance user empowerment and automatic avoidance of undesirable consequences. However, decision making should be done by the user.

2.2 Extendend Reality

XR is an umbrella term used for many types of real and virtual environments (VE) generated by immersive technologies. It includes all representation forms of the virtuality-continuum such as virtual reality (VR), augmented reality (AR) or mixed reality (MR) [17].

2.2.1 Sense of Presence. While immersion is a variable of technology and can be described objectively, the feeling of presence is a variable of UX [23]. Presence is a subjective feeling of the individual user to be in a VE [25]. The independent subscales *Spacial Presence*, *Involvement* and *Experienced Realism* are used in the standardized igroup presence questionnaire (IPQ) to measure the sense of presence experienced in a VE [13]. *Spacial Presence* describes the sense of being physically present in a virtual environment. It is supported by immersive displays so that the environment surrounds the user, even when while moving or rotating [6]. *Involvement* measures the attention that is devoted to

Fig. 1. Metaphorical visualization of a passenger with a VR headset, immersed in a *holoride* gaming experience [12].

Fig. 2. The interior of *Intels* concept car equipped with a large display, projectors and further components in order to create an immersive car entertainment experience [19].

a VE. Thereby the level of interest in the virtuality and the awareness of reality is evaluated [13]. The last subscale *Experienced Realism* is about the presented realism in a VE compared with real environments.

2.2.2 *In-Car XR Experiences.*

Autonomous vehicles could have the potential to create novel experiences and innovative forms of interactions [16]. Experts predict that automation portends a change in how people use their time [19]. One advantage, for example, is that the driver himself becomes a passenger and could engage in non-driving-related activities [18]. Some companies [19], startups [12] and universities [11] are researching and developing on new XR concepts that will be integrated into vehicles. The CEO of the *holoride* company sees entertainment experiences as an important aspect in future mobility [2].

The tech startup *holoride* develops a new kind of XR experience by combining navigational car data and virtual content [12]. Passengers on the back seat can use a VR headset to enter an immersive world of gaming, entertainment or information (see figure 1). Physical feedback, like accelerations and steering, as well as as travel route and time will be considered in the experience. For this, *holoride* introduces the term *elastic content*, where virtual content is created and adapted flexibly to match conditions from reality. Autonomous driving means for *holoride* that the driver will also be able to enjoy an immersive in-car entertainment [12].

Another concept was unveiled from *Intel* in collaboration with *Warner Bros. Entertainment* at the Consumer Electric Show (CES) 2019 [19]. A *BMW X5* was equipped with a large display, projectors, mobile devices, sensory, haptic feedback and immersive audio and lights (see figure 2). Passengers were immersed in a virtual 270-degree experience to *Gotham City*, home of the popular superhero *Batman*. *Batman's* trusted butler *Alfred Pennyworth* guided them through comic and movie sequences and provided instructions and important traffic alerts. By transforming the cabin into an immersive entertainment platform, *Intel* and *Warner Bros* want to show the possibilities that will come with the future [19]. Through the visions presented, it is assumed that:

H1: Immersive and multisensory XR experiences distract autonomous passenger from road traffic, make time pass more quickly, and are used with pleasure.

2.3 Interactions

A main objective in Human Computer Interaction (HCI) is improving the interface between users and computers [26]. Especially for the design of futuristic features, interactions should be facilitated to improve the intuitiveness of new technological developments. For this purpose, we distinguish two types of interaction.

2.3.1 Explicit Interaction. Reactive interactions that are initiated and driven by the user are referred as explicit interactions [15]. Currently, most interactions with computers are done in this way. Users tell the computer what they expect the computer to do. Therefore various input methods can be used such as direct manipulation of a GUI, gestures, or speech [20]. Due to the widespread use of explicit interactions and the resulting familiarity with them, it is assumed that:

H2: Explicit designs are more clear and understandable in usage.

2.3.2 Implicit Interaction. The term implicit interaction is used for interactions that differ from traditional communication concepts [24]. It describes an action performed by the user that is not primarily aimed to interact with a system but which such a system understands as input [20]. In other words, this type of interaction is based on assumptions that a computer does for the user in a certain situation.

Schmidt shows parallels to the human communication where a lot information is exchanged implicitly. Communication is based on assumptions and contextual information such as gestures, body language, and voice [20] that are import for the correct interpretation of information. Using the example of an entertainment feature in an autonomous vehicle, the car as a system could initiates an interaction based on the passengers' attention and contextual information. But the passenger does not perform any interaction actively. As computers become more capable of sensing their environment and recognizing contexts, the potential for implicit interactions arises [24].

While it is an objective to design implicit interactions intuitive and freeing up users' cognitive resources [24], they are also susceptible to difficulties with hidden modes, unexpected action, and misunderstood intent [15]. From these issues it can be deduced that more than intuition is required to design effective, implicit interactions and make things subtle or invisible. Furthermore, it is assumed that implicit interactions will be used additionally to explicit interaction for the most applications [20] and not as an independent type of interaction. However, difficulties in designing implicit interactions exists, but due to the system initiated interactions and the recognition of contextual information, it is hypothesized, that:

H3: Implicit designs are more intuitive in use.

3 CONCEPT DEVELOPMENT

Besides the question how an immersive feature could look like in the future, the research focuses on designing an implicit interaction concept. The central question is whether we can change the way we use interfaces and make interactions more intuitive. In this context, limitations of implicit interactions will be identified and influences on the UX investigated.

3.1 Extended Reality Concept

The *Augmented Fusion* experience is developed in a student project and serves as the basis for the interaction concept. In the experience, the passenger is immersed in a VE to escape the monotonous traffic. A visual transition from real world to the VE is shown on window shield displays that surrounds the passenger. Ambient lighting and sound support the visual impressions for a multisensory experience. The virtuality is depending on the context of the user. For example, in the scenario of the user study, the passenger goes to a nightclub with a friend to celebrate a successful week at work. He also plans to go on vacation by the sea soon. To match this, a virtual nightclub and beach experience is suggested by the entertainment feature (see figure 3).

Fig. 3. Subject experiences the *Augmented Fusion* where the switch to virtual environments is provided through augmented icons.

3.2 Interaction Concept

The interaction concept includes the passenger and the autonomous vehicle as communication partners. For the implicit interaction, contextual information about the passenger is processed by the vehicle. Based on the points of interest to the passenger, corresponding virtual worlds are proposed. It should be mentioned that the contextual information in the user study was given in a scenario, such as the information about the nightclub and the beach. During the ride, the system checks where the passenger's attention is. In the user study, this was realized using eye tracking. If the passenger shows interest in an icon by looking at it, the appropriate interaction was executed with a *Wizard-of-Oz* control. However, subjects were not told that eye-tracking was used in order to test how the participants intuitively interact with the feature. All steps of the interaction concept including the realization in the user study are shown in Table 1.

To compare the implicit interaction concept, an app prototype was also developed to provide an explicit concept as a baseline. With the app, passengers have an overview about all virtual environments with options to start or exit the experience at any time.

4 USER STUDY

A qualitative user study was conducted to investigate the effects of the implicit interaction concept on the UX and the feeling of control. Furthermore, we collected insights about the sense of presence and the acceptance of the developed product.

4.1 Method

The participants were recruited on basis of the target group defined in the research project. Five subjects are working or pursuing a PhD in the field of computer science, while two subjects are in the last semesters of a computer science degree. A total of N = 7 subjects participated in the user study, of which five were male and two were female. The mean age was 26.57 (SD = 3.85) years, with an age range of 21 to 31 years. All subjects drive a car several times a week, whereas three of them use it every day. The own technological affinity was rated as *high* by 6 subjects and as *rather high* by another subject.

Step	Role	Action	Realization in the Study
1	Passenger	Provides contextual information	Subject chats with a friend about going to a nightclub tonight.
2	Vehicle	Data processing and personalization	Not necessary. Contextual information are already defined in the scenario.
3	Passenger	Observes the environment through vehicle windows.	Video with traffic is shown on the screens. Study managers observers the gaze path of the subject with eye tracking.
4	Vehicle	Augmented Icons are displayed as overlay when passenger is bored.	Study managers add augmentations with a video software.
5	Passenger	Shows attention to augmentation or not.	Study managers observers the attention of the subject with eye tracking.
6	Vehicle	Extension of augmentation and transition to virtuality	When the subject fixes an icon, an animation is started. If it continues looking at the icon, the environment is changed in the video.
7	Passenger	Immersion and re-transition	The subject is provided with an icon to go back to reality. The interaction into reality works according to the same procedure.

Table 1. Steps of the interaction concept *Augmented Fusion*.

Before the subjects tested the experience and interaction concept, they were introduced to a scenario with contextual information. In addition, it was mentioned that the vehicle in the scenario is already able to drive autonomously and reliably and that they no longer need to pay attention to traffic. Subjects tested both designs, in a counterbalanced order. After each design, the standardized User Experience Questionnaire (UEQ-S) [22] was completed to measure the UX. The feeling of presence was queried with the two items *Spacial Presence* and *Involvement* from the IPQ [13]. One additional item regarding perceived sense of control consisted of the two likert-scales: (*During the experience I had the feeling to stay in control*) and (*During the simulation I had the feeling to control the experience*). Further, the item included when and why the feeling of control was felt stronger or lower. After subjects tested both designs, a semi-structured interview was conducted asking comparative questions about the designs and gaining insights about the product acceptability. The questions about acceptance were based on the items *Effort Expectancy* , *Social Influence* and *Behavioral Intention* of the Autonomous Vehicle Acceptance Model (AVAM) [10] and were transferred to the entertainment feature in our concept.

4.2 Results

4.2.1 Preferred Design. The app prototype was favored by five of seven subjects, due to a stronger feeling of control, practical controls, and a familiar way of navigating. Further, the subjects noted that they did not understand the interaction in the implicit design. The other two subjects preferred the implicit design because of the feeling of being more immersed in the experience and less distracted from the smartphone.

4.2.2 Presence and Control. The feeling of presence was rated on the IPQ scale from 0 (weak feeling) to 6 (strong feeling) with a mean of 3.57 (SD = 1.47) in the implicit design. The baseline was given a mean score of 3.44 (SD = 1.43). Thereby, the item *Spatial Presence* is rated lower in both designs [Implicit (M = 3.26; SD = 1.37); Baseline (M = 2.97; SD = 1.76)] than the item *Involvement* [Implicit (M = 3.96; SD = 1.87); Baseline (M = 4.04; SD = 1.70)]. No significant differences were found between designs for the sense of presence.

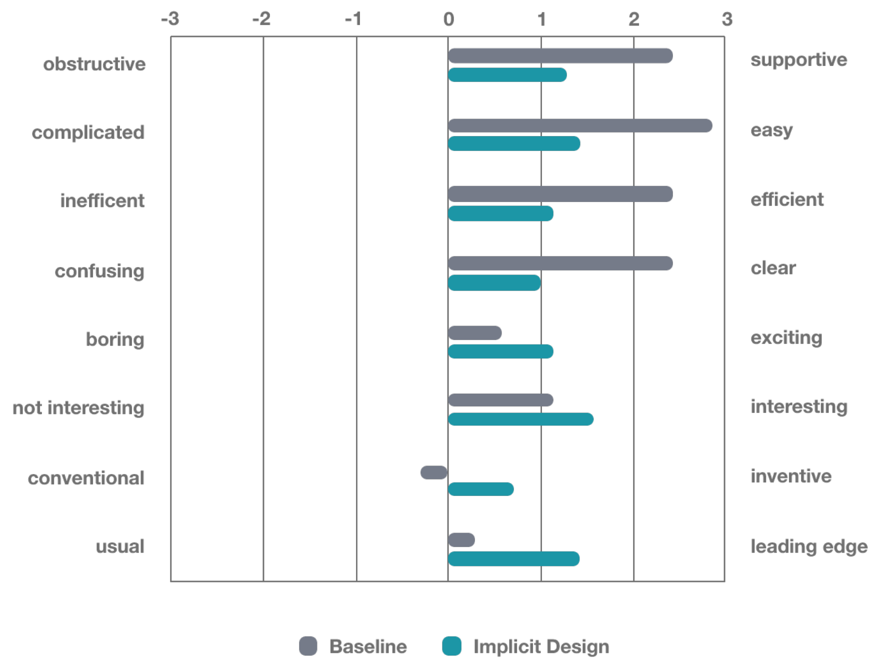

Fig. 4. Mean values of the UEQ-S questionnaire [22] results. Each item is given a score between -3 and 3, corresponding to the negatively and positively worded properties respectively.

Sense of control was rated significantly ($p \leq 0.05$) higher on a scale of -3 (low level of control) to 3 (high level of control) in the baseline (M = 2.21; SD = 1.47) than in the implicit design (M = -0.71; SD = 1.91).

4.2.3 User Experience. The UX was rated on the UEQ-S scale on a scale from -3 (negative) to 3 (positive). The first four items covering pragmatic quality were rated significantly lower ($p \leq 0.01$) in the implicit design (M = 1.21; SD = 0.67) compared to the baseline (M = 2.54; SD = 0.34). The hedonic quality items are rated higher in the implicit design (M = 1.21; SD = 1.20) than in the baseline (M = 0.43; SD = 1.35), but no significant difference was found. On figure 4 the biggest difference can be seen in the item *conventional* - *inventive*, where the baseline mean score was in the negative range (M = -0.29; SD = 1.98), while that of the implicit design was in the positive range (M = 0.71; SD = 1.70). The deviation between the means for the item *usual* - *leading edge* is also wider than for the rest of the hedonic quality items [Implicit (M = 1.43; SD = 2.07); Baseline (M = 0.29; SD = 2.36)].

As shown in figure 5, in comparison with other products which were also evaluated using the UEQ-S questionnaire, the pragmatic quality for the implicit design can be categorized as *average*, while that one for the baseline is *excellent*. The other way around, the hedonic quality for the implicit design is ranked higher as *good* than the explicit baseline that is *below-average*. This results in a *good* overall UX for the baseline and *above-average* one for the implicit design.

4.2.4 Relations Between Variables. A significant correlation was found between the pragmatic quality of the UX and the feeling of control (r = 0.69; $p \leq 0.01$). This means that with increasing control, the pragmatic part of the UX also increases. The feeling of presence also has a significant influence on the overall UX (r = 0.65; $p \leq 0.05$).

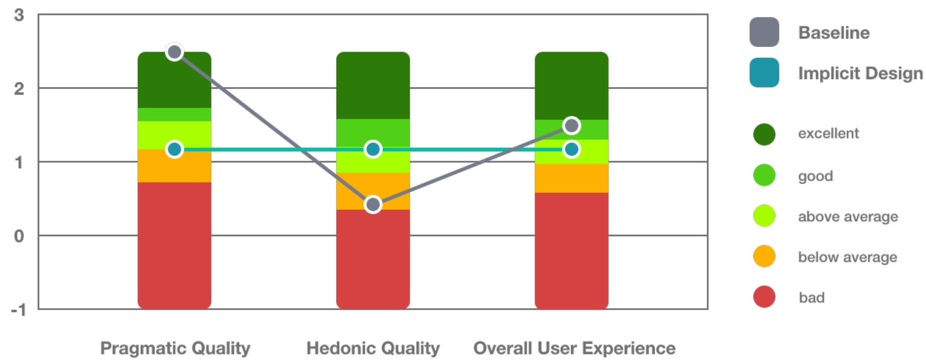

Fig. 5. The result of the UEQ-S questionnarie [22] in relation to benchmark values.

4.2.5 Qualitative Feedback on the Designs. The findings of the qualitative feedback revealed that all subjects were confused about the interaction in the implicit design with eye tracking. However, three of seven subjects used the correct control but experienced an uncertain feeling until the end of the user study. Two further subjects assumed gesture control to be the correct interaction. The remaining two subjects did not understand how to interact with the system. Six of seven subjects lacked a sense of control during interaction. Participants reported that they felt thrown into the experience and were controlled by the experiences rather than controlled it themselves. In addition, it was noted that the augmented icons were taken as a demand for interaction. In contrast, five participants reported a greater sense of presence, as they were not distracted by the smartphone and more able to immerse themselves in the experience.

The interaction in the baseline is perceived as easy by all subjects. Reasons for this are the feeling of control during the interaction, an easier switch to virtuality and back, and more freedom in deciding when to interact with the system.

4.2.6 Acceptance. Regardless of the interaction, all subjects agree that the feature would make time pass more quickly. If the feature would be available in their own vehicle, the subjects like to use it. It is noted that it can also be enjoyed together with friends and family during a trip. They liked the idea of an immersive and multisensory experience that could be expanded for watching movies and series or listen to podcasts.

4.2.7 Hypotheses. Hypothesis 1 (*Immersive and multisensory XR experiences distract autonomous passenger from road traffic, make time pass more quickly, and are used with pleasure*) is accepted. From the identified acceptance for the developed experience, it can be concluded that all participants would like to use the feature in an autonomous vehicle. Furthermore, a positive correlation between presence and UX was found.

Based on the pragmatic quality of the explicit baseline, which is categorized as *excellent* and the correlating significantly stronger sense of control, hypothesis 2 (*Explicit designs are more clear and understandable in usage.*) can be confirmed as well in the context of our concept and sample. From the findings of the qualitative feedback, it can be seen that the explicit interactions were familiar and simple.

Hypothesis 3 (*Implicit designs are more intuitive in use.*) is rejected because the strictly implicit control was problematic and not understood by all subjects. In addition, the design has a significantly lower pragmatic quality and a lower sense of control than the baseline.

5 DISCUSSION

5.1 Presence vs. Control

According to the feedback of the subjects, it becomes clear that the feeling of control and presence has influenced the UX. The subjects valued the simple and clear navigation in the explicit design, which leads to a stronger sense of control that positively influences the pragmatic quality. Conversely, in the implicit design, many users had the feeling of being thrown into the experience, resulting in a low sense of control. As already stated in the research definition, decision making should be done by the user [1]. Although the majority of subjects prefer control over presence, there are also subjects who value immersion more highly in the experience. The opinion of these subjects is supported by the significant correlation between presence and UX. The statement of Schubert et al. that the feeling of presence is a variable of UX [23] can be also confirmed for the context of entertainment features in autonomous vehicles.

5.2 User Experience

When comparing the overall UX between the designs, no noticeable difference becomes apparent. In terms of individual qualities, there is a strong conflict between an *excellent* pragmatic and a *below-average* hedonic quality for the explicit baseline. The familiar interaction using an app was perceived by the subjects as efficient and effective, according to Burmester et al. description of the pragmatic quality [3]. However, the results indicate that the subjective expectation of an entertainment feature of the future was not met by the baseline. This leads to the question of whether novel forms of interaction will be demanded by the user in the future. Even if the pragmatic quality is significantly lower in the implicit design, the interaction is still perceived as more innovative. Serim et al. draw attention to the fact that implicit interactions differ from traditional interactions [24]. Especially the last two items of hedonic quality show the highest difference between the designs. Subjects tend to rate the implicit interaction as more inventive and more leading edge.

5.3 Problems with the Implicit Interaction

The implicit control was not clear for all subjects. One reason for this could be that users are not familiar with these type of interaction. Without a matching mental model of how the system works, the subjects have major problems using the system. Also Ju et al. recognize problems with implicit interactions, such as hidden modes, unexpected action and misunderstood intent [15]. It should be considered that the study tested an extreme form of implicit design without explicit cues, although the subjects were interacting with the feature for the first time.

5.4 Potential for Implicit Interaction

The findings, however, do not indicate that implicit interactions cannot be intuitive. They rather emphasize the statement that the design of effective implicit interactions needs more than intuition to make things subtle or invisible [15]. Therefore, the existing interaction design should be adapted and improved in the next iteration. Furthermore, Schmidt's statement that for most applications, implicit interaction will be used in addition to explicit interaction [20] should also be taken into account. That implies that a extreme form, as used in the study design to identify weaknesses of implicity, is rather unsuitable for a final product design. Advantages of the explicit design, such as a better control and comprehensibility could be combined with implicit elements. This could create the potential to provide passengers an immersive experience with novel control that still has an appropriate pragmatic quality.

5.5 Design Recommendations

For the implicit design, a more transparent interaction should be designed. We recommend adding a tutorial or explicit hints at least for the first use. *Intels* show car demonstrates with *Batman's* butler, how the passenger can be guided through the experience, provided with explanations and sensitized with alerts in a playful way [19]. Additionally, it should be ensured that the user can select, control, and also cancel all functions at any time. It is an objective to empower the user with more control and improving the pragmatic UX. As Jokinen mentions about the feeling of control, negative emotions caused by indistinct or frustrating interactions should be avoided and positive emotions should be reinforced [14].

5.6 Limitations

The study has several limitations that must be considered when interpreting the results. Firstly, the developed prototype only simulates the interior of an autonomous vehicle without any movement. Further, the feature was controlled by *Wizard-of-Oz*, making interactions less responsive. It is also important that all users tested the design for the first time. If the implicit design was tested multiple times, habituation effects could occur that might affect the results.

As mentioned earlier, a qualitative user study was conducted. Consequently, only limited numerical statements can be made that refer to the sample in the study. In order to be able to reference the results to an entire user group and to determine more significant results, quantitative tests with a higher number of subjects have to be conducted.

6 CONCLUSION AND FUTURE WORK

In this paper, implicit interactions were conduced for an immersive entertainment feature which could be part of an autonomous vehicle in the future. For this, an experience was created and prototyped that allows passengers to immerse themselves in virtual worlds using immersive displays, ambient lighting and sound. An implicit interaction concept was provided for communication with the feature, using eye tracking to track subjects' attention. However, subjects did not know that eye tracking was involved. For comparison, explicit control was implemented using an app as baseline to identify weaknesses and strengths of both designs.

The findings show that both the sense of control and the sense of presence influence the UX. Nevertheless, explicit interactions, that led to a stronger sense of control, are preferred over implicit interactions, that are perceived as more immersive. In terms of pragmatic UX, it was shown that implicit interactions were evaluated as more inventive and more leading edge. This raises the question of whether users will demand novel forms of interaction in the future.

In future research, it should be examined wheather the hedonic UX of implicit interactions is rated significantly better than conventional interactions in the context of entertainment experiences for autonomous vehicles. In addition, it would be interesting to see, if using implicit interactions multiple times has an impact on the pragmatic UX.

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