An AR-Enabled Interactive Car Door to Extend In-Car Infotainment Systems for Rear Seat Passengers

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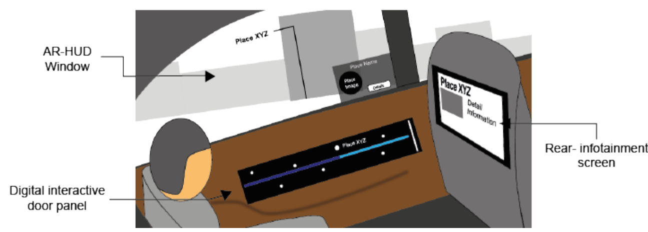

Figure 1: We introduce the concept of an AR-enabled interactive car window and door panel which allow rear seat passengers to engage with the surroundings.

ABSTRACT

Modern cars create a high-tech interactive space by providing entertainment and information functionalities to the driver and partly to the passengers. By introducing rear-seat infotainment systems especially in luxury cars, manufacturers started to also focus on the passenger's experience. However, such systems offer mainly standard entertainment and internet-based services. To enhance the user experience of rear seat passengers, we present the concept of an interactive car door that enables passengers to engage with and explore their surroundings. Our system consists of an interactive door panel that shows points of interest along the progressing route, more detailed information is shown on the AR-enabled side window in addition to the rear seat display. Results from a pilot study ($n = 11$) show that our concept leads towards a positive user experience. The qualitative feedback reveals that such an interactive car door helps to make riding as a passenger more attractive and pleasant.

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CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**.

KEYWORDS

In-car interaction, augmented reality, contextual in-car interface, passenger experience, rear seat passenger, infotainment system

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1 INTRODUCTION

The car has become indispensable in our lives as it enables individual mobility to visit places and it allows us to easily carry goods [17]. When we take a closer look at current in-car technologies, we see a trend towards improving especially the driver's experience by introducing driver-based systems and user interfaces (e.g., driving assistant functions, infotainment systems) [17, 18]. These functions increasingly change the car's role since innovations are no longer about addressing issues of mobility only. Due to these technical innovations, a modern, assisting car provides a place for a multitude of non-driving-related activities [15] communication, information access, and digital media consumption [10]. This enables new possibilities to design in-car interaction concepts for an advanced user experience (UX).

Looking at current research, products, and concepts, we see that the driver is still the most essential person for current in-car user interface concepts, as driving safety is crucial [18]. Yet, 56% of all car rides (in the United States) happen with at least one additional passenger[1]. This shows that (rear seat) passengers are often neglected in the invention of in-car technologies, which limits their riding experience.

Nowadays, only luxury cars offer basic entertainment and online services through an integrated rear seat infotainment system [4]. However, the provided functions are often not tailored to the driving context of the car or to the act of riding itself as these system mostly replicate what an off-the-shelf tablet can offer. Looking at prior research we see a focus mainly on avoiding driver distraction by e.g., entertaining passengers – especially kids in the back [8, 10, 13]. Concerning in-car user interfaces, Inbar & Tractinsky [7] report a positive impact that contextual interfaces have on the passenger experience. Matsumura and Kirk [10] suggest to combine context-based and trip-related data to sharpen the riding experience. With this regard in combination with passenger's needs to observe the landscape [16] and to look up trip-related information [7], we see the need to design for a higher level of UX for rear seat passengers by introducing a contextual user interface. Despite the advent of autonomous driving, we believe that fully automated driving will only be introduced gradually with an expected start around 2030 (Europe). Thus, we still see the importance of designing a passenger-based automotive user interface for the near future of manual driven cars.

Therefore, we present in this work our design concept of a contextual, interactive car door, that fosters rear seat passenger's UX. The guiding research questions was: How does the introduction of an interactive car door affect the user experience of rear seat passengers? Our contribution lies in a novel idea of engaging with the surrounding points-of-interests (POIs) that provide rear seat passengers with additional information. We implemented a first digital prototype of this concept and report on the results of our pilot user study (n=11) and show our implications for future improvements.

2 RELATED-WORK

Already a decade ago, research and industry recognized the rear seat of a car as an interesting space for interactive systems [9] that helps to create a unique riding experience [2]. While industry neglected passengers in earlier years with regard to in-vehicle systems [7, 17], they currently try to improve the passenger's experiences by introducing rear seat infotainment systems [4] that offer access to the Internet and video/audio-based services [13].

Research in the meantime focused on designing for a high level of in-car UX with a focus on entertaining people–especially kids in the back to reduce driver distraction. The project *Backseat Playground* developed by Broy et al. [5] allows a collaborative game setting through several, different mini-games while riding. This aims to enhance the riding experience for both, the kids at the back and the front-seat passenger. An additional, game-based approach has been investigated by Meschtscherjakov et al. [12] who designed a multi-player card game. This digital game helps to foster collaboration between all occupants and makes riding more pleasant [12].

Despite the gamified approaches, research also looked into the integration of the outside environment through the development of different contextual in-car interfaces. Berger et al. [3] tested a passenger-targeted infotainment system that provides access to a movie library and recommends attractions, hotels, or restaurants. Displayed on an integrated screen, the recommended point-of-interests are within a specific radius of the current car's GPS position [3]. The *Periscope* from Loehman et al. [8] is a system that allows kids at the back to observe specific attractions near the road by looking through it. This hand-held device focuses on one attraction at a time that has been chosen by the user. Overall, it improves passenger's UX and enables also a shared experience through handing over the device [8].

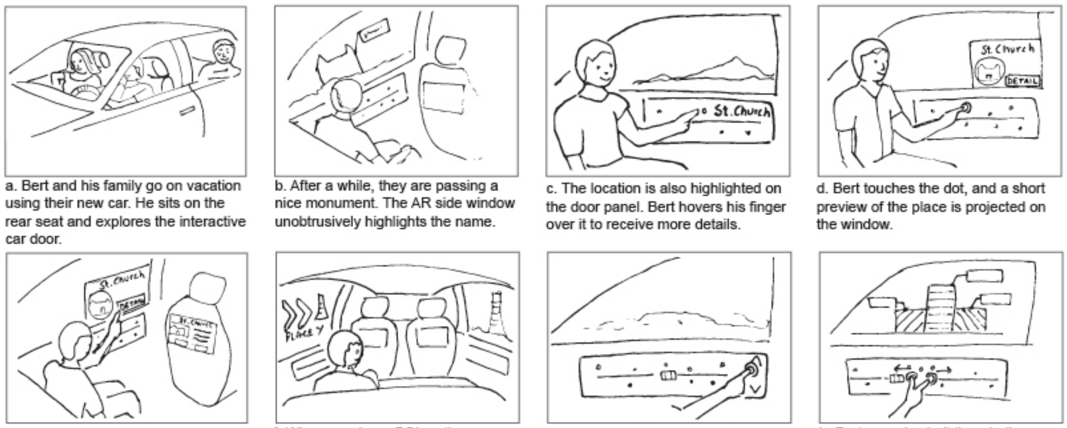
With the concept called *Windows of Opportunity*, General Motors envisioned to entertain both adults and children [14]. The specialized function for kids projects an animated character onto the window that moves over passing scenery corresponding to the real-time car performance. For adults, the system allows to *peek into other users' windows* around the globe in real time [14]. This interactive window is similar to the back seat application developed recently by Matsumara et al. [10]: Their touch-sensitive augmented-reality (AR) window allows passengers to save any interesting view as a picture. In addition, the interactive window enables to share these pictures via social media platforms or to rate the overall trip [10]. More recently, Daimler introduced with their *F 015 Luxury in Motion* concept car big digital screens that are deployed below the windows, on the unused door regions [1]. These touch screens can be used for entertainment or for work reasons. In addition, it provides the functionality of browsing through any world's attractions [1].

To summarize prior work, we see that contextual interfaces can have a general positive impact on passenger's experience. However, live and location-based recommendations in combination with real-time interaction with the visible surrounding have not yet been explored in detail as in-car applications. With this regard, in addition to Inbar & Tractinsky's [7] recommendation to use trip-related data to sharpen passenger-based concepts, we demonstrate a novel interactive car door. This car door enables especially rear seat passengers to engage with the surroundings through highlighted attractions along the route.

3 CONCEPT

With our interactive car door concept, we address two main in-vehicle interface aspects: First, our design idea targets especially rear seat passengers with a goal to empower them and to enhance their personal riding experience. Therefore, we combine their motivation of looking out of the window [16] with their need of receiving additional, trip-related information [7]. Second, we want to make use of contextual information to reduce the barrier between the outside world and the rear seat passenger in the car. Thus, our goal is to give adult passengers the opportunity to better engage with

[1]BTS: https://www.bts.gov/archive/publications/highlights_of_the_2001_national_household_travel_survey/section_02, last access: 2020-09-15



a. Bert and his family go on vacation using their new car. He sits on the rear seat and explores the interactive car door.

b. After a while, they are passing a nice monument. The AR side window unobtrusively highlights the name.

c. The location is also highlighted on the door panel. Bert hovers his finger over it to receive more details.

d. Bert touches the dot, and a short preview of the place is projected on the window.

e. Bert selects the 'detail button' on the preview window to see even more details on the rear infotainment screen.

f. When passing a POI on the oppside side of the passenger, the system projects an animated arrow on the window to direct the attention.

g. To increase the number of attractions along the route, Bert adjusts his preference on the door panel.

h. Bert saw nice buildings in the neighborhood. By zooming-in, he gets the name of the buildings.

Figure 2: Exemplary storyboard to outline the key aspects and user interactions of the interactive car door.

the outside environment, especially in situations where they are tourists or travel through an unfamiliar area. To achieve a high level of UX, we address these user needs by introducing an interactive car door that enables passengers to explore the landscape in a more detailed and informative way using AR on the side window and a touch-sensitive door panel.

The storyboard in Figure 2 highlights the main aspects of the interactive car door and acted as a reference through our whole design process: Overall, it shows that our system acts as an extension of a rear seat infotainment system that displays real-time trip progress in the armrest area, and augments points of interests (POIs) along the route through the AR-enabled side window (Figure 2 b). The system allows passengers to also interact with POIs along the route (Figure 2 c, d, and e). Passengers can see the preview of a POI on the AR side windows (Figure 2 d) before switching to the rear infotainment screen in order to receive more detailed information (Figure 2 e). For attractions on the opposite side of the passenger's seat, an animation is projected on the passenger's window which gives hint to look to the other side of the road without disturbing other rear seat passengers (Figure 2 f). Moreover, the user can adjust the number of attractions that are being displayed. This can be done by zooming in to a particular area (Figure 2 g & h). We expect this concept to foster user engagement and to create a positive UX by enabling interaction with attractions along the route.

4 PROTOTYPE

Due to the ongoing Covid-19 pandemic and its accompanying restrictions, we aimed for a first prototype that allows for a remote user study. Therefore, we implemented a digital on-screen prototype using Processing[2] which simulates the interactive car door, the side window, and an interactive rear seat infotainment system (see Figures 3 to 5).

Figure 3 shows the overall prototype including the interactive door panel and the simulated AR-enabled side window. The door frame itself was static. In Figure 5 we show the rear seat infotainment screen which shows additional information about a POI if needed. To simulate the feeling of driving around, we showed a stop-motion video of driving on a pre-defined route through Paris, embedded as underlay content of the window.

The door panel was designed to look like a touch-based screen that displays the overall trip (light blue line) and the route progress. In addition to the route progress, the door panel outlines POIs (as white LED-lit dots) along the route, which are in the vicinity of the car at a specific segment of the trip. POIs that are located on the side of the user's sitting position are visualized by an LED above the line that represents the route. In contrast, white LEDs below the line symbolize attractions that are on the opposite side of the passenger.

During the ride, whenever the car passes an attraction, the corresponding LED on the door panel flashes green and the name of the attraction gets shown on the AR-based window (see Figure 3). In addition, users can hover over any white dot that is displayed on the interactive door area to reveal the name of a POI. By touching a specific white dot, a pop-up box shows preview information about the attraction in the corner of the window (Figure 4). This pop-up box allows users to get first details or switch to the rear seat screen for more details (e.g., historical facts or navigation details, Figure 5). If passengers are curious to explore even more attractions, they can increase the number of visualized attractions by zooming in into a specific area. This can be done with a double-tap gesture on the corresponding segment of the door panel.

5 REMOTE USER STUDY

To receive user insights regarding our concept and to understand its effect on the passengers' riding experience, we conducted a remote user study. In this study, users had to perform three different tasks using the proposed concept.

[2]Processing: https://processing.org/ last accessed: 2021-01-07

Figure 3: Interactive car window: Being close to the Eiffel Tower in Paris, the AR-enabled window highlights the POI in the real world while the corresponding on-route location of this POI is visualized as a green dot on the door panel.

Figure 4: A preview information pop-up box (right lower corner) appears when touching a POI on the door panel. It provides first insights about a POI and allows to switch to the rear infotainment screen to retrieve more information.

Figure 5: The simulated rear seat infotainment system shows detailed information about a POI.

5.1 Participants

We recruited participants through internal university mailing lists. Overall, 11 students (9 male, 2 female) from the Technical University of Eindhoven participated in our study. Their age ranged from 20 to 27 years (M = 23.81 years, SD = 1.84 years). The participants had a variety of nationalities including the Netherlands (4), India (4), Greece (1), Romania (1), and Hungary (1). All of our participants were right-handed and had normal or corrected-to-normal vision.

Regarding their riding experience, four participants reported being a passenger at least several times per week. The other participants travel at least once a week (1/11), several times a month (5/11), or once a month (1/11) as a passenger. Before the study, all of our participants mentioned preferring to sit at the front seat over the rear seat as this position offers a better view to the environment (9/11) and enables access to the infotainment system (5/11).

5.2 Set-Up and Apparatus

Due to the Covid-19 pandemic and local regulations, we conducted a remote user study that lasted on average one hour. We hosted individual online sessions via Microsoft Teams. As inclusion criteria, participants had to have access to a desktop setup with a standalone screen (≥ 22”), an external computer mouse, and an adjustable office chair to create the illusion of sitting at the left rear seat (see Figure 6). Participants had to put their computer mouse close to the edge of the desk. Right behind they had to place their monitor with the lowest possible position as shown in Figure 6. They also had to lift their office chair to the highest possible position while turning the chair parallel to the desk. Thus, every participant was sitting in a way that their left shoulder faced the screen similar to a passenger on the left rear seat.

To experience the prototype remotely, the experimenter shared his screen (and mouse control) with the remote participant: the left part of the screen shows a virtual version of the interactive car door, while the right part of the screen shows the rear side of the driver seat with an attached rear infotainment screen. The participants can use their mouse to interact with the prototype: hovering with the cursor replaces hovering with a finger (above the interactive door panel) and clicking replaces touching an object. The experiment was approved by the local ethics board.

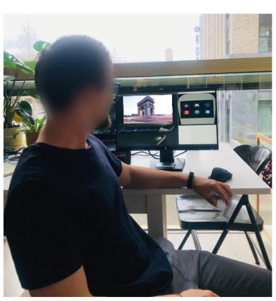


Figure 6: Experimental set-up: the participant uses an external screen at its lowest position (representing door panel & side window). To best simulate the rear seat perspective, the participant turns parallel to the desk, facing the screen with his left shoulder.

5.3 Procedure and Measures

At the beginning of the experiment, the participant signed a consent form and answered some demographic questions. Afterwards, we instructed how to set up the environment (screen, mouse, & chair position, see Figure 6), and asked the participants to perform three tasks. Before each task, we shared a task instruction slide with each participant. Once the user had read the instruction and all open questions were answered, the participant started the task.

First, the user started with exploring the system. This included hovering over a POI (LED dot), checking the trip progress line, and observing what happens when a car passes a POI. As a second task, the participant had to look up more information about a POI by pressing a white dot and pressing the *Detail* button on the information pop-up box, that occurred on the window. To complete task 3, the participant had to zoom in into an area to get more attractions displayed that are along the route.

We were interested in whether such a contextual interface with the possibility to interact with the outside environment is suitable for the rear seat and improves the user experience. To do so, we measured the perceived UX by means of aesthetic, hedonic, and pragmatic qualities using the AttrakDiff questionnaire [6]. As we wanted to get deep insights if our concept is self-explanatory, we also asked a set of open-ended questions after each task to get more insights into the users' opinions. After the last task, we conducted a semi-structured interview to understand the subjective aspects of our proposed concept. All answers from open-ended questions were categorized based on inductive, thematic free coding [11].

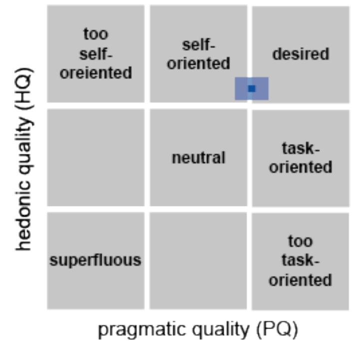


Figure 7: UX results out of the AttrakDiff [6] questionnaire. The blue marker represents the UX for the interactive car door (HQ: 1.41, confidence 0.3; PQ: 1,08, confidence 0.22)

6 RESULTS

The pilot study revealed first interesting insights regarding the UX of our interactive car door and how the participants perceived the proposed concept.

User Experience: The virtual prototype received overall good UX ratings regarding its hedonic (HQ), pragmatic (PQ), and aesthetic qualities (ATT) (see also Figure 7). The concept was perceived as practical, simple, and pleasant (PQ). In addition, it satisfies users as it is creative and original (HQ) while it also presents a high level of likeability and ordinariness (ATT).

Comprehension of the Concept: With our first task we explored how self-explanatory the concept is. 10 of 11 participants mentioned that the concept is intuitive and easy to use (e.g., "*very easy and requires little effort*", P#3) while nine understood the representation of the route and its corresponding POIs. Eight participants rated the preview information of a POI as pleasant. In addition, two subjects stated that the system helps to feel connected with the surrounding as the flashing LED when passing a POI automatically catches their attention (e.g., "*even when you don't look at the points, the fact that it appears on the window itself is quite cool because it catches your attention*", P#9). Therefore, no direct interaction is needed as mentioned by P#9: "*it is nice that you don't have to interact with the screen much, so you can enjoy looking outside*".

Perceived Usefulness: The functionality to get more details about a POI was highly appreciated by all participants. In addition, 10 out of 11 participants mentioned that this function is important and that they expect to use it frequently. In general, the concept is described as informative (9 times, "*it is nice that you can even see more information*", P#4), intuitive (3 times, "*more convenient than looking up things on the phone*", P#7) and as adding value to riding on the back seat (1 time, "*I like to stare out the window for that reason it definitely adds a lot more value to my trip while sitting at the back*", P#1). Users also enjoy the fact of browsing manually through additional information (6 times, "*I am able to get more and more information*", P#1). With this regard, participants mentioned that they want to get additionally the possibility to navigate to a POI (5 times) and to retrieve additional information such as ticket prices (4 times) or historical explanations (3 times). They would also like to see the estimated time of arrival at a POI (2 times), the average time people spend there (2 times) and the opening hours (2 times). Also, access to pictures or a virtual tour was suggested twice. The feature of adjusting the number of POIs was on the one hand described as useful (7/11, e.g., "*you can explore the whole city and maybe focus on what you want* ", P#10) but also as not a necessity (4/11, e.g., "*most of the time it will be enough what is shown already*", P#2). Only two participants would like to use this feature frequently.

Perceived Future Use: The final interviews gave insights into the overall impression of our concept. Generally, it was perceived as innovative and novel by seven participants and described as intuitive and useful (4/11, e.g., "*It is interesting that it is not too invasive and I think it's good*", P#2). Also, it adds value to riding as a rear seat passenger and empowers them (4/11 e.g., "*prioritizing the rear passenger and providing them also some level of control*", P#1). It is also seen as communicative (e.g., "*it also offers you things to talk about with another passenger*", P#3) as it helps to start conversations with others in the car (2/11). Furthermore, three participants felt engaged with the environment while using this interactive car door, described by P#6: "*it makes the whole journey more interactive towards the city you are in*". This led to the statement that all eleven participants wanted to use the concept, ten of them on a frequent basis. The main reasons were the possibility to explore new places (10 times), especially during vacation trips (11 times). It was also seen as informative (12 times) and as an assistant to find out important information/places (7 times) and to avoid missing an attraction (4 times). Less frequently mentioned aspects were that it is fast and easy to use (2 times), that it helps to prepare for a trip (2 times) and that it gives a sense of control (1 time). While the participants appreciated the concept for the use case of vacation trips, three participants stated that they were missing how to use this concept in familiar areas.

Given the provided features and benefits, the interactive car door convinced eight of the participants to prefer the rear seat over the front-seat as "*it would make the rear seat much more attractive*" (P#6) and as it allows "*to share things that you find out with others*" (P#3).

7 DISCUSSION

The results indicate that our contextual interface is self-explanatory and helps to shape the passengers' riding experience. This is reflected by the users' motivation to use the system frequently.

The qualitative feedback unveils that automatically highlighting attractions on the window in combination with the flashing LED lets passengers engage with the surrounding better while avoiding intrusiveness. In addition, the participants highly appreciated the chance to browse manually through POI-related information. This is in line with previous findings [3, 10]. Despite information access, contextual functions like navigating to an attraction add higher value to the system from a user's perspective, as already identified in our previous study [3].

A potential limitation of our concept is the focus on vacation trips instead of daily rides. To extend the current concept, we envision to add other frequent use cases e.g., by unveiling hidden spots or by showing unknown facts when driving in a well-known environment. As all participants were right-handed, UX and usability for left-handed users is subject to future research.

The participants perceived our concept as intuitive, informative, and easy to understand. Furthermore, it acts as a possible conversation starter and adds a higher value to the rear seat passengers. As our interactive car door also convinced 72% of our participants to choose the rear seat over the front seat it can be seen as an innovation that makes the rear seat row more attractive and pleasant.

With this pilot study we got first insights about the impact that a contextual interface has on passenger's experience, as proposed in prior work [7, 10]. The received feedback motivates us to continue investigating this concept. We are aware that our results are limited due to the remote user study with a simulated in-car environment and the in-balance in both participants' age and gender. While the smaller number of participants did not allow for a detailed quantitative analysis, the qualitative data generated valuable insights, which we hope to use soon to implement and test in the real world, also to study long-term UX effects.

8 CONCLUSION & FUTURE WORK

In this paper, we introduced an interactive car door that improves rear seat passengers' UX and lets them engage with the outside environment. This contextual interface highlights POIs near the road through an AR-enabled side window. Users can interact with POIs by using a touch-sensitive door panel to receive additional information. This door panel displays the overall trip progress and its corresponding attractions along the route.

Results from a remote pilot study unveil that this concept contributes positively to rear seat passengers' UX. Users appreciated the possibility to be informed about the trip progress and the most famous attractions along the route. They also enjoyed the way of receiving more detailed information about a specific POI. Overall, we see the opportunity through this concept to make riding as a rear seat passenger more attractive and pleasant.

As a future step, it is interesting to integrate more POI-related information and to investigate additional use cases, e.g., for trips in a familiar area. This especially concerns the type of provided information about the surroundings and the integration of attraction-based functions (e.g., navigate to an attraction). By preparing a physical prototype, we plan to deploy our concept in a car and to run a real-world experiment to deepen our insights on passenger experience in comparison with a state-of-the-art rear seat system.

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