Participatory Design Fictions with Mixed Reality: A User Study Framework for Future Smart Cockpit

Cheng Chi, Yiwen Zhang, Yate Ge, Wenjia Wang, Jianuo Li, and Xiaohua Sun(✉)

College of Design and Innovation, Tongji University, Shanghai, China
{1933633,zhangyw,xsun}@tongji.edu.cn

Abstract. Before widely adopting in the real life, Emerging technologies and design concepts require appropriate user studies to explore demands from users. Smart cockpit is a typical fields driven by cutting-edge technologies, and vehicles are becoming more intelligent touchpoints empowered by V2X technologies. A repeated, correlative and continuous framework was employed for future-oriented user study such as smart cockpit's connectivity capability in the context of V2X, by presenting the Participatory Design Fictions with Mixed Reality, which aims for stimulating imagination of the participants to gather their views and discussions about the future. Thematic analysis, discourse analysis and creative analysis were adopted to evaluate this framework and method. Results indicated that Participatory Design Fictions with Mixed Reality provided researchers with more in-depth insights about the preferable futures articulated by different groups when conducting future-oriented, demand mining-oriented user study as a effective tool and method.

Keywords: Design Fiction · User study · Participatory design · Mixed reality · Smart cockpit

1 Introduction

Currently we are living in a time when science and technology are developing at one of the fastest rates in the history, with numerous innovative ideas in laboratories around the world that have already changed, or could be profoundly change all aspects of our daily lives in the future. So it is necessary to find out how users want these things to be before they actually come to life. Researchers need to find a creative form to present future technology and design in advance, which can stimulate the imagination and thinking of users, in a way that invites them to create a better vision of future life.

Among these future topics, Vehicle to Everything (V2X) has received a lot of attention and discussion. It takes the moving vehicle as the information sensing object and realizes the interconnection between the vehicles and other ones, people, roads, service platforms, and urban facilities with the help of information

M. Rauterberg et al. (Eds.): HCII 2022, LNCS 13520, pp. 440–459, 2022.
https://doi.org/10.1007/978-3-031-18158-0_32

and communication technology [23]. In the context of V2X, the smart cockpit will not only be a daily travel tool, but also a comprehensive and integrated mobile terminal in the future life, and a mobile touchpoint in the future smart city [22]. As an important part of V2X, the connectivity ability of the smart cockpit will bring many new service scenarios that can profoundly affect the travel experience, and life style. Therefore, this paper attempts to use this topic as an example to explore methods for conducting future-oriented and requirements-mining-oriented user study.

2 Related Work

2.1 Science Fictions

Definition. Many future technologies and conceptual designs are often found in Science Fictions (Sci Fi), and the public is becoming familiar with regarding Sci Fi as a channel to learn about future visions. Sci Fi is a genre of speculative fiction that typically deals with imaginative and futuristic concepts such as advanced science and technology to explores the potential consequences of these innovations. [11] Sci Fi is often referred to as "literature of ideas" because of the depth of thought and the quality of the work itself [3], which can inspire the audience to think and discuss accordingly. So Sci Fi, in addition to providing entertainment, can often serve as a starting point for criticism and reflection on today's society [1]. Rising rapidly in popularity during the first half of the 20th century, Sci Fi was closely tied to the popular respect paid to science at that time, as well as the rapid pace of technological innovation and new inventions [4]. In fact, the relationship between Sci Fi and future technology is much closer than one might think, and the history of science has demonstrated that the dividing line between science fiction and scientific fact is often overlapping [24], with some of the imagery that appeared in completely unrealistic Sci Fi works at one time may become scientifically possible even guide the development of science within a few decades. [5,14]

Features. From books and drawings to the powerful visuals of today's film industry, Sci Fi can provide a "sense of wonder". [20] More importantly, Sci Fi criticize present-day society and explore alternatives, provide the audience with the inspiration to think and reflect on its subject matter. The thought-provoking nature of Sci Fi makes it an infectious medium, with George Slusser (2019) commenting that Sci Fi "is the one real international literary form we have today, and as such has branched out to visual media, interactive media and on to whatever new media the world will invent in the 21st century.". And based on the qualities that Sci Fi possesses to depict the future, the more better the visual and interactive experience in these media forms, the more profound the impact of Sci Fi on the audience.

For Design Research. Design researchers have also discovered the value of Sci Fi and have used Design Fictions (DFs) as a research tool for the recently emerging design practice and design research [15], or rather, DFs are design practices that aim to explore and critique possible futures. DFs draw on both science fiction's ability to depict imagined design objects within a diegesis and its critical potential in exposing the use of technologies within possible worlds with using Design Thinking to integrate design solutions into future scenarios [24].

Brief Summary

- Sci Fi is a genre of speculative fiction, with a "sense of wonder" and "criticality" that often provokes the viewers to explore and think about the future;
- Sci Fi has a profound impression on the viewer and is an infectious medium that takes many forms, and the better the sensory effect and interactive experience, the more profound the impact created;
- Sci Fi is recognised as a research method and tool in the form of DFs in the field of design research.

2.2 Participatory Design Fiction

Speculative Design and Design Fictions. DFs' criticality comes from Speculative Design thinking. In fact, Speculative Design is a subsidiary of critical design extracted by Dunne and Raby [7], which does not aim to propose commercial or solution-driven design solutions, but rather to design proposals that identify and discuss key issues that may occur in the future. This anti-solutionist tendency is a good example of the critical nature of Speculative Design, and as such, Speculative Design is used to challenge preconceptions, raise questions and to provoke debate [6].

Speculative Design is an approach enabling us to think about the future prospectively and critically [12], and one of its main manifestations is through the negation of the status quo and the initiation of discussion of possible future scenarios through a confrontation with a tangible object or process, the so called DFs [24]. However, DFs are not always tangible, prototyping is only intended for more arguments [10], and DFs can be created in a variety of mediums to inspire viewers and get them started on exploring the future. In addition, DFs are defined as design practices that explore and critique possible futures by creating speculative, provocative scenarios through design artifacts, which is a way to facilitate and foster debates [7]. The important characteristics of DFs are mentioned here: future scenarios, criticality, and encouraging debate. With DFs, prototypes and stories remove the obstacles of understanding, creating spaces where the audience holds an openness to change [17]. Thus, DFs serve both to give account and intervene [24]. DFs make the future understandable, the diegetic prototype is a form of explaining future technological needs and feasibility to the viewers [13]; the intervention role stimulates discussion and finds insights, DFs do not claim to predict the future, they act as aids to enable their audiences to act as interlocutors.

Participatory Design Fictions in Design Research. One of the challenges and issues of DFs is that they are typically designed and developed by individuals with a certain educational background and skillsets [2]. The individual perceptions and opinions of designers or researchers have a great impact on users and their lives, which is the "Butterfly Effect of Design"[?]. Future-oriented user study needs to focus on the perceptions of people and the daily lives they represent, which means bottom-up innovation and continuous discussion. The characteristics of DFs, which are creative provocation, questioning, innovation and exploration have been seen as highly suitable for participatory activities [18]. Lyckvi explores the possibility of integrating DFs with participatory design processes and suggests that Participatory Design Fiction (PDF) is a critical approach that means re-imagining, a participatory approach that means co-speculating, a interventionist approach that means rehearsing, and a discursive approach that means debating. PDF can take into account the perspectives of people who are marginalized in society, as Nägele focused on vulnerable's perspectives, which were collected in healthcare-related DFs to allow the public to hear their voices and reflect on their situation and imagine a more reasonable future together [19]. It is the vision and responsibility of designers and researchers to build confidence and good experience for more users to face the unknowable future problems and life. We are also concerned that DFs with more interactive effects and better sensory effects will get more attention and collect more discussions.

Brief Summary

- DFs are an approach that allow us to think critically about the future, it serve both to give account and intervene;
- PDF has the potential to bring social groups together to provoke, innovate and explore the future;
- With better presentation and interaction, as well as repeated and continuous discussions, PDF can create a more profound impact among the viewers.

2.3 Virtual Simulation

Scenario Simulation. Scenario building means that empathy can be shared more efficiently, and scenarios that correspond to the research topic can enhance the understanding of the user's context and thus facilitate the achievement of the research objectives [25]. Thomas Kohler investigated that participants' willingness to participate and express, effectiveness of expression, and creativity and imagination were all enhanced when a consistent and enjoyable experience was created for them in a simulated scenario [16]. Aceituno compared the feedback given by participants on driving related research in the driving simulation scenario and ordinary interview scene. Aceituno defined several dimensions and made quantitative and qualitative analysis on the user feedback content under these dimensions, The results showed that user interviews in driving simulation scenario can obtain more effective feedback [9].

AR/VR/MR Based Simulation. AR/VR/MR based simulation is called Virtual Simulation technology which has a powerful ability to create scenarios. Current researchers have begun to explore the use of Virtual Simulation in design research. El-Jarn explored the possibility of using XR technology for co-creation in the initial stages of the design process, examining emerging tools and checking whether they offered the potential to improve the design process [8]. The technical features of Virtual Simulation technology are well suited to help in the field of design research that relies on future service scenarios such as robotics and automobiles, Rosa explored the construction of robot models in MR environments and assisted researchers in presenting diverse design solutions and inviting users to participate in tests to gather the extent and dimensionality of the robot's appearance on the user's interaction with the robot [21].

Brief Summary

- Scenario research is a key step in understanding users' pain points, motivations and needs, requiring a way of depicting scenarios that can build consensus between researchers and participants;
- Virtual Simulation has a powerful ability to create immersive, interactive, illusory, and vivid scenarios, and has a wide range of applications in all phases of design research.

3 Method

3.1 User Study Framework

Three Main Phases. The entire user study practice is divided into three phases: 1) expert workshop, 2) PDF, and 3) MR simulation. we hope to stimulate participants' imagination, expression and discussion repeatedly, correlatively and continuously, and to explore future users' needs in these talks to support the exploration of more design opportunities (see Fig. 1).

- In the first step we conducted an expert workshop based desktop research and literature review on the topic to think of possible scenarios and plots for PDF as stimulus to help facilitate the understanding and imagination for the participants in the subsequent session;
- The methodology of PDF was used in the co-creation phase, where participants imagined and created DFs, and scenarioized and storytold them. The DFs created will be used as stimulus tools for more discussion in the final session;
- The final interviews will be conducted in the MR environment, which simulate the DFs created at previous phase. We re-invited the participants and some creative professionals for interviews and discussions after experiencing DFs in MR to explore their thoughts and suggestions on the relevant plots in DFs.

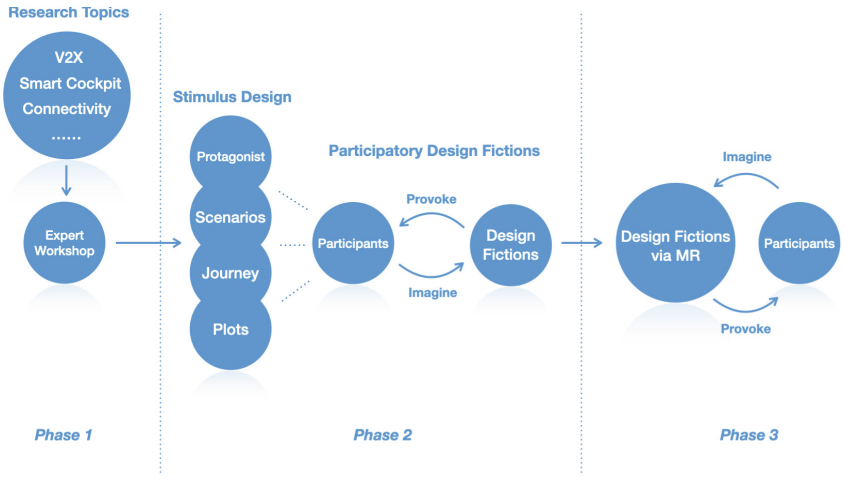

Fig. 1. The user study framework.

Ethical Considerations. The user study focused on the participants' reactions, imaginations, and discussions of future scenarios. The co-creation study was ethical in nature, but it also included the participants' own information and past experiences to support their imaginations and expressions, as well as their physiological acceptance of MR.

- Throughout the user study, we provided each participant with a personal information sheet before participating in the formal user study, asking whether they would consent to audio and video recording during the study while maintaining privacy protection, and allowing sufficient time for each participant to ask questions and make decisions;
- Each participant was asked about their physiological acceptance of extended reality (i.e., VR/AR/MR) in first-person perspective and any previous relevant experiences. Advice and assistance was provided in the event of any discomfort for the participant during the study;
- Most importantly, given the subject matter, they will need to have a driver's license.

3.2 Phase 1: Expert Workshop

Workshop Design The workshop was held in Shanghai and featured eight experts in automotive HMI and eight automotive consumers.

Participants. The experts include university professors, university PhDs, and automotive industry research experts. The experts will be divided into 4 groups with 8 consumers to discuss relevant topics and prepare debriefings. The 8 typical consumers are divided according to car grading criteria (A/B/C/D) and their

general family situation, one single and one married consumer are invited for each car tier. (Females = 4, Males = 4; Aged form 23 to 34, M = 28 years old, SD = 3.74 years old).

Procedure. The workshop started with a discussion on the main driving scenarios. Each group started to think about what are the most representative driving scenarios and prepared presentation. Finally, four main scenarios were identified: Commuting to work, Go to a party with friends, Road trip, and Go to a business meeting. The group then started to enrich the story of each scenario in the form of user journey maps, thinking about two questions: What will change in the journey in the future of V2X, and what features and services will help us get a better driving experience? The workshop finally determined that five types of functions and services would be the key research directions: Third-party Application Ecology, LBS Services, Face Recognition, Context Awareness, Active Learning, and Intelligent Assistant. These 4 types of scenarios and 5 functions and services will be the important support for designing the stimuli used in the next phase of PDF.

The Stimulus for Participatory Design Fiction (PDF). Based on the results of the expert workshop, we designed a stimulus toolkit for PDF (see Fig. 2).

Scenario Cards. Four main scenarios and others mentioned in the discussion. Participants can choose and add to them.

Protagonist Cards. In which each group creates a character to be the protagonist of the DF according to the content of the information on the cards and considers the impact of these information on the DFs.

Scenario Journey Cards. Where each group of participants portrayed the entire journey according to the chosen scenario, including the protagonist's goals, the plot story at each point and the corresponding touchpoints, needs, helps and hindrances.

Function Depiction Cards. From the 5 categories of functions and services, which included an image and a fictional passage depicting a specific function, and formatting annotations to help each group of participants to imagine and edit.

3.3 Phase 2: Participatory Design Fiction (PDF)

The phase 2 included 14 workshops in 7 key cities in China (Shanghai, Beijing, Hangzhou, Xi'an, Chengdu, Zhengzhou, Guangzhou), and each workshop invited 6–8 participants and divided into two groups according to car classification criteria, gender and family status. 96 participants were invited to the workshop, 52 males and 44 females, with an age distribution of 24–35 years (M = 28.61; SD = 3.37).

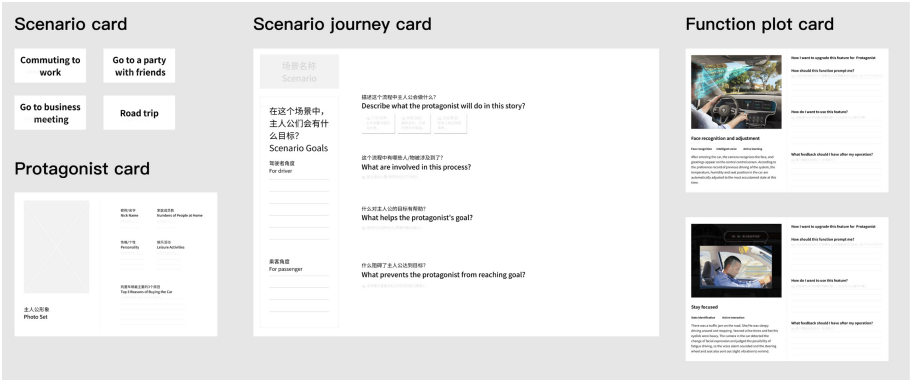

Fig. 2. Stimulus for participatory design fiction (PDF).

Protagonist. Creating the protagonist is also seen as an icebreaker. After completing the grouping, each participant is asked to briefly introduce themselves, and the facilitator will remind the other group members to focus on the similarities to themselves. The group's protagonist is then created by following the format of the content of the Protagonist Card. The information includes a portrait image, nickname, number of family members, personality, recreational activities, and the most important reason for acquiring the vehicle. During the creation process, participants instinctively brought their own situation and ideal situation into the protagonist, which helped the transition from realistic to imagined perspective (see Fig. 3).

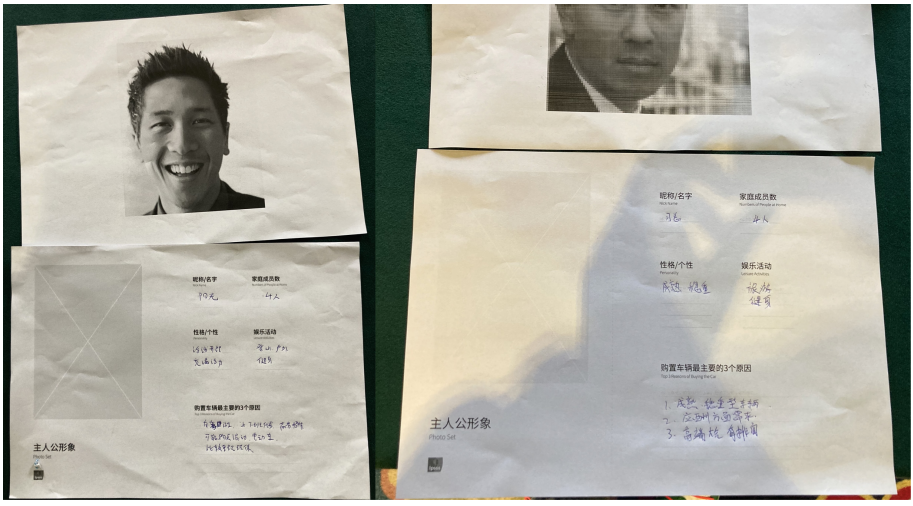

Fig. 3. Sample outputs of protagonist cards.

Journey. After the discussion and addition of scenarios, each group freely decided to choose 2 Scenario Cards. (see Fig. 4) Firstly, the group members discussed the goals and expectations of the protagonist from both the driver and passenger aspects. Because the protagonist persona draws on the commonalities among the group members, which helps to reflect the real situations. Secondly, group members collaborated to write down what the protagonist might do and the events that would be encountered by sticky notes, and then which touchpoints are involved, which things will help protagonist accomplish the goals, and which things will prevent the protagonist from accomplishing goals. After the journey is completed the group members rearranged the order of the sticky notes for a complete and smooth story, which contains the real needs and pain points of the users. Finally, intergroup debriefing allowed two groups to learn about each other's stories and vote for the representative plots. The voting rules included which ones were the most helpful and the most depressing according to the protagonist's goals and experience, which led to a shift in the participants' perspective towards seeking help from future functions.

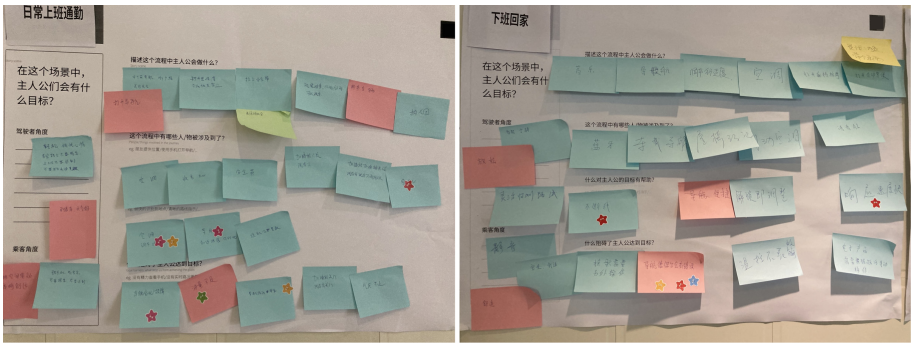

Fig. 4. Scenario journey cards.

Plots. Participants chose from a series of Function Depiction Cards based on the protagonist and journey. Each group freely discussed and decided to select 3–4 cards depicting the features, and rewrote them to make them better for the experience of the plots elected by votes (see Fig. 5). The Function Depiction Cards introduced the function in a easy-to-understand format. The group members created DFs based on three aspects: what the protagonist would do before the function takes effect, the steps the protagonist would take to use the function, and the changes the protagonist would feel after the function takes effect. After the creation of the DFs, there was also a debriefing and discussion between the groups, where they gave comments on each other's plots and improved them together. The DFs created in the workshop will be organized and optimized for presentation in the MR environment.

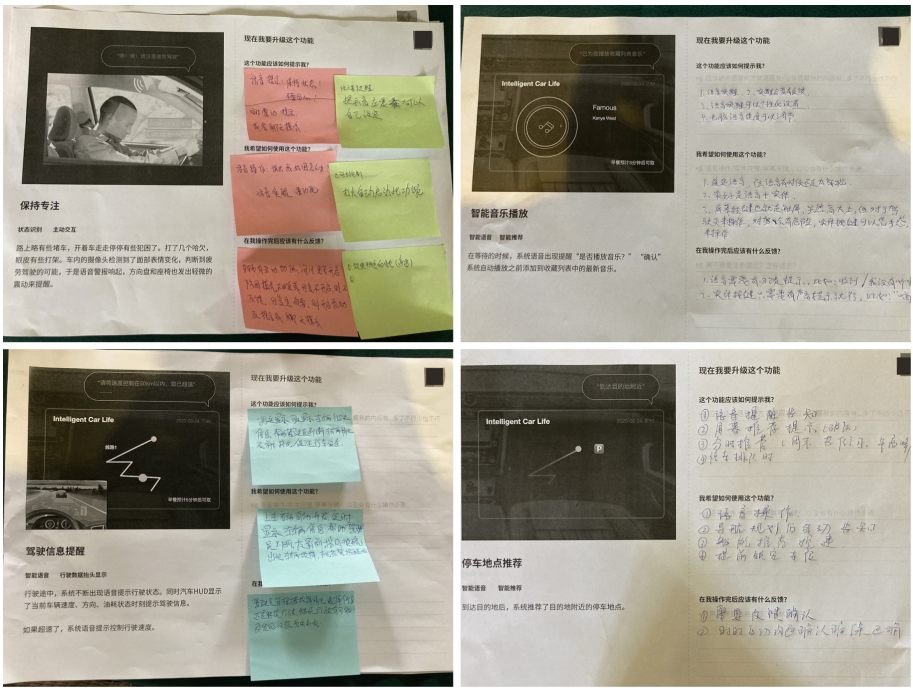

Fig. 5. Function depiction cards.

Summary. Obviously, it is unrealistic to make participants think and discuss a series of incomprehensible future technologies and conceptual designs at the beginning. The workshop divided the co-creation of DFs into three phases: protagonist, journey, and plots, aiming at gradually shifting the participants from a realistic to an imaginative perspective. In terms of scenarios, the most frequently selected ones in the 14 workshops were Commuting to work, Go to a party with friends, Road trip, and Go to a business meeting. This is consistent with the results of the preliminary expert workshop, which validates the representativeness of these four typical scenarios in daily life. In terms of functions, participants' interests in the 14 workshops were ranked in the order of Intelligent Assistant, Context Awareness, Third-party Application Ecology, and Face Recognition. It was worth noting that in the DFs, participants consistently showed a preference for quick, accurate and efficient voice interaction. Overall, the DFs from the 14 workshops will be thematically categorized together, optimized with current forms of travel and lifestyles, and ultimately presented in MR.

3.4 Phase 3: MR Simulation

Implementation. MR's powerful ability to simulate scenarios allows presenting visual experiences with a sense of reality and immersion, which is the advantage of MR as a design research tool, and a more inspiring and provocative way to present DFs. Since the subject of this user study is related to driving, the development of the MR also requires the realization of the cockpit experience in reality, in line with the virtual scenario (see Figs. 6 and 7).

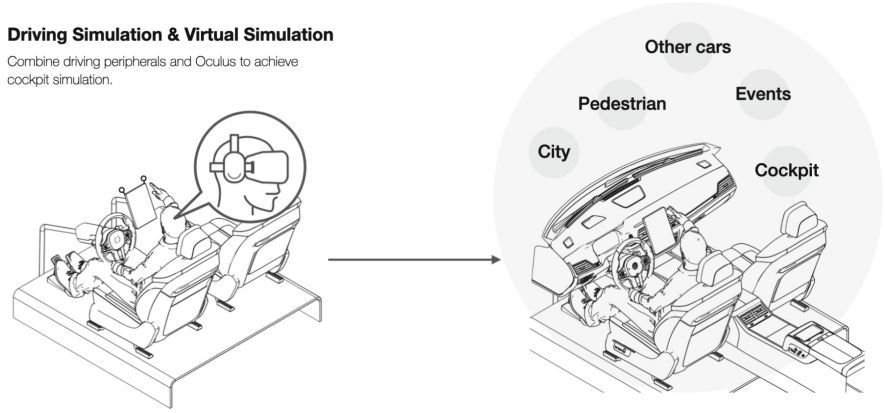

Fig. 6. The technical architecture of DFs via MR.

The driving simulation is achieved through a series of hardware devices, including the seat, steering wheel, throttle, and brake. These devices are programmed by Unity to ensure that when the participant turns the steering wheel in reality, the corresponding perspective reversal occurs in the virtual context, e.g. At the same time, the human- machine scale of the devices is aligned with the virtual context, which ensures a consistent experience and focuses the participant's attention on the storyline of the driving journey.

The virtual scenario is realized using the Oculus rift. Participants wearing the Oculus find themselves in a car parked on a city road. The virtual scenario includes city buildings and roads, pedestrians, other vehicles, cockpit models, HMI design and pre-defined events, which make up the complete content of the DFs.

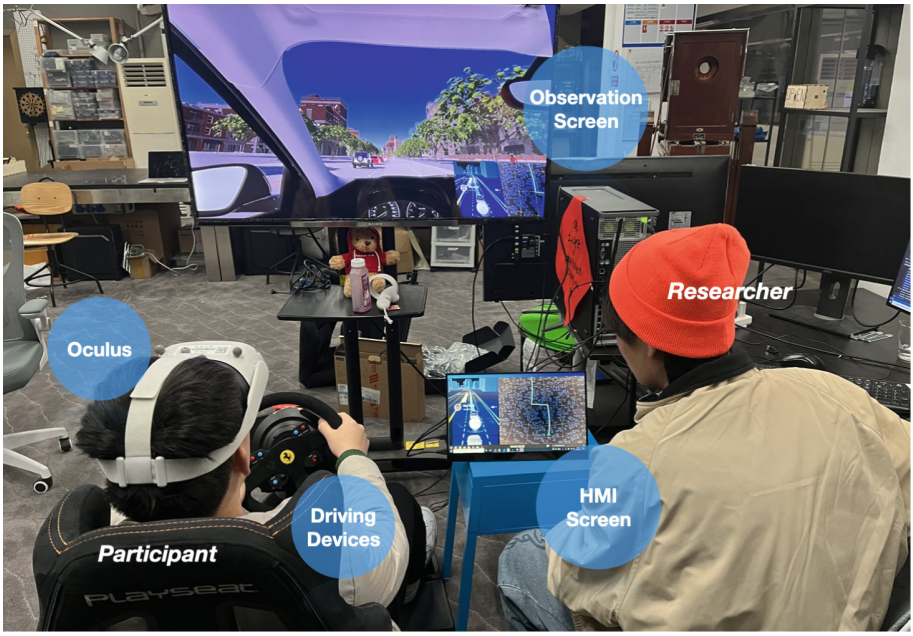

Fig. 7. Apparatus supporting participants to experience DFs via MR.

The participant can receives and interacts with the HMI content on the center screen of the smart cockpit in the virtual scenario. This behavior needs to be consistent with the reality. A touch-screen and voice-enabled computer is configured to display the HMI content in reality, and the display is linked to the HMI content in the virtual scenario. At the same time, the click position and the actual scale in the reality were also aligned with the virtual.

A display was set up to show the first-person view of participants wearing the Oculus, allowing researchers to observe the participants' vision and related behaviors, as well as to provide assistance and advice in the event of special circumstances.

Stimulus Design. A specific plot in the DFs, i.e., an event, is treated as a stimulus. An event includes the triggering conditions, the occurrence and the feedback, these three phases also correspond to the three content formats of the Function Depiction Cards. Events are portrayed in a version that is close to everyday life. The many coherent events form a complete DFs and a complete experience script. Although the final DFs presented was optimized and not exactly the version co-created by the participants in the workshop, the discussion and imagination of the participants in the workshop were retained as much as possible. This means that the DFs have undergone an iterative design process, and after inviting participants to experience it, it will be subject to their thoughts and modifications again, which satisfies the purpose of continuously

prototyping arguemets. A sample design fiction, the "Commuting to work", in MR environment was presented as follows.

Scenario. Scenario "Commuting to work" is set on a city road, where the participants will drive a car from the starting point and drive a distance to the designated location. During the process, the participants will see the relevant city facilities, buildings, pedestrians and other vehicles (see Fig. 8).

Fig. 8. A sample scenario "commuting to work".

Events and HMI. The DF "Commuting to work" includes 5 important plots: 1) Boarding And Face Recognition, 2) Navigation And Route Selection, 3) Intelligent Music Recommendation, 4) Intelligent Route Switching, 5) Breakfast reservation, and 6) Parking.

- *Boarding and Face Recognition. Yuki (the protagonist) enters the vehicle, the intelligent assistant performs face recognition and greets, then adjusts the settings according to Yuki's habits, gets Yuki's schedule and proactively asks for destination. Yuki can see how other smart devices are connected to the car, including smart phones and furnitures.*
- *Navigation and Route Selection. Based on the schedule and Yuki's driving habits, the intelligent assistant recommends two routes and displays specific information, and after selection the vehicle switches on driving mode.*
- *Intelligent Music Recommendation. When driving near the traffic lights and waiting, the intelligent assistant can sense the situation, actively ask whether to play music, and recommend different types of music according to Yuki's habits and emotional state at that time. Yuki can view the song list in the music application, switch music, or operate on phone. The music volume will automatically decrease during voice interaction.*

- *Intelligent Route Switching. Yuki can switch routes ahead of time to avoid congestion by using the intelligent assistant that detects congestion ahead of the route and proactively explains the situation and recommends a new navigation route.*
- *Breakfast reservation. When approaching the restaurant where Yuki is accustomed to, the intelligent assistant will actively recommend according to Yuki's habits, Yuki can adjust the products and quantity, and choose the pickup method.*
- *Parking. When approaching the destination, the intelligent assistant will analyze road information to proactively recommend places to park. After Yuki finishes parking, it will remind Yuki of next travel schedule.*

Execution

Participants. Ten of the participants (Females = 5, Males = 5; Aged from 25 to 31, M = 28 years old, SD=1.79 years old) were members of the previous workshop and were re-invited to experience DF in MR and describe the difference of imagining and modifying DFs between two occasions. The other 45 (Females = 21, Males = 24; Aged from 22 to 28, M = 25.11 years old, SD = 2.08 years old) participants included typical consumers as well as some creative practitioners and automotive industry personnel. Fifteen of the participants read the printed sheet version of the DF, another 15 watched a video of the first-person perspective experience of the DF, and the final 15 experienced it in an MR and then discussed and imagined it.

Procedure. DFs in MR subtly curates illuminating details for the participants' experience. For example, the voice mood of the intelligent assistant changes each time a different event occurs: it is upbeat when actively recommending music and gentle when booking breakfast. These details can stimulate the participants' interest and open their imagination to reinforce the stimuli.

During the experience, participants are not limited in their responses to events, or they can respond in any way they want. This is completely different from the logic of the usability test, for example, participants can choose to control the screen by tapping on it or by voice interaction, and these reactions and behaviors are all considered correct and recorded as a topic of discussion after the experience. At the end of the experience, participants will go back the DF with the researchers and discuss how they reacted, tell their attitudes and feelings, and imagine a more ideal form.

4 Evaluation and Discussion

4.1 Analysis and Results

Thematic Analysis. The first step was to thematically categorize participants' discussions and imaginations of the DF, and to explore the characteristics of narrative data that emerged from this user study. This included 10 participants who

had previously participated in the PDF workshop, and these characteristics were more distinct with their talk about the experience of imagining and modifying the DFs. The analysis of the collected texts and recordings revealed four themes, which are described in more detail below.

Understanding and Acceptance of Future. The value and potential of DFs to increase participants' understanding and acceptance of future technologies and conceptual designs was one of the key themes in the analysis of the interview data, and the DFs presented in MR will be even more characteristic of this. It is difficult for participants to start discussions when faced with these technologies and designs that are not yet available. With the help of DFs, which presents future technologies and conceptual designs in a form that is close to everyday representations, they quickly and well understood these features, built consensus among the group, and started to share their ideas.

"Some of these features I once seemed to have read somewhere that probably meant the same thing. I can't remember exactly what it was, because that article was written so professionally but I just wanted to read it briefly."

For participants who had attended the PDF workshop before, the immersive experience of DF in MR environment was more realistic and immersive.

"When I wrote it on paper before, I was understanding it more in the context of my own experience based on the pictures and the introduction, and I tried to put myself in that situation. But everything changed when I put on the glasses, and being there and experiencing the story was impressive."

Imagination and Contextualization of Future. The fact that DFs served as a stimulus to open the participants' imagination and consistently stimulate their thinking and expression was certainly a surprise to the researchers.

"Sitting inside this car, what had just happened seemed to exist in my mind as if it were a true memory of reality, and I could base my thinking on first reaction at the time as well as my imagination to help me think."

The participants who attended the PDF workshop said that the inspirational nature of the DF presented in MR made them start thinking about issues and scenarios they had not thought about before.

"When I was imagining how to use this feature, I closed my eyes and imagined myself sitting in the car in the picture. And now that I have glasses on, I can imagine more things, the range becomes broader, and I start to imagine what to do if there is a change in the external environment like being distracted while operating music and getting into a dangerous situation."

"Is it possible that the interior of the cockpit is a very different design from what it is now? Maybe I don't need a steering wheel, the screen will be bigger and I want the content to be displayed on it..."

Interests and Expectations for Future. Participants reported that they were interested in reading, thinking, and writing DFs, and were willing to share and listen to others' passages. Repeated, correlative and continuous DFs study have the

advantage of maintaining participants' interest and attracting their continued participation and active contributions.

"I feel that in either form, sheet or just in MR, this is more interesting than a bland and emotionless description of a feature. I'm eager to continue to learn more, and I keep looking forward to the later parts."

In addition to showing their interest in the future of technology and conceptual design in daily lives, the participants were excited about the features included in the DFs after experiencing it in MR.

"When I wrote on the printed DF, I was just describing an ideal situation and not fully thinking about whether it was possible. But after I just experienced MR, I think these things are achievable, I'll believe in it, and I'll pay for it."

Requirements Extraction. DFs can help researchers observe participants' reactions and collect their discussions and statements to identify future design needs, opportunities, and challenges, and it acts as a stimulus to help researchers capture these perceptions of the future.

"The intelligent assistant has a pretty interesting voice, and I was wondering if I could go to a nickname for it or configure some of its features to my liking."

"While the music is playing, is it possible to transfer the navigation information to be displayed on the HUD instead of continuing by voice?"

While experiencing DF in MR, the immersive experience allows participants to put themselves more into the scenario and think about the issues more comprehensively and rationally.

"When I was participating in the workshop before, I thought I could pick up my breakfast after booking it directly after passing through the restaurant. But after the MR experience, I considered the fact that parking is not always available on the side of the road, perhaps setting up take-out delivery and controlling the timing of the order would be a better way to go."

Discourse Analysis. A control experiment was set up between other 45 participants with different forms of DF. The objective metrics adopted for this analysis are the number of words spoken, the variety of words (number of unique words occurring in the expression), and the length of time it takes to complete the expression, for the discussion after the DF experience (see Fig. 9).

For the number of words in the expression, participants who experienced MR gave the longest answers, exceeding both printed sheet and video forms (MR: Printed, $p < .001$; MR:Video, $p < .001$; see Fig. 9(a)). Regarding the variety of vocabulary used, participants who experienced MR narrated more diverse expression, exceeding printed sheet ($p = .004$). However, no significant difference were found between MR and video groups (see Fig. 9(b)). For interview duration, participants who experienced MR maintained sustained expression for a longer period of time than using printed sheet and video (MR: Printed, $p < .001$; MR: Video, $p < .001$; see Fig. 9(c)).

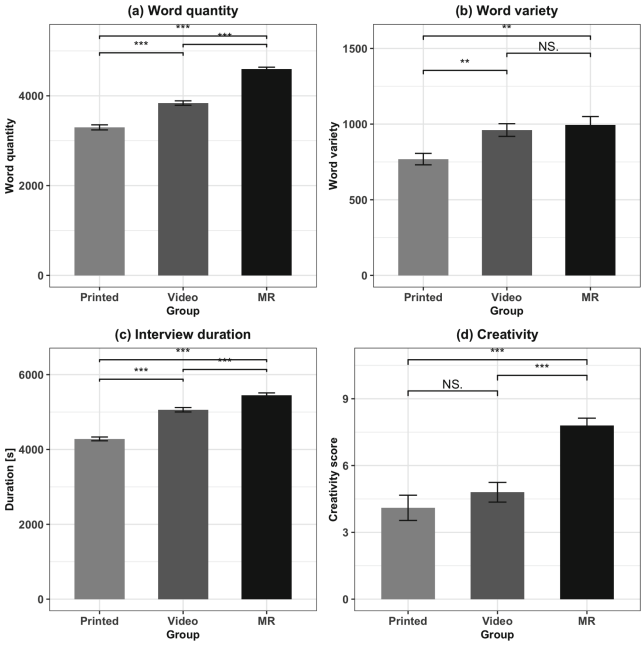

Fig. 9. Results of discourse analysis and creative analysis.

Creative Analysis. The Consensual Assessment Technique was used to estimate the degree of creativity of the interview contents which relies on the judgement of a panel of experts for the evaluation of creative achievement. The panel of experts re-invited the eight experts who had initially participated in the workshop in Shanghai to assess the imagination and rewriting of DF in different forms by three groups of participants. Each of the eight professional experts was first asked to articulate his or her own personal definition of creativity and to define the criteria for measuring it in a series of statements. The declared self-selected criteria of creativity included the concepts of positive thinking, elaboration, surprise, originality, abstractness and novelty. Each expert read the 45 scattered statements and scored according to their own creativity criteria (from 0–10). Then, the average score given by the entire panel of experts was calculated as the score for that statement. Finally, a comparison of the scores within the 3 groups was performed. Participants who experienced MR made more creative expressions when they engaged in subsequent reflection and imagination (MR: Printed, $p < .001$; MR: Video, $p < .001$; see Fig. 9(d)).

4.2 Discussion

The results of the user study and data analysis reflect several findings, which are discussed in this section.

The Use of PDF as a User Research Method. DFs integrates future ideas into everyday life scenarios, providing a starting point for participants' imagination and speculation. The imagination of the participants in the PDF was subtle, profound, and constructive, the results showed that the participants had many creative and reasonable insights in imagining the smart cockpit's connectivity capabilities. The inspirational nature of DFs, as well as the authenticity and immersion, make them a tool in participatory design that provoke participants into delving more in-depth and offering valuable insights.

Immersive Imagination: Presenting DFs in MR. The contextual depiction of the future in DFs is what makes them so important for participants to be able to understand and be motivated quickly. The presentation of DFs in MR further expands the sense of authenticity, immersion and inspiration. On the one hand, for the participants, the immersive experience of DFs in MR was more attractive, and to a certain extent, deepened their understanding and expectations of the technology. On the other hand, for the researchers, the DFs in MR increased participants' willingness to participate and contribute to the study, and the length, richness, creativity, and validity of the expressions were significantly improved.

Future Oriented User Study Needs to Prototype Arguments Repeatedly, Correlatively and Continuously. DFs are meant to stimulate more perspectives and discussions, which can help user study, not as an iteration-oriented usability test, but as a way to create future life scenarios with the wisdom of the group, and then put the group in the scenarios for reflection and discussion. Participants in both the PDF workshop and the MR experience showed enthusiasm for repeated participation, as well as a more in-depth and more detailed imagination.

5 Conclusion

The future life scenarios depicted in DFs can stimulate the viewer's speculations and are particularly relevant to the exploration of innovations affecting interaction design, especially human-computer interaction. Further more, DFs' conjunction with participatory design is considered an effective method for design research. The technical characteristics of MR have driven it to become a key direction for interaction design research and a tool to support design research. MR provides participants with an immersive experience of the future scenarios, allowing researchers to represent concepts that would be difficult to prototype in reality.

For the trend of smart cockpit's connectivity capabilities in the contxet of V2X, this study explored a repeated, correlative, and continuous user study framework, presenting the DFs co-created using MR and maintain the space for the imagination of the participants to gather their views and discussions about the future.

After compiling the interview data, four themes were identified for PDF with MR. First, the value and potential to increase participants' understanding and acceptance of future technology and conceptual design; second, it facilitated participants' imaginations, encouraged expressing, sharing, and discussing in-car features and scenarios; third, it increased participants' interests and expectations, and strengthened their support for future technology and conceptual design; fourth, it captured participants' real perceptions into future technology needs and design opportunities, supporting the conception of new in-vehicle features and services. In addition, MR enhances participants' contributions to the study compared to other forms of DFs to help researchers better understand, more effectively analyze the desirable futures proposed by different groups.

Finally, this study provides a basis for exploring the application of PDF and MR technology, and the integration of the two as a method for future-oriented user study, the opportunity and value of which suggests that this area merits further research explorations.

References

1. Asimov, I.: How easy to see the future. Nat. Hist. **84**(4), 92 (1975)
2. Auger, J.: Speculative design: crafting the speculation. Digital Creativity **24**(1), 11–35 (2013)
3. Barthell, R.J.: Science fiction: a literature of ideas. Extrapolation **13**(2), 56 (1971)
4. Cheng, J.: Astounding wonder: Imagining science and science fiction in interwar America. University of Pennsylvania Press (2012)
5. Dourish, P., Bell, G.: "Resistance is futile": reading science fiction alongside ubiquitous computing. Personal Ubiquit. Comput. **18**(4), 769–778 (2014)
6. Dunne, A.: Hertzian tales: Electronic products, aesthetic experience, and critical design. MIT press (2008)
7. Dunne, A., Raby, F.: Speculative everything: design, fiction, and social dreaming. MIT press (2013)
8. El-Jarn, H., Southern, G.: Can co-creation in extended reality technologies facilitate the design process? J. Work-Appli. Manag. **17**, 1254–1269 (2020)
9. de la Flor Aceituno, D., Giacomin, J., Malizia, A., Skrypchuk, L.: Virtual workshops on the road: co-designing with drivers, within context in real-time. In: Ahram, T., Taiar, R., Colson, S., Choplin, A. (eds.) IHIET 2019. AISC, vol. 1018, pp. 35–41. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-25629-6_6
10. Forlano, L., Mathew, A.: From design fiction to design friction: Speculative and participatory design of values-embedded urban technology. J. Urban Technol. **21**(4), 7–24 (2014)
11. Gilks, M., Fleming, P., Allen, M.: Science fiction: The literature of ideas. Writingworld.com (2003)
12. Hales, D.: Design fictions an introduction and provisional taxonomy. Digital Creativity **24**(1), 1–10 (2013)
13. Kirby, D.: The future is now: diegetic prototypes and the role of popular films in generating real-world technological development. Soc. Stud. Sci. **40**(1), 41–70 (2010)
14. Kirkpatrick, C.J., Fuchs, S., Peters, K., Brochhausen, C., Hermanns, M.I., Unger, R.E.: Visions for regenerative medicine: interface between scientific fact and science fiction. Artif. Organs **30**(10), 822–827 (2006)

15. Knutz, E., Markussen, T.: The role of fiction in experiments within design, art & architecture-towards a new typology of design fiction. Artifact J. Des. Pract. **3**(2), 1–8 (2014)
16. Kohler, T., Fueller, J., Stieger, D., Matzler, K.: Avatar-based innovation: Consequences of the virtual co-creation experience. Comput. Hum. Behav. **27**(1), 160–168 (2011)
17. Lindley, J., Coulton, P.: Back to the future: 10 years of design fiction, pp. 210–211 (2015)
18. Lyckvi, S., Roto, V., Buie, E., Wu, Y.: The role of design fiction in participatory design processes. In: Proceedings of the 10th Nordic Conference on Human-Computer Interaction, pp. 976–979 (2018)
19. Nägele, L.V., Ryöppy, M., Wilde, D.: Pdfi: participatory design fiction with vulnerable users. In: Proceedings of the 10th Nordic Conference on Human-Computer Interaction, pp. 819–831 (2018)
20. Prucher, J.: Brave New Words: The Oxford Dictionary of Science Fiction. Oxford University Press (2007)
21. de la Rosa, S., et al.: Visual appearance modulates motor control in social interactions. Acta Physiol. (Oxf) **210**, 103168 (2020)
22. Sharma, S., Kaushik, B.: A survey on internet of vehicles: applications, security issues & solutions. Veh. Commun. **20**, 100182 (2019)
23. Shen, X., Fantacci, R., Chen, S.: Internet of vehicles [scanning the issue]. Proc. IEEE **108**(1), 242–245 (2020)
24. Tsekleves, E., Darby, A., Whicher, A., Swiatek, P.: Co-designing design fictions: a new approach for debating and priming future healthcare technologies and services. Archives Des. Res. **30**(2), 5–21 (2017)
25. Wang, P., et al.: A comprehensive survey of AR/MR-based co-design in manufacturing. Eng. Comput. **36**(4), 1715–1738 (2020)