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Timo Strohmann
Technische Universität Braunschweig, t.strohmann@tu-braunschweig.de

Dominik Siemon
Technische Universität Braunschweig, Braunschweig, Niedersachsen, Germany, dominik.siemon@lut.fi

Susanne Robra-Bissantz
Technische Universität Braunschweig, s.robra-bissantz@tu-braunschweig.de

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Timo Strohmann

Technische Universität Braunschweig, t.strohmann@tu-braunschweig.de

Dominik Siemon

Technische Universität Braunschweig, d.siemon@tu-braunschweig.de

Susanne Robra-Bissantz

Technische Universität Braunschweig, s.robra-bissantz@tu-braunschweig.de

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Timo Strohmann
Technische Universität Braunschweig
t.strohmann@tu-braunschweig.de

Dominik Siemon
Technische Universität Braunschweig
d.siemon@tu-braunschweig.de

Susanne Robra-Bissantz
Technische Universität Braunschweig
s.robra-bissantz@tu-braunschweig.de

Abstract:

More and more people use virtual assistants in their everyday life (e.g., on their mobile phones, in their homes, or in their cars). So-called vehicle assistance systems have evolved over the years and now perform various proactive tasks. However, we still lack concrete guidelines with all the specifics that one needs to consider to build virtual assistants that provide a convincing user experience (especially in vehicles). This research provides guidelines for designing virtual in-vehicle assistants. The developed guidelines offer a clear and structured overview of what designers have to consider while designing virtual in-vehicle assistants for a convincing user experience. Following design science research principles, we designed the guidelines based on the existing literature on the requirements of assistant systems and on the results from interviewing experts. In order to demonstrate the applicability of the guidelines, we developed a virtual reality prototype that considered the design guidelines. In a user experience test with 19 participants, we found that the prototype was easy to use, allowed good interaction, and increased the users' overall comfort.

Keywords: Systems Design, Virtual Assistant, Design Science, In-Vehicle Assistance.

Christoph Schneider was the accepting guest senior editor for this paper.

1 Introduction

An increasing number of people use virtual assistants (VAs) in their everyday life (McTear, Callejas, & Griol, 2016). These intelligent software programs support users with various concerns while interacting with them in a seemingly natural and human-like way (Skalski & Tamborini, 2007). Numerous VAs that serve different tasks and operate in different contexts exist. For instance, Apple's Siri, Google Assistant, and Microsoft's Cortana operate on mobile phones and use their sensors to better react to specific contextual information. In contrast, VAs such as Amazon Echo and Google Home operate in smart homes and help users fulfill various tasks (Pearl, 2016). Due to the fast growth in the artificial intelligence (AI) and information technology (IT) areas, user assistance will soon become increasingly more intelligent (Morana, Friemel, Gnewuch, Maedche, & Pfeiffer, 2017). While user assistance in the past focused more on helping functions in textual form, personal assistants on mobile phones can now process natural language and react in a human way (Morana et al., 2017; Skalski & Tamborini, 2007). With this growing AI technology, one may even find machines in collaborative settings with humans, which will fundamentally change the way we work with information technology (Seeber et al., 2018). Beyond using VAs on our mobile phones or in our homes, cars represent another promising context in which we can use VAs (e.g., while driving). In this paper, we focus on VAs in the car, which we refer to as virtual in-vehicle assistants.

In the automotive context, researchers have already examined vehicle-assistance systems that proactively support the driver over the past 30 years (Bengler et al., 2014). They began by examining vehicle dynamics stabilization systems such as anti-lock braking systems (ABS) in the 1980s before examining systems for information, warning, and comfort such as navigation systems or adaptive cruise control in the 1990s and 2000s (Bengler et al., 2014). More recently, the development effort shifted to systems for automated and cooperative driving such as collision avoidance or self-driving technology (Bengler et al., 2014). However, we still lack systematic design guidelines and research approaches and agendas for virtual in-vehicle assistants. Designing a voice user interface (VUI), especially for in-vehicle use, has additional challenges compared to designing one for mobile phones or the home (Pearl, 2016). While driving, users have special needs, desires, and pains. To provide a convincing user experience (UX), designers need to tailor the assistant's character, the way the user handles the system, and the functions to a vehicle context (Pearl, 2016).

We address this challenge with our design guidelines since we lack well-formulated and structured guidance to design in-vehicle assistants in particular. Accordingly, we develop design guidelines for in-vehicle VAs that focus on two design activities: representational design and interaction design. According to Benyon (2014), representational design deals with the system's style, aesthetics, and the overall look and feel. Interaction design concerns the allocation of functions to the user or the machine and how the interaction between user and machine will occur (Benyon, 2014). We focus on these two design activities because they significantly affect how users will perceive a system, how easy and enjoyable they will find it to use, and, therefore, the overall UX (Benyon, 2014).

We developed guidelines, which build on prior research in the field and on qualitative expert interviews, following design science research (DSR) principles (Hevner, March, Park, & Ram, 2004). Further, in order to bridge academic research and industry practice, we conducted interviews with experts from the automotive sector who worked on designing and developing in-vehicle assistance.

In this paper, we address the research question (RQ):

> **RQ:** How can one design a virtual in-vehicle assistant that provides a convincing user experience as it concerns representational and interaction design?

The paper proceeds as follows: in Section 2, we discuss the theoretical background on UX and VAs. In Section 3, we describe our research approach and, in Section 4, present our proposed guidelines. In Section 5, we discuss how we assessed the applicability of the design guidelines with a virtual reality (VR) prototype that simulated a car surrounding for users who talked to our implemented virtual in-vehicle assistant. Furthermore, we discuss how we evaluated the prototype in a user experience test with 19 participants. Finally, in Section 6, we discuss our results and conclude the paper.

2 Theoretical Background

2.1 Criteria for a Convincing UX

The ISO standard defines UX as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service" (Wallach, Conrad, & Steimle, 2017, p. 507). Therefore, UX "includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments that occur before, during and after use" (Wallach et al., 2017, p. 507). The UX has a tight correlation with usability as the latter defines how easy users find a product to learn and how effective and enjoyable they find it to use (Rogers, Sharp, & Preece, 2011). Since these criteria also greatly influence how users experience an interactive product, it makes sense to consider usability principles as well when striving to create a convincing UX (Rogers et al., 2011).

To create good usability, designers often refer to Nielsen and Molich (1990) who developed usability heuristics for designing graphical user interfaces (GUIs). Nielsen (1994) refined the heuristics in the following years in several iterations, which resulted into the following ten heuristics: 1) visibility of the system status, 2) the match between the system and the real world, 3) user control and freedom, 4) consistency and standards, 5) error prevention, 6) recognition rather than recall, 6) flexibility and efficiency of use, 7) aesthetic and minimalist design, 8) help for the users to recognize, diagnose, and recover from errors, and 8) help and documentation (Nielsen, 1994).

According to Zhou and Fu (2007), both a product's usability and hedonic aspects can significantly influence the UX. Hassenzahl (2004) confirms as much in arguing that a product has to provide both a set of functional features and an experience to convince users. Emotions and affects represent integral aspects of such an experience (Hassenzahl, Wiklund-Engblom, Bengs, Hägglund, & Diefenbach, 2015). As Schmitt describes, customers want products to "dazzle their senses, touch their hearts, and stimulate their minds" (Schmitt, 1999). Thus, designers should consider UX in this comprehensive way (i.e., as depending on not only a product's pragmatic usability but also its hedonic aspects) during the design process.

2.2 Design Principles for VAs

VAs refer to software programs that fulfill tasks and answer questions for users (Zhao, 2006). Therefore, they can process natural language and interact in a human-like way (i.e., follow social norms for interpersonal communication) (Guzman, 2017; Skalski & Tamborini, 2007; Zhao, 2006). We can summarize systems that interact with their user with natural language as conversational agents (McTear et al., 2016). Many today see the chatbot ELIZA (Weizenbaum, 1966) as the first implemented conversational agent that simulated human conversations. Due to advances in natural language processing and machine learning, chatbots today have far more capability then chatbots from the past, which mainly used simple pattern recognition (Knijnenburg & Willemsen, 2016; McTear et al., 2016; Shawar & Atwell, 2007). In contrast to chatbots, which use a text-based communication approach, VAs use speech (Gnewuch, Morana, Heckmann, & Maedche, 2018). Moreover, VAs assist their users in, for example, fulfilling their everyday tasks (Gnewuch, Morana, & Maedche, 2017; Guzman, 2017). Given that several notable VAs have appeared in recent years (e.g., Siri, Alexa, and Google Assistant), a wide range of users can now use VAs that offer a new way to interact with information systems (Maedche, Morana, Schacht, Werth, & Krumeich, 2016; Pearl, 2016). As voice-based VAs have become more mainstream in recent years (Pearl, 2016), researchers have similarly published more work that focuses on the principles and process of designing VUI. For example, Cohen, Giangola, and Balogh (2004) give advice for designing interactive voice response systems (an early form of VAs that became common in 2000 and helped callers over the telephone with various concerns). Later, Pearl (2016) transferred Cohen et al.'s (2004) findings to voice-enabled mobile phone apps such as Siri, Google Now, Hound, and Cortana, which did not exist in 2004. She gives advice on what to consider when it comes to designing VUIs and includes statements, tips, and best practices from other experts such as Ian Menzies, senior voice UX designer at Amazon Lab126 (Pearl, 2016).

Pearl (2016) mentions some new requirements and challenges that occur when designing VUIs for cars. For instance, she explains that designers particularly need to focus on minimizing the user's cognitive load when designing in-vehicle assistants because conversations with the VA must not distract drivers from the road and traffic (Pearl, 2016). However, the literature does not offer concrete guidelines with all the specifics that one needs to consider to build VAs that provide a convincing UX (especially in a vehicle).

3 Methodology

3.1 Design Science Research

For our integrated research design, we adopted principles from DSR (Hevner et al., 2004), a well-established research approach in the information systems (IS) field (Gregor & Hevner, 2013). We derived the motivation for our research from existing organizational problems and business needs as Hevner et al. (2004) describe in their proposed research framework. We primarily focus on offering researchers and designers guidance in developing and implementing virtual in-vehicle assistants that provide a convincing UX. We developed guidelines following DSR, which focuses on creating innovative and novel artifacts that solve the existing organizational and human problems (Hevner et al., 2004). In contrast to design-based practice in engineering research, DSR relies on an existing knowledge base with applicable theories that help one develop an artifact. Additionally, evaluating and assessing an artifact with existing methodologies that one draws from the knowledge base ensures one rigorously justifies the results and demonstrates the artifact (Hevner et al., 2004). By designing an artifact and subsequently evaluating it, one can contribute to knowledge and theory. The levels of artifact abstraction in DSR vary and range from models, processes, instantiations, methods, or software. Gregor and Hevner (2013) note that any artifact has a specific level of abstraction. An artifact can be described by the two attributes “abstract” and ”specific” and by their general knowledge maturity. A specific and limited artifact (level one), such as software products or implemented processes, contribute situated and context-specific knowledge. An abstract and complete artifact (level three), such as design theories about embedded phenomena, contribute a broad and mature knowledge. Design guidelines and constructs, methods, models, or technological rules (level two) fall between a solely abstract or specific artifact and contribute nascent design theories or operational principles (Gregor & Hevner, 2013).

Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) further developed a nominal process model for conducting DSR in IS. This process model incorporates a systematic procedure and practices and principles to carry out a consistent DSR project. The model focuses on strengthening the degree to which researchers recognize DSR and view it as legitimate and provides guidance for them to conduct and present DSR. Vaishnavi and Kuechler (2007) introduced a similar but reduced process model that includes five steps for conducting a DSR project. The steps include recognizing the problem, suggesting a potential solution for it, actual developing the solution, rigorously evaluating the solution, and drawing a final conclusion.

In the first design cycle in our research project, we followed Peffers et al.’s (2007) DSR approach. In the second and third design cycles, we conducted DSR according to the framework that Vaishnavi and Kuechler (2007) provide since it follows a similar approach but adopts a reduced process model and expanded underlying DSR activities. We compare the two DSR process models in Table 1.

Table 1. Comparing Peffers et al.’s (2007) and Vaishnavi and Kuechler’s (2007) DSR Process Models

<table>
<tr><th>Peffers et al. (2007)</th><th>Vaishnavi and Kuechler (2007)</th></tr>
<tr><td>Identify problem and motivate</td><td>Recognize the problem</td></tr>
<tr><td>Define objectives of a solution</td><td>Suggestion</td></tr>
<tr><td>Design and development</td><td>Development</td></tr>
<tr><td>Demonstration</td><td rowspan="2">Evaluation</td></tr>
<tr><td>Evaluation</td></tr>
<tr><td>Communication</td><td>Conclusion</td></tr>
</table>

While Vaishnavi and Kuechler’s (2007) process includes only the evaluation after the development, Peffers et al. (2007) put demonstration before evaluation. Moreover, Peffers et al. (2007) speak of communication as a last step in the DSR cycle and, therefore, call researchers to face the community. In contrast, Vaishnavi and Kuechler (2007) refer to this step more generally as “conclusion”, which indicates that a specific design project has finished. In fact, they also say that, in the conclusion phase, researchers commonly contribute results in the form of scientific publications. Apart from adopting a similar process model for conducting a DSR cycle, the two frameworks differ in the overall approach to a DSR project. Kuechler and Vaishnavi (2012, p. 396) define three general activities for conducting DSR in IS:

> *1) Construction of an artifact where construction is informed either by practice-based insight or theory, 2) the gathering of data on the functional performance of the artifact (i.e., evaluation), and*

3) reflection on the construction process and on the implications the gathered data (from activity (2)) have for the artifact informing insight(s) or theory(s).

While Peffers et al. (2007) mention the two first activities, they do not explicitly mention reflection (though they do not preclude it). As we conducted several design cycles in our DSR project, we needed to reflect on our process and data we gathered to initiate the iterations.

In our research, we developed two main artifacts in three respective design cycles, which we illustrate in Figure 1. According to Vaishnavi and Kuechler (2007), a DSR cycle can have several DSR outputs in the different process steps. Our design cycles (marked with orange circles in Figure 1) had the following main outputs: requirements for the virtual in-vehicle assistant (1), design guidelines for the virtual in-vehicle assistant (2.1), refined design guidelines for the virtual in-vehicle assistant (2.2), design of the virtual in-vehicle assistant (3), and VR prototype (4).

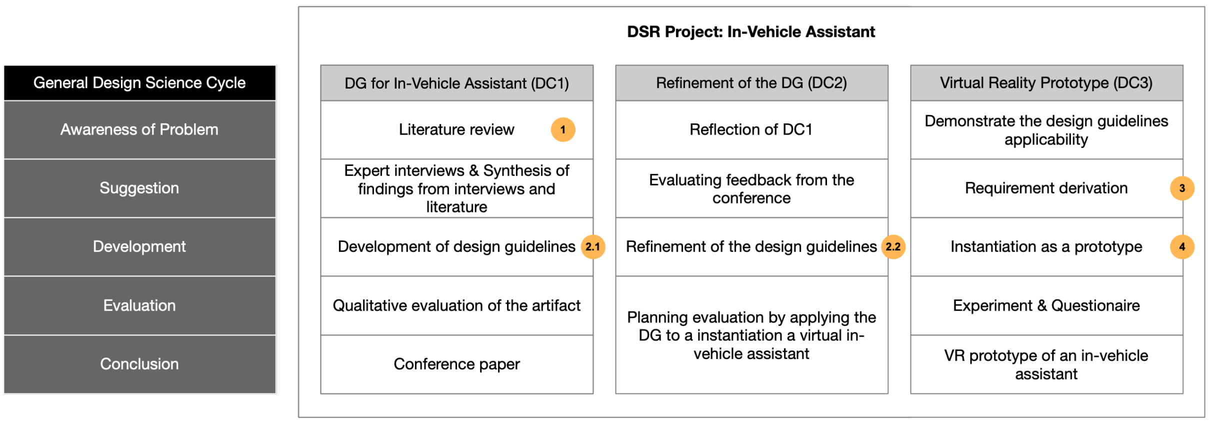

Figure 1. Design Cycles of the DSR Project

According to the artifact levels that Gregor and Hevner (2013) present, our design guidelines for in-vehicle assistants (Output 2.1 and 2.2) constitute a level-two artifact since one can apply them in different contexts and they provide technological rules. They build on prior research in the field and on qualitative expert interviews. To bridge academic research and industry practice, we selected primarily experts from the automotive sector who worked on designing and developing in-vehicle assistants. The VR prototype (Output 4) represents a level-one artifact since it contributes situated and context-specific knowledge.

We used the knowledge base to not only develop the artifacts through existing theories and principles but also to evaluate them through established research methods. Thus, we used methods such as systematic literature reviews (Webster & Watson, 2002), expert interviews (Bogner, Littig, & Menz, 2009; Meuser & Nagel, 2009), exploratory studies, and experiments (Babbie, 2015; Dennis & Valacich, 2001) to design and evaluate the developed artifacts (Hevner et al., 2004).

3.2 Expert Interviews

To design and develop guidelines, it made sense to learn from existing research literature on creating a convincing UX and on what to consider while designing VUIs. In reviewing previous findings, we found some requirements for VAs about providing a convincing UX. As the literature has scarcely dealt with designing in-vehicle assistants in particular so far, we could derive only primarily general assistant requirements from the research literature. Thus, to examine the validity of the derived assistant requirements (especially for in-vehicle assistants) and to generate concrete guidelines for the design, we conducted six expert interviews. Expert interviews have become increasingly popular as a reliable method to gain knowledge that one cannot otherwise easily discover (Bogner et al., 2009; Meuser & Nagel, 2009). We created an interview guide for the semi-structured expert interviews based on the assistant requirements derived from literature research. The interview guide included various questions that examined how valid they found the derived assistant requirements (especially for in-vehicle assistants) and whether we needed to change or extend them. In addition, the interview guide contained questions that addressed how one could implement the derived assistant requirements from literature into a concrete design. A final question offered the opportunity for the interviewees to mention additional assistant requirements or design implications that the literature had not covered or we had not considered so far.

3.2.1 Expert Interview Participants

In selecting the six interviewees, we focused on ensuring that we included participants with various (i.e., a design, psychological, and technological) perspectives on designing in-vehicle assistants. Expert 1, a psychologist, dealt with psychological topics in human-machine interactions (especially in vehicles). Expert 2 also dealt a lot with psychological topics during his studies, but, in comparison to Expert 1, he had a more technological background as he earned his doctorate in automotive engineering. Expert 3, an electrical engineer and project manager, worked for a software-development company in the automotive sector, where he researched and developed speech assistants. Expert 4 dealt with UX design in vehicles and coordinated UX design workshops for VAs. Since we conducted this study in an automotive company context, we interviewed individuals who designed and developed VAs in and around vehicles in their projects. To prevent bias, we also interviewed an independent machine-learning and speech-recognition researcher (Expert 5). Finally, we interviewed a UX designer (Expert 6) to evaluate the design guidelines we created with help from the first five experts. The following table summarizes the experts and their background and qualifications.

Table 2. Experts

Expert	Background and qualifications
1	**Psychologist** Focus on human-machine interaction especially in vehicles
2	**Doctorate in automotive engineering** Focus on human-machine interaction, relation to psychology
3	**Electrical engineer** Project manager for research and development of speech assistants
4	**UX designer** Holistic UX design in vehicles and design of VAs
5	**Researcher** Machine learning and speech recognition
6	**UX designer** UX design in several VA projects

3.2.2 Expert Interview Analysis

We recorded the expert interviews with the first five experts with an audio recorder to capture all the details in order to transcribe them afterwards. We analyzed the interviews based on Meuser and Nagel's (2009) approach: after the transcription, we paraphrased thematically relevant passages. Next, we used the descriptive coding approach. As Miles, Hubermann, and Saldaña (2014) explain, a descriptive code labels a unit of qualitative data with one word or phrase that summarizes its main topic. We inductively created the applied codes, which means that they progressively emerged as we collected data (Miles et al., 2014). Specifically, the first author and a research assistant separately conducted the coding and discussed and aggregated their results after each coding cycle. In sum, 40 codes grouped into 15 categories evolved during the coding session. After coding, we compared the experts' statements and linked thematically comparable passages together (Meuser & Nagel, 2009). We condensed commonly shared expert knowledge regarding the particular topics and connected it to the academic discourse. By relating the results from the expert interviews to the findings in the literature, we ensured that we produced true and relevant assistant requirements for providing a convincing UX for in-vehicle VAs. We extended some requirements and added some additional requirements.

3.3 Development of Design Guidelines

Based on the assistant requirements that we derived from literature and the interviews with the first five experts, we developed concrete design guidelines for virtual in-vehicle assistants to help designers fulfill the assistant requirements and, therefore, provide a convincing UX with an implemented VA. For the evaluation, we evaluated the design guidelines with the final expert (Expert 6) who worked on designing the UX for different VA projects for a large German automaker. Having a lot of practical experience with designing VAs, we asked this expert to suggest improvements and to add missing design guidelines. We used her feedback to evaluate the artifact. After the evaluation, we refined the design guidelines with the new insights following Peffers et al.'s (2007) iterative DSR methodology.

After presenting the guidelines to the research community, we refined them in a second design cycle (see Figure 1).

3.4 Virtual Reality Prototype

To show that the design guidelines applied to a real-world scenario (Hevner et al., 2004), we implemented a VR prototype of a virtual in-vehicle assistant based on our proposed design guidelines. Therefore, we defined eight different possible scenarios that might naturally occur while driving a car. We evaluated the prototype in a user experience test with 19 participants, who we subsequently asked for their experiences with and perceptions of the virtual in-vehicle assistant.

4 Design Guidelines

In this section, we present the evaluated and refined guidelines for designing virtual in-vehicle assistants. To provide a clearly structured overview, we cluster the guidelines in four thematically related blocks. Thus, while Table 3 focuses on guidelines for representational design, we divide the guidelines for interaction design into design guidelines for intuitive conversation (Table 4), simple and transparent operation (Table 5), and companionship (Table 6). All four tables summarize the assistant requirements for a convincing UX that we derived mainly from the existing research literature and then refined and extended according to the expert interviews and feedback we obtained from researchers at the Hawaii International Conference on System Sciences (Strohmann, Höper, & Robra-Bissantz, 2019a). Readers can find references to experts' (E) and conference reviewers' (CR) statements in the fourth column in each table. At their core, the tables present the evaluated design guidelines for in-vehicle assistants that will help designers to fulfill the assistant requirements and to provide a convincing UX. To simplify using the guidelines in practice, we prioritize some guidelines based on our findings from analyzing the expert interviews. In the four tables, we bold the guidelines that practitioners should focus on in particular.

Two requirements that have particular salience for in-vehicle assistants compared to assistants in other contexts: Requirement 7 (which refers to reducing users' cognitive load)) and Requirement 14 (which refers to proactive behavior). The experts suggested various vehicle-specific use cases where proactivity could vastly increase users' experience with a VA in a vehicle. For example, according to Expert 5, the user would find it pleasant if a VA proposed an alternative route in a timely manner before the user became stuck in a traffic jam. Expert 2 suggests that, if the VA had access to the technical vehicle data, it could proactively warn users if something needed their attention. To conclude, compared to designing virtual assistants for other contexts, designers should particularly focus on Guidelines 7.1 to 7.4 and 13.1 to 13.4 when designing assistants for in-vehicle use.

As we state in Section 3.3, we refined the guidelines in a second design cycle after we presented them to the research community at the Hawaii International Conference on System Sciences (HICSS). We made the following refinements and additions to the design guidelines based on the feedback from the community:

- We added trust as a topic (see Requirement 11) and corresponding design guidelines (see Section 4.3.4)
- We added the companionship concept (see Section 4.4.1)
- We added the different possible automotive contexts (see Section 4.4.4)
- We added the possibility that users would take the VA into another car (see Section 4.4.4), and
- We added further supporting literature.

4.1 Guidelines for Representational Design

4.1.1 Personality and Background Story

As Table 3 shows, Pearl (2016) and Cohen et al. (2004) note that a VA needs a consistent personality and a background story to provide a convincing UX (Cohen et al., 2004; Pearl, 2016). All the experts supported that one could improve UX if a VA had a personality because it would allow the VA to build emotional rapport with the user; provide hedonic, playful, and surprising aspects; and make the VA more fun to use. To ensure consistency, designers can create a persona for the VA, which includes a name, background story, and personality traits, during the whole design process. For the background story, Experts 2 and 4 recommended that designers should not try to imitate a humane biographical sketch but rather integrate fictional descriptions. When it comes to defining personality traits, no expert could describe an ideal personality for a VA because it depends on a user's preferences. According to Expert 2, comprehensive user research can help designers to tailor a VA's personality to particular customers. It would be even better if the personality suited individual users and their moods in certain situations by evolving certain personality traits over time based on how the users interacted with the VA. In this case, predefined borders can help designers ensure that the character still represents the brand values.

4.1.2 Voice and Linguistic Register

A VA's voice and linguistic register represents another aspect that great influences the VA's look and feel. Cohen et al. (2004) note that "[w]hatever you decide in terms of the most appropriate register for your application, make sure that it's exercised consistently throughout your dialog" (Cohen et al., 2004, p. 163). All the experts believed that, when designing the linguistic register, designers should take advantage of the conversational norms that users already recognize in order to let the conversation appear more natural. Thus, the VA should use rather informal everyday language though still represent the brand image. For a convincing UX, it makes sense to reflect the user's word choice in how the VA speaks. Nevertheless, Expert 6 warned that designers have to ensure that the VA does not allow someone to manually approve which expressions the VA learns to avoid it from learning undesirable words (filtering).

4.1.3 Visual Appearance and Humanity

According to Pearl (2016), designers need to consider whether a VA should have a visual representation. Experts 2, 3, and 4 recommended that a VA should have some kind of visualization because the user needs something to turn towards while speaking and because the VA can use it to give visual feedback. By clarifying the system's different modes (e.g., VA is listening), visual feedback can help users to handle the interaction and to understand the system.

The experts also advised designers to not use an avatar or a human-like visualization but something more abstract such as a flickering light. This advice refers to a concept called the "uncanny valley" that Masahiro Mori invented in the 1970s. Mori (2012) says that a robot with a human-like appearance can make people feel eerie and even fooled when they learn the robot is not a real human. As such, Expert 2 pointed out that a VA should honestly communicate that it is not a human. As Mori invented the uncanny valley theory by observing robots, it does not encapsulate the complexity of situations that feature interactivity as recent findings have shown (Seymour, Riemer, & Kay, 2017). These insights apply to the virtual in-vehicle assistant because the user interacts with it. If a user prefers a more realistic design, designers might follow Seymour, Riemer, and Kay's (2019) suggestions for designing realistic agents. To avoid raising false expectations, the VA should also communicate that it is just a machine with a limited range of functions. If something falls outside its domain, the VA should clearly state that it cannot help with the topic. While evaluating the guidelines, Expert 6 suggested that the VA could show human errors and idiosyncrasies while talking because they can make the conversation appear more natural and the VA more lovable. Here, designers have to consider whether a VA that mistakenly delivers the wrong content or conducts the wrong function would rather cause users to mistrust it.

Table 3. Guidelines for Representational Design

Assistant requirements	Supporting literature	Design guidelines for in-vehicle VAs	Experts
1. An in-vehicle VA needs a consistent personality and a background story.	Cohen et al. (2004, pp. 78, 82) Pearl (2016, p. 72)	1.1. Create a persona for the VA (name, background, personality) and use it as a style guide during the whole design process.	E1-5
		1.2. Do not try to imitate a humane biography with the VA's background story but rather integrate fictional descriptions.	E2 & 4
		1.3. Predetermine one or a few personalities based on user research results and brand values.	E2-4
		1.4. Let the VA evolve some character traits more than others within predefined borders depending on the interaction with the user.	E1

Table 3. Guidelines for Representational Design

2. An in-vehicle VA has to use a consistent voice and linguistic register.	Cohen et al. (2004, p. 163)	2.1. Decide if the VA should have a default voice or if the user should have the choice between various different voices.	E1-3
		2.2. Take care that different voices also imply different personalities.	E6
		2.3. Use conversational norms that users find familiar.	E1-5
		2.4. Use casual and informal everyday language but ensure that the VA still represents the brand image.	E1 & 4
		2.5. Reflect the user's word choice in the VA's utterances (with filtering).	E1, 2, 4, & 6
		2.6. Allow the VA to evolve a different conversation style and register after some time interacting with the user.	E6
3. An in-vehicle VA needs a visual representation.	Pearl (2016, p. 71)	3.1. Use an abstract and not a human-like VA visualization.	E2-4
		3.2. Give visual feedback.	E3-4
4. An in-vehicle VA should not pretend to be a human.	O'Neill (2018) Villar (2017)	4.1. Communicate honestly that the VA is not a human.	E2
		4.2. Be transparent about the VA's limitations.	E6
		4.3. Integrate human errors and idiosyncrasies regarding how the VA talks but not regarding content or functions.	E2 & 6

4.2 Guidelines for Interaction Design: Intuitive Conversation

4.2.1 Detecting Voice Interaction

As Table 4 shows, an important design decision concerns how the in-vehicle assistant knows when to listen and react to users (Pearl, 2016). Most of today's voice assistants require users to explicitly indicate when they want to speak to the system, such as by using a push-to-talk button or a wake word (Pearl, 2016). Researchers have begun to focus on discovering new methods that involve interpersonal interaction behavior.

As Experts 2, 3, and 4 explained, people indicate to whom they are talking by, for example, looking at the person, calling a name, or saying specific things such that a listener recognizes themselves as the addressee. They propose that, at best, the VA should use these conventions and calculate the likelihood that users will address it in a certain situation by combining relevant information.

4.2.2 Navigation in the Conversation

Every expert had the same opinion on one point: that designers need to design the VA in such a way that the interaction with it resembles interpersonal communication (e.g., as natural and intuitive interaction as possible). To allow users to simply navigate the conversation with a VA, designers need to integrate the functions undo, repeat, help, and stop into it. To create a convincing UX, the VA should ideally understand not only short commands but also more natural speech. As Expert 6 noted, the conversation should not rely on a static dialog flow but on more flexible dialogs that allow users to access it at any point.

Table 4. Guidelines for Interaction Design: Intuitive Conversation

Assistant requirements	Supporting literature	Design guidelines for in-vehicle VAs	Experts
5. An in-vehicle VA has to detect when users address it.	Pearl (2016, p. 152)	5.1. Learn from interpersonal communication how people initiate conversations and transfer patterns to the human-machine interaction.	E2-4
		5.2. Collect information to calculate how likely a user will be to address the VA in a certain situation.	E3
		5.3. Be transparent about the functionality of active listening and observing and enable the user to shut the system off completely.	E6

Table 4. Guidelines for Interaction Design: Intuitive Conversation

6. An in-vehicle VA has to enable intuitive conversation.	Nielsen (1995) Pearl (2016, p. 226)	6.1. Learn from interpersonal communication to design the interaction to be as natural and intuitive as possible.	E1-6
		6.2. Integrate at least the functions undo, repeat, help, and stop.	E3
		6.3. Let the VA understand short commands and say something in a more natural way.	E2, 3, 5
		6.4. Design flexible dialog that allow the user to access the conversation at any point.	E6

4.3 Guidelines for Interaction Design: Simple and Transparent Operation

4.3.1 Minimizing Cognitive Load

Table 5 summarizes the guidelines for designing a system's operation and control aspects. In cars in particular, VAs need to minimize the extent to which they distract users to avoid distracted driving (Pearl, 2016). Expert 5 argued that the more activities a VA can accomplish for users, the less the VA will distract them from their actual task (i.e., driving the car). Nevertheless, listening and speaking still adds cognitive distraction (Pearl, 2016), which explains a VA should provide crisp and clear messages that focus on the most important information (Pearl, 2016). In order to not overwhelm users while they communicate with a VA, it makes sense to break down information and processes into small pieces and to provide next steps sequentially (Moore, Arar, Ren, & Szymanski, 2017). Trying to explain complex information through the VUI makes it still unnecessarily complicated for users. In such situations, Expert 4 recommended showing additional visual feedback on the car's infotainment screen to clarify the VA's utterances. Nevertheless, designers should try to use the GUI while driving as less as possible to avoid distracting the driver (Pearl, 2016).

4.3.2 Providing Help

In general, a user does not necessarily know what a VA can do and which voice commands it understands because it does not show its functionalities on a screen (Cramer & Thom, 2017). Therefore, VAs need to be able to inform users about their functionalities (Moore et al., 2017). According to Expert 6, an in-vehicle VA also has to have this information available if the user asks for it.

Further, Expert 6 added that setting expectations about a VA's functionalities in the onboarding process can help users to learn what to ask for. In addition, Expert 1 recommended that a VA could proactively inform users about certain functions that they have not used before if it fit the current situation. In line with Cohen et al. (2004), Expert 2 suggested that the VA should give just-in-time instructions for the imminent activity if needed. Here, the VA should not exaggerate and permanently teach the user how to answer because, in the best case, the user should be able to answer intuitively (Giangola & Cao, 2017).

4.3.3 Feedback and System Familiarity

As Table 5 presents, a convincing UX needs to gives appropriate feedback in a reasonable timeframe to keep users informed (Nielsen, 1995). Designers have to define how much feedback the VA should give about what it understands and about its actions (Pearl, 2016). The possibilities range from explicitly asking users for their permission, to only letting them know what the VA recognized by repeating what the user said, to just doing it without revealing what the VA has understood (Pearl, 2016). Expert 2 emphasized that, even if the VA gives no feedback, it still has to be able to explain what it did and why it did it if the user asks for it.

According to Experts 2 and 3, which kind of feedback is appropriate in a certain situation depends on how confident the VA is that it understood correctly and how critical a mistake and its consequences would be. Further, how familiar the user already is with the system represents another factor that influences how much the feedback should give. Expert 2 noted that it makes sense to let the VA give less and less feedback over time for functions that users use on a regular basis. In general, Experts 1-5 argued that an in-vehicle VA should provide more explanations for novice users and reduce the amount and extent step by step. Nevertheless, Expert 6 explained that, if people do not trust the system, they might want the VA to tell them exactly what the VA understood and what it did although they are already familiar with it. In such case, the VA has to figure out this personal preference in order to behave appropriately.

4.3.4 Trustful and Transparent Environment

When interacting and working with ISs of all kind, trust represents a highly important aspect (Schroeder & Schroeder, 2018). In particular, privacy concerns often arise when VAs require a significant amount of personal information from users (Saffarizadeh et al., 2017). However, the more information users reveal, the more value they will get from the VAs. This reciprocal self-disclosure highly relates to trust; therefore, designers need to implement it in a VA so that it openly communicates what data it needs to generate a value. Knowing why a system needs what kind of information therefore increases users' trust in and uncertainty about the system (Saffarizadeh et al., 2017).

A consistent relationship (which includes a consistent voice, appearance, and mode of interaction) that builds over time also fosters users' trust in VAs (Schroeder & Schroeder, 2018). Such a relationship also increases how well users generally perceive the system's expertise, which, in turn, creates trust and lowers uncertainty (Elson et al., 2018). Yu et al. (2018) propose a taxonomy for building ethics into AI including aspects for human-AI interaction, which states that AI should not violate the user's autonomy.

4.3.5 Error Handling

Designers have to develop a good strategy to handle errors because they one cannot completely prevent them (Pearl, 2016). First of all, Experts 3, 4, and 5 pointed out that the system should recognize when it understands something incorrectly or that something falls outside its domain to avoid undesired actions. However, repeatedly admitting "Sorry, I don't understand" would also not appear intelligent. Expert 1 suggested that, if the VA at least understood part of what the user said, it could react accordingly and give feedback about what it did not understand by using a simple request. When the VA repeatedly does not understand what the user says or if it recognizes that it cannot help the user with a certain problem, Expert 3 suggested that it could transfer the user to a human customer service agent. An emergency situation (such as a car accident) also represents another use case where it makes sense to automatically call a human agent.

Table 5. Guidelines for Interaction Design: Simple and Transparent Operation

Assistant requirements	Supporting literature	Design guidelines for in-vehicle VAs	Experts
7. An in-vehicle VA has to minimize the user's cognitive load.	Cohen et al. (2004, p. 119) Moore et al. (2017, p. 5) Pearl (2016, p. 226)	7.1. Let the VA accomplish as many activities for the user as possible.	E5
		7.2. Ensure the VA provides crisp and clear messages that focus on important information.	E4
		7.3. Break down information and processes into small pieces and provide next steps sequentially.	E4
		7.4. Recognize the situational context to choose the best way to provide content (VUI or GUI).	E2, 4
8. An in-vehicle assistant has to be able to inform the user about what it can do.	Cohen et al. (2004, p. 127) Cramer & Thom (2017, p. 3) Moore et al. (2017, p. 5) Pearl (2016, p. 65)	8.1. Create an additional app or a website to inform users about functionalities but also allow the VA to have this information available.	E6
		8.2. Set expectations about functionalities in the onboarding process.	E6
		8.3. Inform the user proactively about certain unused functions tailored to the current situation.	E1
		8.4. Let the VA give just-in-time instructions for the imminent activity if needed but do not permanently teach the user how to answer.	E2

9. An in-vehicle VA has to give appropriate feedback within reasonable time.	Nielsen (1995) Pear (2016, pp. 144, 226)	9.1. Define how much feedback the VA should give about what it understands and does.	E2-3
		9.2. Define if and how the user should confirm the VA's actions.	E3
		9.3. Determine appropriate feedback based on how confident the VA is that it understood correctly, how critical a mistake and its consequences would be, and how familiar the user is with the system.	E2-4
		9.4. Take care that the VA is always able to be transparent about what it did and why it did it.	E2
10. An in-vehicle VA has to tailor the interaction style to the user's familiarity.	Cohen et al. (2004, p. 207) Nielsen (1995) Pearl (2016, p. 47)	10.1. Let the VA change the way that users give feedback over time for functions that they are already familiar with.	E2-4
		10.2. Provide more explanations for novice users and reduce the amount and extent step by step.	E1-5
11. An in-vehicle VA has to create a trustful and transparent environment.	Elson, Derrick, & Ligon (2018, p. 4) Saffarizadeh, Boodraj, & Alashoor (2017, p. 2) Schroeder & Schroeder (2018, p. 477) Strohmann et al. (2018, p. 7) Yu et al. (2018, p. 2)	11.1. Let the VA detect the extent to which the user trusts the system to be able to fit its interaction style to the user's trust level.	E6
		11.2. The VA should incorporate reciprocal self-disclosure by transparently explaining why it needs specific (personal) information in order to generate specific value for the user.	CR
		11.3. The VA should have a consistent voice, appearance, and mode of interaction (preferably voice communication) in order to build trust, establish a relationship, and demonstrate expertise.	CR
		11.4. In order to build trust, the VA should maintain and signalize full autonomy to the user.	CR
12. An in-vehicle VA has to prevent errors but in case also needs a good strategy of handling them.	Cohen et al. (2004, p. 228) Nielsen (1995) Pearl (2016, p. 41)	12.1. Try to prevent errors as much as possible but also create a good strategy for handling the errors if they occur.	E1-2
		12.2. Make sure the system recognizes when it misunderstands something or when something falls outside its domain to avoid undesired actions.	E3-5
		12.3. Create charming responses for when something falls outside the VA's domain.	E2
		12.4. Instead of repeatedly admitting "Sorry, I don't understand", let the VA react to parts that it recognized and enquire about what it did not understand.	E1
		12.5. Enable the VA to ask further questions to elicit information that it needs to conduct a certain task.	E1, 3-5
		12.6. Help the user after a certain number of errors if something falls outside the VA's domain or in critical situations by transferring the user to a human customer service agent.	E2-5

4.4 Guidelines for Interaction Design: Companionship

4.4.1 The Concept of Virtual Companionship

In this section, we look at the requirements for the virtual in-vehicle assistant that make it more a human companion than a technical assistant. Strohmann, Siemon, and Robra-Bissantz (2019b) introduced the virtual companionship concept as an evolution of the virtual assistant. They defined the virtual companion as "a conversational, personalized, helpful, learning, social, emotional, cognitive and collaborative agent, that interacts with its user proactively and autonomously to build a long-term relationship" (Strohmann et al., 2019b). In fact, the virtual companion covers a virtual assistant's characteristics but crucially extends them with more collaborative, companion-like, and human-like characteristics. We introduce such characteristics (e.g., understanding emotions, empathy, proactive behavior, and context awareness) in the following sections. This companion approach can additionally fosters trust since it focuses on building a benevolent long-term relationship over time between the user and the system (Schroeder & Schroeder, 2018).

4.4.2 Emotions and Empathy

As we describe in Section 2.1, a product has to provide both functional features and an experience to convince users (Hassenzahl et al., 2015). Emotions and moods influence how people experience situations and how they interact in them (Nass et al., 2005). A VA can recognize the user's emotions by analyzing gestures, facial expressions, text, voice tone, and physiological signs such as heart rate or skin changes (Noga, Saravana, & Overby, 2017).

To convey the image of an emotionally intelligent assistant, a VA has to not only detect the user's emotions and mood but also react to them appropriately (Noga et al., 2017). Expert 1 suggested that designers should let the VA tailor its communication style and what it says to the user's mood and to possible issues in the current situation. The VA could also react to the user's emotional state via showing emotions itself. However, Experts 1-4 warned designers to take care that, while showing emotions, the VA still has to focus on assisting the user and that it does not behave inappropriately, ridiculously, or strangely. Expert 1 clarified that it depends on the situation and on the individual user (e.g., the user's mood) if showing emotions has a positive or rather a negative effect. Thus, Expert 6 recommended that designers preset how emotional the VA should be in general but to allow flexible adjustment in some extent.

4.4.3 Proactivity

Expert 5 noted that designers can increase UX if a virtual in-vehicle assistant proactively tells the user something that makes the user's life easier or that prevents the user from unpleasant situations. In some situations, proactively addressing the user can even improve driving safety. For instance, Expert 3 suggested that, if the user is not concentrating on the road and a critical traffic situation occurs ahead, the VA can warn the user to prevent a possible accident. Especially during long travels, an in-vehicle assistant can help to keep the driver awake and attentive.

Experts 3 and 4 noted that users could also benefit from a VA that not only proactive speaks but also proactively acts in some situations. Users may find it pleasant if a VA learns about their preferences and does things that they normally want the VA to do automatically after a few times. However, Experts 1 and 2 noted that the VA has to recognize the context and the user's individual preferences to decide whether a proactive utterance or action is appropriate in a certain situation because proactivity can also annoy or distract the user. According to Expert 6, it makes sense to learn from the feedback the user gives to detect the contents and situations in which the user is open to proactive behavior.

4.4.4 Context Awareness

According to Pearl (2016), "[o]ne reason many virtual assistants…currently struggle with conversational UI is because they lack context" (Pearl, 2016, p. 153). Experts 1-5 agreed that the VA needs to recognize the situational context to behave appropriately. Expert 1, for example, said that:

> *The VA has to be aware of the situational context (e.g., the user's mood and aims, the traffic situation, if multiple people are in the car etc.)…to be able to behave appropriately (e.g., regarding showing emotions, behaving proactively and to not always feel addressed).*

Since users can experience various situations when driving a car, the VA should analyze and keep in mind several different context factors and compositions of such factors when interacting with them. Helmholz (2015) conducted a study to explore different possible automotive contexts (see Figure 2) and structured them in a diagram with the three main context categories: place, time, and identity.

The three main categories also contain several subcategories and relevant characteristics. The figure shows the different characteristics of the overall context and illustrates its complexity. When designing a VA, designers must consider the various possible context characteristics. If drivers enter a stressful situation, the VA should not address them at the same time. In contrast, if a driver drives a long distance relatively monotonously straight ahead, the VA can certainly provide entertainment.

Moreover, the VA also has to remember things about the user and their previous conversations/interactions. The VA might even collect knowledge about the user from other data sources such as the user's calendar to provide a more holistic user assistance. Beyond that, a user should be able to move the VA into another car. Expert 6 noted that designers have to take care that the VA does not bring up something in the conversation that it talked about with the user a few weeks ago and that a human would not be able to remember anymore since it could appear creepy and not human like. Thus, designers have to define after which period of time a VA should not refer to a certain memory again towards the user.

Figure 2. Automotive Contexts According to Helmholz (2015)

Table 6. Guidelines for Interaction Design: Companionship

Assistant requirements	Supporting literature	Design guidelines for in-vehicle VAs	Experts
13. An in-vehicle VA has to have the ability to recognize, understand and react appropriately to emotions.	Hassenzahl et al., (2015, p. 531) Nass et al. (2005, p. 1973) Noga et al. (2017) Pearl (2016, p. 146)	13.1. Recognize the user's emotions by analyzing gestures, facial expressions, text, tone of voice and physiological signs of mood such as heart rate or skin changes.	E1, 5
		13.2. Tailor the VA's communication style and the content of what it says to the user's mood and to possible pains in the current situation.	E1
		13.3. Preset how emotional the VA should be in general but allow flexible adjustment in some extent based on the user's preferences, his mood and the current situation.	E6
		13.4. Take care that the VA still focuses on assisting the user so that it does not react emotionally if it is inappropriate, ridiculous or strange.	E1-4

Table 6. Guidelines for Interaction Design: Companionship

14. An in-vehicle VA has to figure out the right situation for proactive behavior.	Strohmann et al. (2018, p. 7)	14.1. Use proactive behavior to make the user's life easier, prevent him from unpleasant situations or improve his driving safety.	E2-5
		14.2. Learn from the user's preferences and habits to let the VA do things automatically.	E2, 4
		14.3. Be aware of the context and the user's individual preference to decide when and how to say or do something proactively.	E1-2
		14.4. Learn from the feedback the user gives to detect the contents and situations in which the user is open for proactive behavior.	E6
15. An in-vehicle VA has to be aware of the context.	Pearl (2016, p. 153)	15.1. Take care that the VA is aware of the situational context to be able to behave appropriately within the interaction with the user.	E1-5
		15.2. Let the VA memorize things about the user and the interaction with him from previous conversations (preferences, behavior patterns).	E1-5
		15.3. Take care that the VA will not bring up or refer to something they talked about a few weeks ago that a human would not remember.	E6

5 Virtual Reality Prototype of an In-Vehicle Assistant

5.1 Design of the Virtual In-vehicle Assistant

In order to show that the design guidelines we developed could apply to a real problem, we developed a prototype for a virtual in-vehicle assistant in a third design cycle (see Figure 1). Before we instantiated the virtual in-vehicle assistant, we designed the overall VA concept using Strohmann et al.'s (2019b) Virtual Companion Canvas (VCC), a tool to design collaborative agents. As we state in Section 4.4.1, the virtual companionship concept extends the VA concept, and, therefore, covers all of a VA's characteristics. With the canvas approach that the VCC adopts, we could creatively, collaboratively, and visually conceptualize our virtual in-vehicle assistant as separate from the technological implementation. We designed the VA together as a team by following our design guidelines that we present in Section 4. By using the VCC, we could discuss the different features our virtual in-vehicle assistant could have. Furthermore, we could develop a shared understanding about what design guidelines to demonstrate in the instantiation. We present the resulting VCC in Appendix A. After we designed our VA in the VCC, we began implementing the instantiation.

5.2 Development of a Virtual Reality Prototype

Since we could not feasibly develop and conduct a user experience test of a virtual in-vehicle assistant in a real-world scenario given road traffic and other factors, we developed a VR prototype. In our case, by using a virtual environment, we could create what Witmer and Singer (1998) describe as immersive presence, also known as immersion, which refers to the perception that one exists in a certain place while physically in another. By creating a virtual in-vehicle environment, we could let the participants feel like they actually sat in a car and interacted with an in-vehicle assistant while keeping them in a controlled test setting.

We used the Web-based tools Figma[1] and VRooms[2] to design the virtual vehicle's cockpit. Figma, an interface design application, allows one to design, prototype, and collaborate with others directly in the browser. With VRooms, an add-on for Figma, one can easily design a virtual room in 2D without executing or compiling VR code. The virtual car cockpit displayed the VA in the center console where the radio usually resides. Since interaction with the VA during a car ride mainly occurs via communication, we limited the designed scenarios to a conversation. Therefore, we created eight possible scenarios that naturally occur

[1] https://www.figma.com/
[2] https://vr.page/

when one drives a car (see Table 7). Each scenario comprised several possible contexts according to the classification we introduce in Section 4.4.4. For each scenario, we designed an interaction with the VA while considering our different design guidelines and implemented it using Google's conversational service Dialogflow[3].

Table 7. Car Scenarios of Our Prototype

Scenario	Context
1	**Route** (Street type): Highway **Route** (Traffic): Low traffic **Start and Destination** (Address): Berlin
2	**Environment** (Weather): Cold outside
3	**Environment** (View): Poor visibility
4	**Route** (Signs): Waiting at traffic light **Mission** (Time): Morning **Start and Destination** (POI): Work
5	**Route** (Signs): Waiting at traffic light **Mission** (Time): Evening **Start and Destination** (POI): Home
6	**Environment** (Weather): Cold **Route** (Street condition): Frozen
7	**Passengers** (Number): Several
8	**Event**: Tire change is necessary

For example, the fourth context demonstrated how the VA learns from the driver's habits and automatically recognizes when the driver has begun to drive to work. The VA greets the driver and reminds the driver about upcoming work appointments. Moreover, we considered scenarios in which the environment might influence the driver, such as poor visibility due to the weather (third context). In this case, we showed that the VA could not only recognize the environment and explain the car's functions to the driver but also autonomously and proactively switch on things such as the car's headlights.

Figure 3 shows an exemplary conversation for the first context (highway, low traffic, navigation to Berlin). At the top, the VA initiates the conversation. Subsequently, it gives the driver some information about the driver's destination to provide some entertainment on the monotonous highway ride. The VA then remembers that the driver searched for a place to eat the day before and asks to reserve a table for dinner. The yellow boxes indicate the design guidelines we used to design the interaction at each step in the conversation.

[3] https://dialogflow.com/

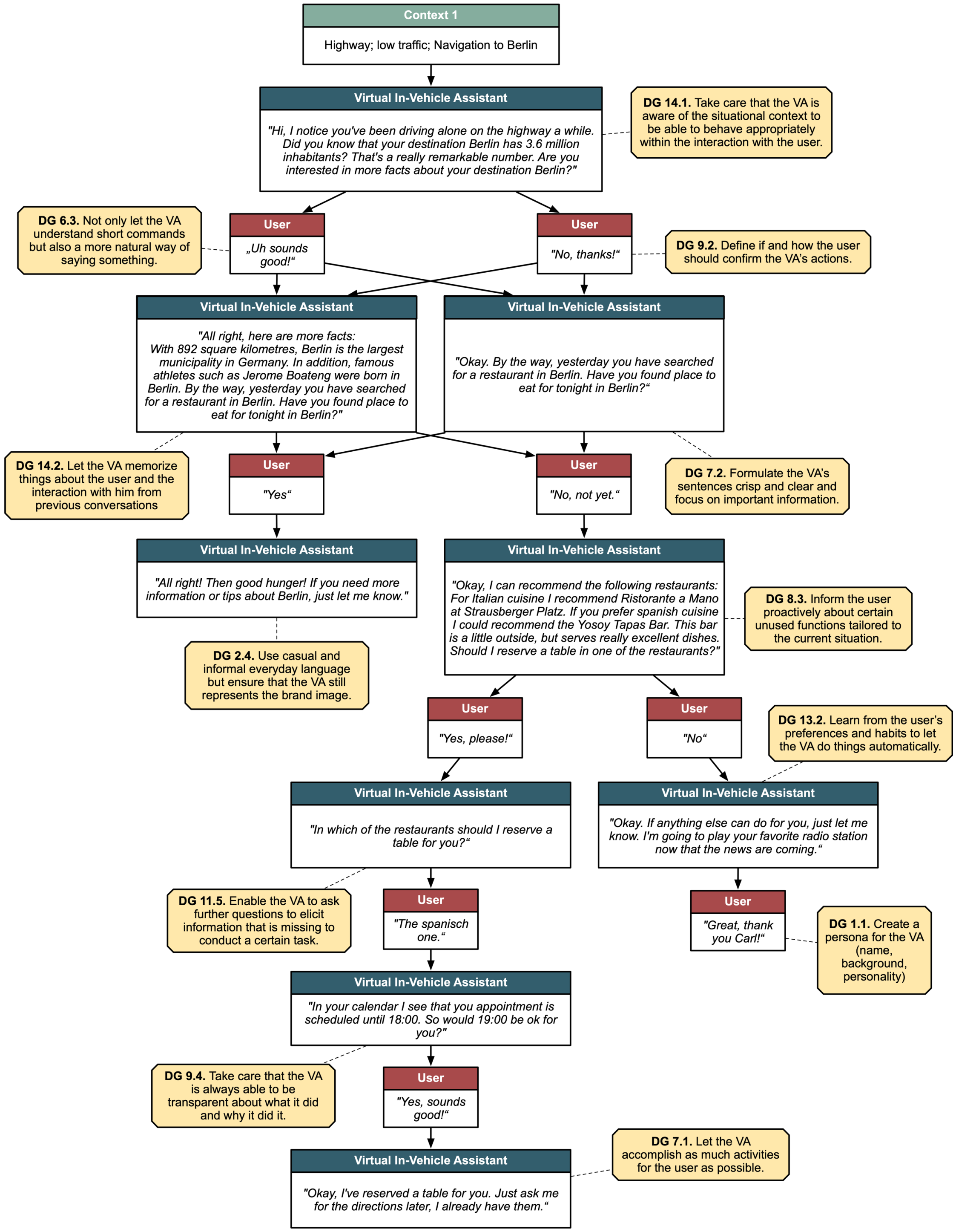

Figure 3. Exemplary Conversation with the Virtual In-vehicle Assistant

5.3 User Experience Test

Figure 4 visualizes our user experience test setting. The participants wore virtual reality glasses that put them into the virtual car cockpit. A researcher initiated the different scenarios in Google Dialogflow. The VA then talked to the participants using a natural voice (a speaker produced the sound). Using a microphone, we recorded participants' answers, which the Google API processed.

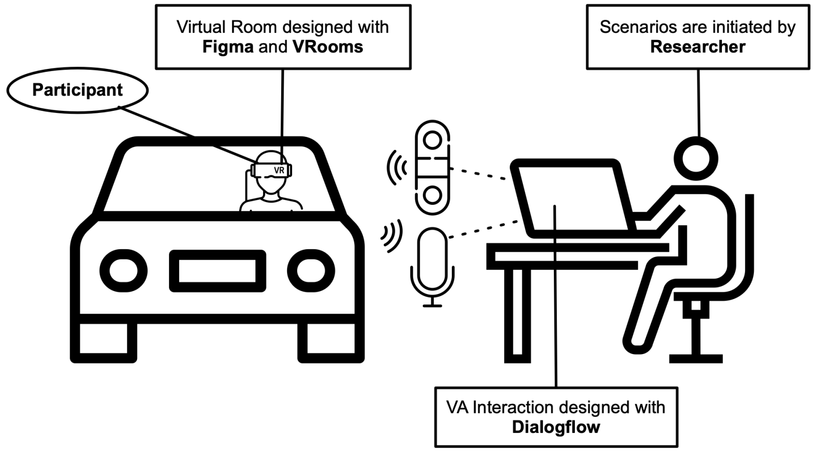

Figure 4. User Experience Test Setting

During the user experience test, we presented different situations to the participants. For example, the test showed how the VA could become used to the driver's habits and, thus, automatically recognize that, for example, on a Monday morning, the driver would likely drive to work. To do so, the assistant would greet and remind the driver about the most important appointments on the respective day. It also showed how, in situations with poor visibility, the VA could provide the driver with a recommendation to turn on the car's headlights. Further, the test showed that the in-vehicle assistant could explain the car's functions on the one hand and actively relieve the driver from performing tasks on the other hand by independently switching on the car's headlights. For this purpose, the VA automatically detected situations that include a restricted view. Another longer scenario involved a congestion-free motorway journey in which the VA entertained the user if required. The VA started conversation with the user.

We developed a post-test questionnaire to evaluate the prototype and assess participants' experience with and perceptions of the virtual in-vehicle assistant. The questionnaire covered questions about the system's entertainment, ease of use, playful handling, user friendliness, and perceived pleasure. We rated all items on a seven-point Likert-scale. Additionally, we asked about participants' prior experience with and knowledge about VAs and various open questions to obtain more insights into specific factors that influence users' experience with and perception of the in-vehicle assistant. We provide the full questionnaire and the descriptive statistics in Section 5.4.

5.4 Results

In total, 19 university students (12 males and 7 females) from various fields took part in the user experience test. Fourteen participants were between 25-30 years old, whereas five were between 20-24 years old. Ten participants owned a car, and nine regularly drove a family/partner or company car. Six participants drove less than 5,000 kilometers a year, seven drove between 5,000 kilometers and 10,000 kilometers, five drove between 10,000 km and 20,000 kilometers, and one participant drove more than 20,000 kilometers a year. Most (75%) participants had already used a VA of any kind; however, 60 percent had never used a VA in a car. The following table shows the descriptive results of the questionnaire.

Table 8. Results of the Post-test Questionnaire

Value/goal	Question	Mean	SD
Increase of the general comfort	Using the VA during the car ride increased my comfort.	5.16	1.64
Entertainment	Using the VA during the car ride made me feel entertained.	4.47	1.07
Ease of use	Dealing with the VA is clear and understandable.	5.53	1.60
	Overall, I find the virtual passenger easy to use.	5.68	1.14
Interaction	I have the feeling that the VA understands me.	5.05	1.19
	Dealing with the VA was clear and intelligible.	5.53	1.24

Looking at the descriptive data, participants rated the prototype overall as easy to use, as increasing their comfort, as having an entertaining atmosphere, and as easy to interact with. In summary, the descriptive data reveals valuable insights about how the participants experienced the VA and its overall benefits. We found support for such a conclusion from our open questions as well since the participants noted that they saw the VA as a suitable tool for operating relevant vehicle functions. In particular, participants that drove more than 10,000 kilometers a year supported this statement. Furthermore, 85 percent of the participants stated that they could imagine using the VA in their everyday driving. When we further asked about the experience of the car drive, participants mentioned “especially the proactivity was a helpful feature”, the “courteous communication and beneficial interaction”, and the “hints and overarching actions that go beyond the functions of the car [was beneficial]”. However, participants also mentioned that the VA’s voice sounded too much like a computer, that some actions were unnecessary (helping with headlights, random city information, or generally asking too much). “Sometimes less is more”, one participant mentioned. Participants also gave various suggestions to improve the VA, such as the support during long drives (especially during the night) in form of a longer conversation to avoid driver fatigue. They also suggested using specific sensors to detect the driver’s mood, emotion, heart rate, and overall condition and offer supporting podcasts, audio books, or a conversation. These aspects essentially support a companion’s character and show that the participants perceived the implemented VA as more than a sole assistant. Even though we did not systematically and rigorously evaluate all guidelines in the user experience test, we did cover several guidelines with questions in the post-test questionnaire. In particular, we fundamentally confirmed Design Guidelines 3.1, 5, 6, 7, 9, 12, 13.2, and 14.1.

6 Discussion and Conclusion

In this study, we address the scarce concrete guidelines for building virtual in-vehicle assistants that provide a convincing UX in the literature. We close this research gap with several proposed design guidelines for designing virtual in-vehicle assistants. In addition, we discuss how we tested the developed guidelines by applying them to a real project, a VR prototype, which we evaluated in a user experience test. In implementing a virtual in-vehicle assistant, we demonstrate the design guidelines’ applicability to real-world scenarios. With our prototype, we did not seek to implement an all-encompassing virtual in-vehicle assistant; instead, we wanted to demonstrate how one can use the design guidelines to conceptualize and implement a VA. According to the DSR contribution types that Gregor and Hevner (2013) present, we contribute two main artifacts as DSR outputs to the knowledge base: a level-two artifact (the proposed design guidelines) and a level-one artifact (our instantiation of a virtual in-vehicle assistant in the form of our VR prototype).

However, designers do not necessarily have to consider all design guidelines necessarily when designing a VA. In addition, designers can apply our design guidelines to other VAs that users do not primarily use in cars and, thus, other contexts since the guidelines cover a broad spectrum. With that said, future work needs to further assess our design guidelines’ generalizability according to the context(s) in which they apply them.

Future research on virtual in-vehicle assistants should focus and especially specify aspects such as trust and privacy concerns. Given that organizations continue to collect more and more, concerns that they will potentially misuse private information have risen. Therefore, an in-vehicle assistant should not only disclose what data it collects but also communicate freely what happens to it and how it is stored. As such, Design Guideline 11.2 represents only a small part of how to deal with users’ privacy concerns and requires further research. With regard to autonomous driving, we also need to rethink the guidelines. An in-vehicle assistant for drivers who hardly take on any activities themselves may become obsolete. In such cases, one could use other forms of virtual assistance to simulate drivers and, thus, assist or interact with passengers (i.e., the actual users). Future research should also deal with user adaptation and explore how a VA can not only respond to individual users but also interact with users generally in an appropriate way. A VA should have individual preferences (response, proactivity, etc.) for each user in order to create the most possible benefit. Therefore, designers might extend the virtual in-vehicle assistant with cognitive abilities, such as the ones that Ahmad, Siemon, and Robra-Bissantz (2018) show, to analyze the user’s personality and adapt its behavior accordingly.

Our guidelines focus on providing a convincing UX to ensure that people find an in-vehicle VA valuable to use and that it makes their lives easier. If designers consider all the design guidelines during representational and interaction design, the developed in-vehicle VA will meet all the requirements for a convincing UX.

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Appendix A

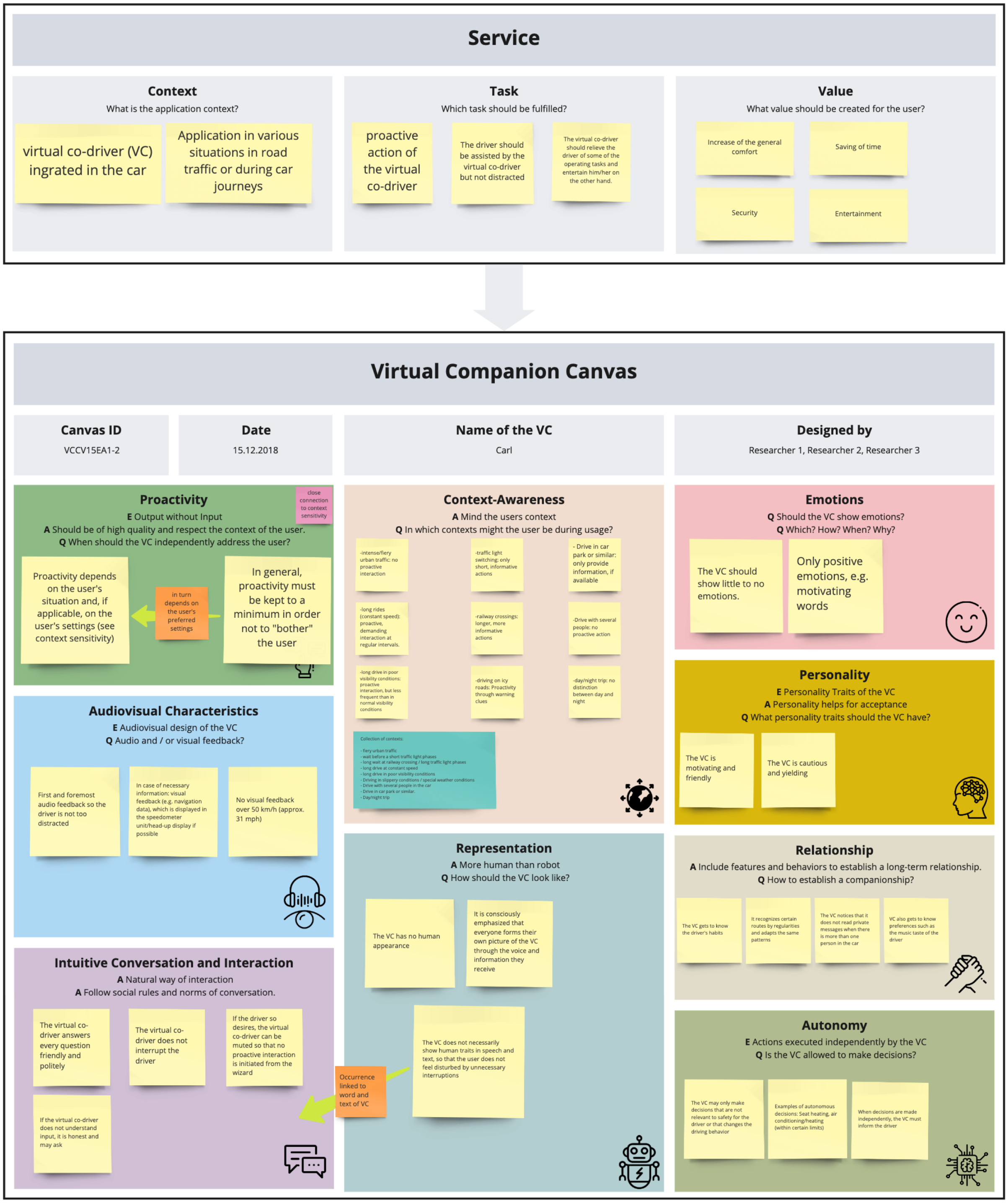

Figure A1. Virtual Companion Canvas for the Virtual In-vehicle Assistant of the VR Prototype

About the Authors

Timo Strohmann is a doctoral researcher of Business Information Systems at Technische Universität Braunschweig. His design-oriented research is centered around the application of conversational agents in different contexts, like in-vehicle assistance, creativity support or virtual facilitation. His publications include studies of implemented conversational agents as well as prescriptive knowledge on how to design them. He especially focuses on designing the human-machine interaction in a forward-thinking manner by investigating the concept of virtual companionship.

Dominik Siemon is a postdoctoral researcher of Business Information Systems at Technische Universität Braunschweig. His work focuses specifically on how Information Technology can be designed to support collaboration and creativity. Furthermore, he researches collaboration with artificial intelligence, gamification, automated personality mining and Design Thinking, with an IT-based focus. His design-oriented research was published in various peer-reviewed journals and top ranked international conferences. He teaches E-business, information management and coaches design thinking workshops. He additionally acquired and works on third-party funded projects, such as Design Thinking for Industrial Services, where he supports companies in using Information Systems to apply digital Design Thinking.

Susanne Robra-Bissantz has been head of the Institute for Business Information Systems and the Chair for Information Management at Technische Universität Braunschweig since 2007. After her appointment as Doctor, she worked as a postdoctoral researcher and habilitated at the Chair of Business Information Systems at Friedrich-Alexander-Universität Erlangen-Nürnberg. She actively works on new forms of teaching like GamEducation or Flipped Classroom concepts and has implemented numerous third-party funded projects in cooperation with industry companies. Her work on eServices, Collaboration Technology, eLearning or context-aware Information Systems was published in international conferences and recognized journals.

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