A Change of Perspective: Designing the Automated Vehicle as a New Social Actor in a Public Space

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ABSTRACT

With the rise of automated vehicles, a new road user had to be designed, an autonomous system that needs to integrate into an ecosystem of human-human interaction. Traditionally automotive UX is focused on the interaction between the driver and the vehicle. This new design challenge however comprised a change of perspective from driver/inside to road user/outside and from a system that is steered by a human being to an intelligent system that proactively makes decisions in a public space. A new approach was necessary to handle this change of perspective in the design process and to instill it into the heads of the stakeholders. We modified a user centered process to satisfy the challenge of designing the automated vehicle as a social actor. For example, we designed for acceptance by defining a character based on hopes and concerns of the public.

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CCS CONCEPTS

• **Human-centered computing** ~ Interaction design process and methods
• **Computer systems organization** ~ External interfaces for robotics

KEYWORDS

Interaction Design; human robot interaction; automated vehicle; autonomous vehicle; communication style; social robot; character; technology acceptance; virtual reality simulator

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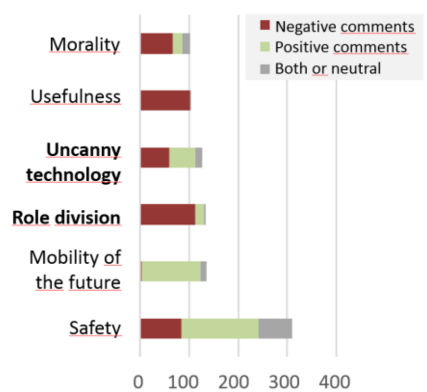

Figure 1: Excerpt of media analysis: Top 6 most mentioned topics from "hopes & concerns" on AVs in comments extracted from Spiegel (one of the major German news journals).

The flow of communication was analyzed and intent based visual and acoustic signals were designed and evaluated in a purpose-built simulator. The lessons we learned from this process might also be applicable to the design of other autonomous, public facing systems.

1 A NEW ROAD USER ASKS FOR A NEW PERSPECTIVE IN UX DESIGN

Traffic grew over decades to fit human-human interaction. The automated vehicle (AV) needs to be designed for integration into this complex ecosystem, as it will be perceived as an actor in a socio-technical system [7]. It needs to be designed for trust and acceptance of human road users (HRUs) and its behavior has to contribute to an ideal flow of traffic [3].

In automotive UX, the focus is traditionally on the inside of the vehicle. With the rise of AVs this perspective had to be changed from driver/inside to road user/outside. But the shift of perspective had to be extended to also account for the following changes:

- From a system that is steered by our users to an autonomous system, that proactively makes decisions
- From a system that is deliberately used by our customers to a system that is encountered in public space

This change of perspective involved questions totally new to the automotive industry. Which role does a robot car play as a social actor in traffic? Which behavior is acceptable and effective? Which information is really relevant for HRUs? When starting the project in 2013 there were no established methods in automotive UX to answer these questions, not even awareness of their relevance, and technology could not be experienced yet.

A new approach was necessary to handle the change of perspective in the design process and to integrate it in the heads of the stakeholders. A user-centered, scenario-based design process was followed as a basis. However, the new perspective begged for a special approach to elicit requirements, define guidelines and scenarios and a new tool for prototyping and evaluation. The following sections describe how we modified the process steps as well as the outcomes.

2 ELICITING EXPECTATIONS OF THE PUBLIC VIA ONLINE MEDIA ANALYSIS

In the early phase of the project, AVs could not be experienced by the public yet and only a few people had even heard about them. Using a standard method for requirements elicitation from users was just not possible. Instead, to dive into the outside perspective and identify aspects potentially relevant for acceptance, the mindset of the public was investigated. We looked at mainstream German online news and gathered articles (158 in total) and comments (1810 in total) that dealt with the hopes and concerns related to AVs. For content analysis, terms describing an attitude towards AVs were extracted and clustered into 14 fields. Besides safety, economic and ecological aspects, there were also two topics that related directly to acceptance of vehicle behavior; role division and uncanny technology. These were amongst the top 6 most mentioned topics in comments from a respected, German journal containing a large majority of the comments on AVs (see **Figure 1**).

AVs need to communicate

“Hopes & concerns” indicated that an AV should not be a data gathering black box, which overrules HRUs but should communicate at eye level. To design for trust, acceptance and ideal traffic flow, the assumption was that an AV has to inform HRUs about its understanding of the traffic scene and its intentions. This is also in line with current research [3].

Character-based Design

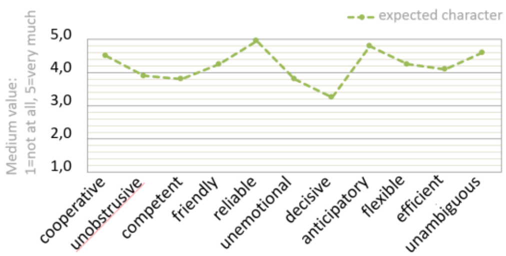

Figure 2: Expectations on character attributes.

An interactive 2½D visualization technique

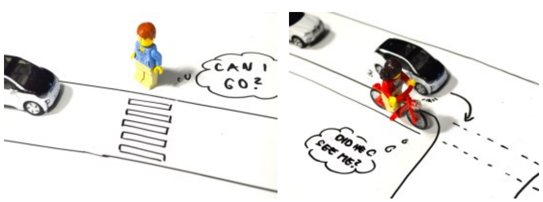

Figure 3. A technique for eliciting, visualizing and discussing interaction between road users.

For each group one A3 whiteboard was placed between them on a table, so it could be used collaboratively to draw street infrastructure on it. Moving traffic participants, relevant for the scenario, were illustrated using the miniature vehicles and Lego figures.

We identified the subtopics, which could potentially be addressed by designing the communication in traffic situations; the concern that an AV will be a black box, the loss of self-determination, having to adapt to an AV, issues with lack of trust in the technology and hopes regarding cooperation with autonomous vehicles. These findings are in line with the current literature [8].

3 CREATING A CHARACTER AS A DESIGN GUIDELINE

Designing an AV for social behavior means creating a player rather than simply a user interface. Therefore, instead of interface guidelines like design principles a character was defined. “Hopes & concerns” were used together with literature about man machine cooperation [1] and insights from interviews with AVs experts to create the character. It consists of eleven attributes; cooperative, unobtrusive, competent, friendly, reliable, unemotional, decisive, anticipatory, flexible, efficient, unambiguous.

When evaluated in a user study (N=20, not working in automotive industry, age evenly distributed between age groups <45 years and >=45 years, gender evenly distributed within these groups), the attributes met the expected behavior of AVs from a high to very high degree (3.8-4.9 on a 5-point Likert scale with 1= not at all, 5=very much; question: “Please mark how the AV should behave”) (see **Figure 2**). The only exception was “decisive” (3.2 on the Likert scale), which met our expectations since this attribute was not derived from people’s „hopes & concerns“ but rather recommended by AV experts to ensure traffic flow. The character did not only serve as an inspiration and guideline during concept creation but also later in the design process, when solutions were tested against it.

4 DETERMINING RELEVANT TRAFFIC SITUATIONS

The goal when interacting with HRUs is twofold: replace communication with the human driver [4], [6] and provide added value for traffic situations which are pain points today [2]. Literature was used to identify traffic situations in which informal communication, such as eye contact and gestures, is used today [4]. Also informal video observations of current traffic helped us to understand the communication behavior. Furthermore, current traffic pain points resulting from a lack of communication or misunderstandings were elicited via qualitative user interviews and statistics on the causes of accidents. Lastly experts on the development of AVs were interviewed and workshops were conducted to depict situations in which communication could be useful.

The complexity of traffic situations, consisting of several objects moving in space, and the relevance of details for road users’ interaction begged for a tangible visualization that could support collaborative work. For eliciting and discussing traffic situations with BMW experts and other international experts on human vehicle interaction, a special, interactive technique employing whiteboards, miniature vehicles and Lego figures was used (see **Figure 3**).

Explorative, holistic prototypes

Figure 4: Examples of prototypes of visual communication media

Prototypes integrated in a full-size vehicle and signal design

Figure 5: "Light-belt": an intent-based 360° communication (top: reflecting detection of a pedestrian via a moving light segment in the "light-belt", bottom: fully pulsing "light-belt" without reflecting detection).

5 IDENTIFYING AND CATEGORIZING SCENARIOS AND MESSAGE TYPES

As AVs intelligently determine their own actions from situational context and the actions of HRUs, the number of potential scenarios are endless. This implies two new challenges for the design process. Instead of designing communication for each single situation, a set of abstract messages is needed. And instead of predefining one set of scenarios for the whole design process, traffic situations have to be broken down into attributes relevant for AV-HRU communication.

To identify the messages, the causes for communication were extracted from the elicited traffic situations. Communication is mainly needed to clarify who goes first to avoid a dead lock situation or increase efficiency. Also, informing the HRU that the AV is aware of it might enhance trust, when the HRU is uncertain whether the AV will respect its spatial needs. Also situations in which it is appreciated to say thank you were identified. A message which was well in line with our character attributes "friendly" and "cooperative". Relevant attributes of traffic situations and their value facets were elicited and used to create a taxonomy, as described in [6]. It was used to identify relevant scenarios and define their details depending on the specific research question.

6 ANALYZING AND DESIGNING COMMUNICATION

After defining "what" and "in which" situations AVs have to communicate, the next step was to elicit requirements on "how" they have to communicate. We could not use a classical method like a task analysis, as not only the user, but also the system has its own goals. The negotiation of these goals rather than user tasks needed to be analyzed. As a first step, scenarios were created using elicited traffic situations. The interaction between HRUs was split into a sequence of messages, analyzed and transferred into design scenarios with AVs. As the role of the car as a social actor was key, the tonality had to be deliberately designed. The implicit and explicit communication [3] of the HRUs was analyzed regarding three of the aspects of Friedmann Schulz von Thun's communication model: factual information, intent and demand [9]. For the AV scenarios and creative work on signals, the assumption was that AVs could also "phrase" the same message in different ways: as an intent or as a demand. Once again, the character and „hopes & concerns" were a valuable guideline. To avoid strengthening concerns regarding loss of self-determination and to meet the character attributes "cooperative", "unobtrusive" and "friendly", we assumed that it would be beneficial to focus on the intent of the AV. This is also in line with considerations regarding safety [5], [8]. Later in the design process signal variants for intents (e.g. "I yield.") and demands (e.g. "You go first!") were created and compared.

7 HOLISTIC EXPLORATION AND PROTOTYPING OF COMMUNICATION CHANNELS AND SIGNAL DESIGN

Designing for interaction in a public space, our goal was a multimodal transfer of messages with visual as well as acoustic signals for accessibility reasons. As design started on a blank sheet of paper, a broad range of visual media had to be explored.

Vulnerable Road Use Simulator

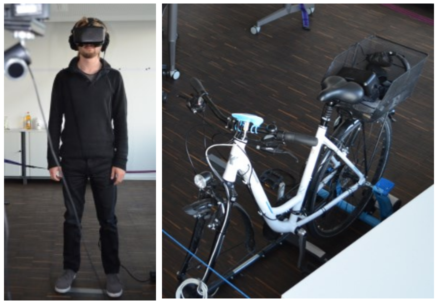

Figure 6: VRU Simulator - to test from the perspective of pedestrians and bicyclists.

To ensure a high level of immersion a head mounted display was used as an output device, so that study participants could look in any direction, getting an impression of the whole traffic scene. In addition to allow movement within the scene, pedestrians could take a few steps and a real bicycle was connected with the system. Bicyclists could ride through the virtual world via pedalling and could use the brakes of the actual bicycle to stop. Acoustic immersion was ensured via earphones transferring 3D sound, which conveyed the direction of the sound source.

To visualize their effects as communication channels of a vehicle, instead of stand-alone prototypes of the potential interfaces, a holistic view on the system was necessary. Initial concepts were created in the context of scenarios and then abstract prototype vehicles were built in 3D or as small scale models (see Figure 4). At the end of this project phase, prototypes and sample scenarios were displayed in an exhibition. Stakeholders from all major divisions of the company were invited. This ignited an interdisciplinary discussion which helped make AV-HRU interaction a relevant topic in the company.

Later, visual communication solutions were designed and investigated including icons on a display, abstract signals using a LED "light-belt" and icons projected on the road. To further explore these media in regards to positioning and perception, low fidelity prototypes were iteratively designed and integrated in a full-size vehicle. The most promising visual solution was the "light-belt". Direct light is a medium used for vehicle communication today (e.g. turn signal). In addition, the "light-belt" allows for a 360° communication, thus covering all potential traffic situations, and provides the possibility to reflect detection of an HRU (see **Figure 5**).

8 AN IMMERSIVE SYSTEM FOR RAPID PROTOTYPING AND EVALUATION OF CONCEPTS

Since an AV makes decisions and interacts with HRUs based on environment variables, its behavior depends on the traffic situation and only makes sense within this context. Additionally, it was assumed that besides explicit signals also implicit signals, caused by the movement of the vehicle, have an impact on communication [3]. This is in line with current literature which shows effects of movement for the perceived cooperativity and unambiguity [6].

Although it was necessary to embed concepts in context and with movement, conducting studies with the prototype vehicle was unfortunately not an option. In the early phase of concept evaluation, the focus was on identifying effects in controlled traffic scenarios. For internal validity, situations need to be reproducible between subjects as well as between concept variants. This is not possible in the real world as the environment such as traffic participants and lighting conditions will constantly change. For testing and rapid prototyping an approach was necessary, which allowed immersion in the scenario and control of the movement of the car and its environment. Usually in automotive UX, driving simulators are used to conduct user studies in controlled traffic scenarios. They are however designed to simulate interaction from the perspective of the driver. Therefore, a new kind of simulator was built which allows one to experience traffic situations as a bicyclist or as a pedestrian. The prototypes and scenarios were converted into a virtual world and integrated into the Vulnerable Road User Simulator (VRU Simulator) (see **Figure 6**). The AVs communication could now be displayed in combination with its movement and embedded into situational context.

Investigating communication media in the adapted driving simulator

Figure 7: Concepts for "light-belt", icon and projection in the adapted driving simulator.

Excerpt of the results from a user study with the VRU Simulator

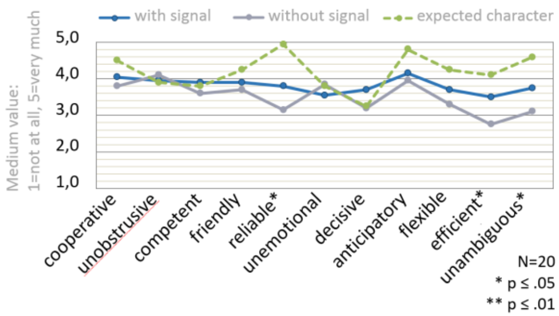

Figure 8: Character-fit of the AV giving way in a parking space with a light signal and without it.

In order to simulate the interaction from the perspective of human vehicle drivers meeting an AV, the existing driving simulator was adapted by integrating signals into the 3D vehicles (see Figure 7) and explicitly controlling their movement.

The two systems were used for concept work, expert interviews and several studies evaluating visual and acoustic signals. In a driving simulator study (N=72) using the new perspective we compared different solutions for explicit visual communication; display, direct light and projection as well as signal variants for expressing intents and prompts. Compared concepts, method and results for projection are described in [10].

Using the VRU simulator we conducted a study where participants experienced visual and acoustic signals in two pedestrian scenarios and one bicyclist scenario (N=20, not working in automotive industry, age evenly distributed between age groups <45 years and >=45 years, gender evenly distributed within these groups). The following describes one of the results from the study concerning the previously discussed character definition. In one of the scenarios, the subject is instructed to cross the street to a parking space. As they are approaching the street, an AV arrives into the scene and gives way to them. The scenario is experienced by each subject without an explicit signal and with a signal: a slowly pulsing "light-belt" (see **Figure 5**, bottom) indicating that the AV is giving way. When asked to rate the behaviour of the AV, results showed a significantly better fit with the character attributes "reliable", "efficient" and "unambiguous" with the signal than without it (see **Figure 8**).

9 DISCUSSION

Implementing the new perspective in the design process

Some of the steps that were used to approach the design challenge, might also be useful for other intelligent systems with a combination of the characteristics mentioned in the side bar on the next page. The following section discusses to which extent they were useful for designing the interaction of an AV:

Media analysis of „hopes & concerns": Opinions from online media do not represent an ideal sample of the general public and statistical results need to be handled with caution. Still, the media analysis was very helpful to dive into the outside perspective and identify „hopes & concerns" discussed in the public and by professionals (journalists) shaping public opinion.

Character and communication style: The character converted insights from public expectations, research on human machine cooperation and AV experts into a form applicable to creative concept work and testing. It helped us design the AV as an actor and led, based on a communication model, to an intent based communication style.

Abstract messages and scenario taxonomy: Though the messages might not be exhaustive, their abstract definition ensures a consistent language, applicable to a broad range of traffic situations. The taxonomy helped us to cope with the multitude of situations. It breaks down traffic situations to significant aspects for AV-HRU interaction and allows us to identify relevant scenarios for a specific research question.

Summary of the design challenge

An AV as a social actor in the ecosystem of traffic, can be broken down into having the following **characteristics**:

- The system autonomously makes decisions.
- It is encountered in a public space.
- It will be integrated into an ecosystem of human-human interaction.
- It is experienced as a physical entity.

For the design process this comprised the following **challenges**:

- The mindset of the public had to be investigated to design for acceptance.
- A social actor had to be developed as the AV needs to autonomously communicate.
- The interaction had to be designed for a multitude of (unforeseen) situations, as the AV intelligently reacts to the real world.
- The AV needs to be experienced as a moving 3D object in scenarios to interpret communication

VRU Simulator and adapted driving simulator: The simulators are highly immersive systems, which allow us to dive into a scenario and provide a holistic impression of the vehicle as a 3D object in space (including size, position, movement direction and speed). This accommodates for the relevance of scenarios and the AV's physical appearance during the evaluation of the behavior. The simulators allowed us to evaluate a broad range of communication concepts regarding acceptance, character-fit and efficiency. However to provide more options for the study design and metrics in the VRU Simulator, a larger movement area is needed.

Helping stakeholders to dive into the new perspective

Some of the process steps, tools and resulting artefacts did not only help to create a solution but also to establish research on this topic within the company:

Media analysis of „hopes & concerns“: Displaying the huge increase in the amount of articles on the topic of AVs within a few years helped to create an awareness of the public opinion and its relevance. Illustrating somewhat provocative headlines and comments and discussing „hopes & concerns“ helped stakeholders dive into the multiple facets of the outside perspective.

A 2½D visualization technique for traffic situations: This was a valuable technique for collaborative work on traffic situations. They can be visualized easily without special drawing skills, as only simple, top-view 2D drawings like streets are necessary. Complex objects like bicyclists can be depicted via the 3D figures. For illustrating the course of action, instead of a static sequence of stills, the movement of the road users can be illustrated and discussed as a continuous flow. Relevant aspects of the situational context such as street, road signs or blocked vision, can be changed easily. Placing it in the middle of a table so that everybody could see and draw also fueled engagement in the discussion.

Exhibition of early, holistic prototypes: An exhibition displaying explorative but holistic prototypes in a scenario context allowed us to inspire and convince stakeholders in the early phase of the project. It provided a platform to ignite stakeholder discussions between different departments and disciplines. By using an abstract style for prototyping and visualization, it still left enough room for an in-depth interaction design of tested and viable solutions.

VRU Simulator and adapted driving simulator: The simulators allowed stakeholders to immerse into the new perspective in a minimum amount of time. Since media and signal variants could be prototyped and changed easily, a broad range of concepts could be discussed with experts from various disciplines. Besides gathering valuable feedback, this involved stakeholders actively in the design process.

10 CONCLUSION & WHAT'S NEXT

With the rise of intelligent systems, the paradigm of interaction design shifts from systems that are used to systems that need to be created as autonomous counterparts of communication. If the system will be in contact with the public, it also needs to be designed for public acceptance. If this means, that we need to change the perspective of stakeholders, then this might be a design challenge of equal importance as the design of the product and the interaction itself.

The approach we used proved valuable for both of these aspects. We successfully established the new research field in the company and visual and acoustic communication solutions were created based on the AVs character and communication style. They were evaluated in several user studies using the VRU simulator and the adjusted driving simulator embedding them into traffic scenarios. However as context research and testing mainly considered German road users, international testing of the solutions in local traffic scenarios is required as a next step. Furthermore a generic interaction model needs to be developed. Consequently, evaluation needs to move from controlled scenarios for investigating specific effects to real world studies for gathering data on interaction behavior in a natural environment.

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