Design for Perception - A Systematic Approach for the Design of Driving Automation Systems based on the Users' Perception

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ABSTRACT

While there is significant potential for driving automation to increase traffic safety and enhance comfort, it is important that these systems are designed in such a way that drivers are supported in building a correct understanding of the system's capabilities and limitations. Hence, it is necessary to understand both the process by which drivers understand a driving automation system and the factors that influence their perception. During three workshops, six practitioners participated in a participatory action research study around a design use case, aiming to enhance mode awareness in a vehicle offering several levels of automation. This facilitated the development of a card deck, which supports practitioners to 1. explore possible solutions driven through a systematic approach, 2. identify areas of improvement through applying the lens of the user, 3. ideate and evaluate design decisions through a guided process.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Interaction design process and methods; User centered design.

KEYWORDS

driving automation, user research, co-creation, design tool, design methodology

1 INTRODUCTION

The design of driving automation systems (DAS) comes with many challenges as the complexity of the driver-vehicle-interaction continues to rise with the introduction of supervised and unsupervised automation systems into the vehicle. While there is significant potential for DAS to increase traffic safety and enhance comfort, the current challenges show that it is important that these systems are designed in such a way that drivers are supported in building a

correct understanding of the system's abilities and limitations [3]. Some of the issues designers and developers are facing are the ambiguity of the Levels of Automation due to the high complexity of the functions [2]. As a result, the similarities in behaviors between functions and their limitations, makes it hard for drivers to build a correct mental model of the driving modes in the vehicle and build appropriate usage strategies [17] [11]. Therefore, designers and developers need to consider the driver's understanding as more than just a task-allocation issue, as often suggested in prior taxonomies [4] [8] [12], but that the user's perception of the system is a key to designing a desirable interaction. Hence, to design DAS that adequately support the driver in building appropriate trust and usage strategies, it is necessary to understand both the process by which drivers understand a driving automation system and the factors that influence their perception of the DAS [10].

In an effort to address the aforementioned challenges, the aim of this work is to present a design tool which supports the development of driving automation systems based on the users' perception and consequent understanding.

2 METHOD

The following sections describe prior work conducted to reach the state which allowed to develop a model describing the users' perception and consequent understanding of DAS, as well as the participatory design process leading to the presented tool.

2.1 Background

This work relies primarily on prior research forming the base for the result in the form of a descriptive model of the users' perception and consequent understanding of driving automation systems [10].

The model shows that the users of such systems, independent of the level of automation, talked about the systems by referring to different elements: the Context, the Vehicle, and the Driver. In addition, eleven recurring aspects describing the drivers' understanding of an automated system were discerned. Furthermore, six factors were identified that influence how drivers perceive driving automation during usage. The seven factors are Preconceptions, Previous Experiences, Perceived Safety, Trust, System Performance, Driving Behaviour and Feedback from the vehicle. All of the identified aspects and factors are comprised of a set of sub-aspects/sub-factors. Collectively, the identified aspects and factors constitute the building blocks of a process. The process is presented as a descriptive unified model (see Figure 1), which describes how drivers perceive and consequently understand driving automation systems.

The flow of the process can be split into three parts:

1. General understanding: This block of the process represents the mental representation the user has of the system's characteristics
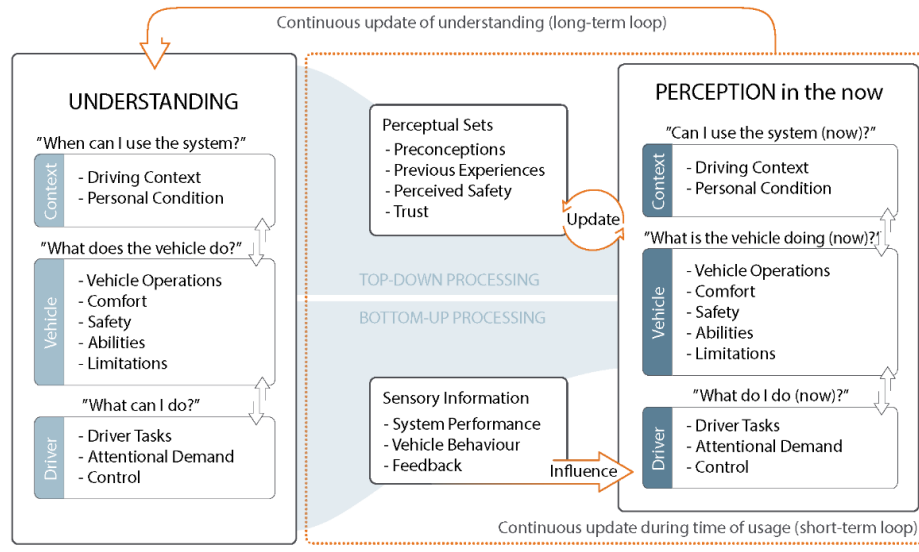
Figure 1: Descriptive model of the process of how perception shapes understanding [10].

and how to interact with it. It includes all the aspects and elements that make up the user's understanding and can be regarded as the baseline element from which all interaction starts.

2. Perception during use: This block represents the user's mental representation of the system during usage and shows how the interaction is influenced through the perceptual sets and sensory information they receive during driving. This block happens in real time and during engagement with the driving automation system, which means there is a continuous update (short-term) of the perception and therefore of the user's understanding of the system and how to interact with it.

3. Shaping understanding: The last part of the process is a long-term loop, which binds the two parts together. Perception of the system in the 'now' is continuously fed back to the users' understanding, causing them to update their understanding based on what they perceive during usage of the driving automation system.

On the one hand the model aims to explain how users understand driving automation systems and what factors influence their perception and consequent interaction with the systems. On the other hand, it aims to support design goals like improving system performance, user satisfaction, user understanding and so on.

The main idea for the developed method was to use the identified aspects from the model as a starting point for the ideation and validation of design concepts. This process is described in the following section.

2.2 Participatory Action Research and Co-Creation

Participatory design was derived from participatory action research (practical interventionistic investigations and parallel theoretical reflections) [6]. Participatory action research was introduced as a tool of empowerment and therefore, participatory designers see themselves as facilitators who empower users in making their own

decisions. To achieve this goal, co-design and co-creation is emphasized during the development stages, meaning all conclusions are created in conjunction with users [15][13].

Since the primary author Since the author, was part of the team working with these topics, they had identified the lack of a process which supports development and validation of driving automation systems as a gap in their toolbox. Therefore, a participatory action research approach was adopted in order to create a design tool for practitioners.

2.2.1 Use Case Study. During three workshops, six practitioners participated in an iterative use case study. The design use case had as a goal to develop a user interface for a vehicle that offers several driving modes and aimed to enhance mode awareness of the driver. The participating practitioners were all working in the field of driving automation as Designers or Developers of these functions, and thus, represent expert users and the target group for the tool.

The study was set up three stages [15]:

1. Exploration of work: At this stage, the team met and familiarized themselves with the task and the background of the tool. This exploration included a discussion of the goals, usual workflows, as well as problematization of the use case.

2. Discovery Process: In this stage, the team got together for the workshops and used the initial version of the tool, which was an excel sheet incorporating all the elements from the descriptive model (see Figure 1). In a first step, one designer and developer of the group ideated around possible design solutions with the help of the design tool. After a first concept was created, the team got together for a moderated review session, which was guided by the tool. After each session, feedback was gathered from the group on what needed clarification or improvement. It is relevant to mention that the author would not participate in the review sessions, but
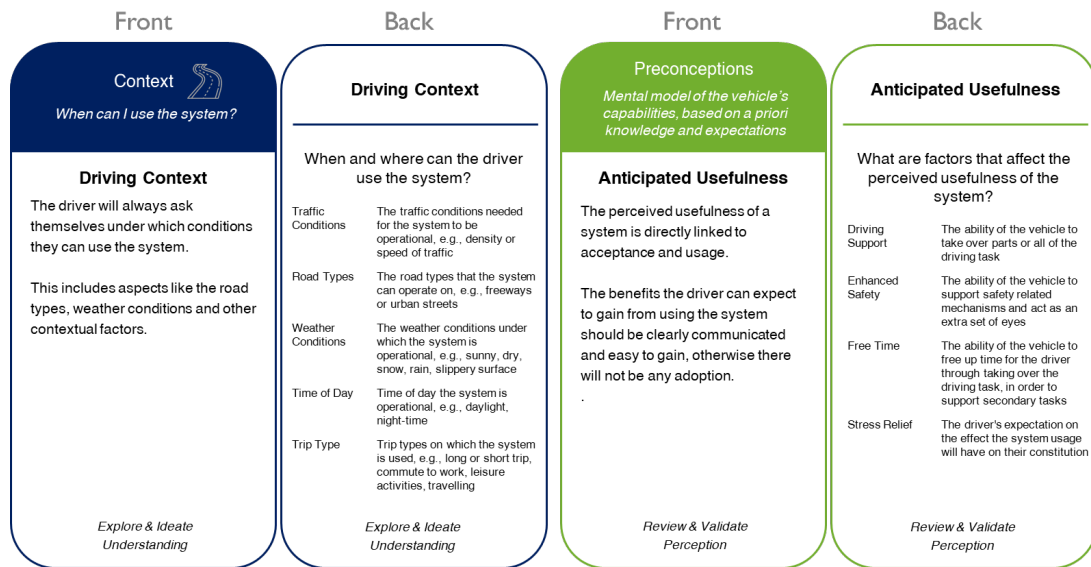
Figure 2: Example cards from Deck 1(left) and Deck 2(right).

mainly facilitate the workshops and observe the team work on the use case with help of the tool.

3. Prototyping: In this stage, the feedback from the team would be discussed and iterations on the tool itself with feedback sessions from the practitioners would be held, to create a prototype which served the needs better. Finally, steps 2 and 3 were iterated, meaning the designer and developer worked on the use case between each workshop and presented their work, which then was evaluated by the team with help of the tool. After the workshops, consecutive interviews were held with the participants of the participatory design study, to gain insights and reflections about the usefulness, limitations, and possible enhancements of the design tool.

3 RESULTS

The described process in chapter 2 resulted in the development of a card deck, consisting of several sets that can be used throughout the design and development process in combination or on their own. This will be presented as follows.

3.1 The "Design for Perception"-Toolkit

The toolkit consists of different parts, which serve as a guide for the design and development of driving automation systems throughout different stages of the process. As mentioned earlier, it is based on the conceptual model described in Figure 1 and is therefore split into three parts.

The toolkit can be accessed and used in different formats, depending on the type of work and phase it is being used in. There is an excel table, a physical card deck, as well as a virtual card deck accessible as a template in the Miroverse. The different solutions were developed in co-creation with the users of the tool, who voiced their needs for hybrid and online collaboration, besides a physical tool that supports a more open workshop character. Figure 2 shows example cards from the deck.

Card Deck 1: Understanding is meant for the exploration and ideation stage of a project. It supports the development process and provides aspects to consider when designing and ideating around possible solutions. Card Deck 1 comprises all aspects which describe the drivers' understanding of driving automation. With the help of this deck, one can identify requirements for a technical solution from a users' perspective or provide technical requirements and scenarios which need to be addressed through design solutions.

Card Deck 2: Review & Validate supports the review of developed design solutions and aids during the validation phase with experts, as well as support for setting up use studies. Card Deck 2 presents the factors that influence how drivers perceive driving automation during usage, as well as prompts the review of identified design solutions through probing questions.

Card Deck 3: Discuss and Decide is a set of action cards, which support the review of considered decisions through a systemic approach guiding the team through the analysis of potential failures and effects of the current design solutions, as well as supports decision making and documentation of design solutions.

4 DISCUSSION AND CONCLUSIONS

Existing frameworks, despite their benefits, have been criticized for being based on detailed technical and functional taxonomies (e.g., [18] [14] [7]), and that they do not provide any basis for design (e.g., [9] [16]). In order to reflect what users are looking for when trying to make sense of the interaction with a DAS, the design work needs to consider the users perception of such systems [1]. The Design for Perception toolkit serves as a common ground which aligns motivations and targets of software developers, interaction designers and strategists with regulations. Consequently, it supports cross-functional teams to 1. explore possible solutions driven through a systematic approach, 2. identify areas of improvement

through applying the lens of the user, 3. ideate and evaluate design decisions through a guided process.

ACKNOWLEDGMENTS

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