

# Methods and Guidelines for Incorporating Human Factors Requirements in Automated Vehicles Development

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## Abstract

Automated vehicles (AV) are transforming the future of the transportation and improving the quality of life. However, due to their societal impact in urban environments, AV development challenges the current development process. Particularly, it is unclear how human factors requirements can be communicated to developers of AI-based AV. It is quite challenging especially in agile development, where the focus is on continuous deployment and rapid release cycles with short lead-times.

Due to the importance of human factors and its impact on trust, acceptance, and safety of AV in urban environments, my work aims at providing a suitable requirements engineering perspective and method.

## Keywords

Requirements Engineering, Autonomous Vehicles, AI systems, Human Factors

## 1. Introduction

Automated vehicles (AV) can improve the safety and reduce the number of accidents. Today, an increasing number of automated vehicles are already on the roads [1], and it is expected that by 2045 half of new cars will be autonomous [2]. Many of the features up to SEA level 3 [3] are already operational. Examples include lane changing [4], adaptive cruise control (ACC) [5], and to some extent car parking [6].

But with the increasing number of AV, many researchers [7, 8, 9] are worried about neglecting human factors while designing automated systems. Human factors is a discipline that considers the physical, physiological and cognitive behavior of humans and apply this information to the design, operation and use of the products for increasing human interaction with the systems by improving human safety, performance and/or satisfaction[10].

These researchers [7, 8, 9] believe that automation brings not only benefits, but also potential disadvantages. Moreover, humans can also mis-use and eventually mislead the technology. To


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cope with these issues of AV technology, human factors must play an important role throughout the engineering and development life cycle of AV, yet it is unclear how human factors perspective can be communicated to AV engineers.

Human factors requirements are important to consider in many scenarios. Such as for the communication between pedestrians and AV,

to build and enhance the safety [11] and trust, [12] driving performance and [13] driver's interaction with AV [14].

But the human factors field has not evolved with the pace of AV technology and remains poorly understood in design and development of automated driving systems [15]. Particularly, while adopting agile development methodology, software teams aim to shorten time-to-market, and tend to focus on the technical perspective and neglect human factors aspects.

My studies aim to investigate and suggest how to resolve the communication challenges between human factors requirements with the AV engineers. To do so, we have started with a qualitative study. The rest of the paper is divided into seven sections. In Section 2, we depict the problem, whereas, Section 3 presents the relevance. Section 4 and 5 illustrates proposed solution and novelty of the topic respectively. Section 6 provides research methods and Section 7 describes the progress. Finally, the last Section concludes the work.

## 2. Problem Statement

Human factors skills are used to collect real world data and manage this data for each feature (how do people deal with these vehicles, when do they turn off and on different features). But currently, instead of collecting such requirements (user's behavior) directly, AV developers are using more data-driven techniques, due to the challenge of short time frame.

Requirements communication is very challenging, agility has added even more complexity to that. The processes for requirements engineering are better explored for traditional development. Traditionally, most of the requirements in most setups were communicated through proper documentation. Now it's quite challenging particularly in large scale agile development.

It is difficult to communicate requirements in agile development because there is no clearly defined requirements communication method. It is different across various organizational cultures. Because in agile development, developers are using just-in-time requirements and there is no traditional documented requirements given to them. It is more difficult because in some scenarios it is less about handing over requirements, but instead being there for discussion of the concepts.

Human factors experts play an important role to describe and discuss concepts related to human behavior. They need to communicate with engineers to point out the user expectations before the development, to guide developers during the development and to validate the product in the end with human factors knowledge. But with agility and being not in a development team, causes a big challenge for human factors requirements communication. Since the lead time to release new functions needs to decrease, developers are much focused on technical requirements.

Thus our problem statement is: *to integrate human factors requirements in the agile development of AI-based AV.*

### 3. Relevance

AV developers are usually concerned with improving the technology. For example, early AV keep the car exactly in the center of a lane. But when overtaking a truck, humans would prefer to leave a bit more space. Understanding such problems are crucial and also difficult. Human factors experts are aware of such aspects and could help defining such requirements.

These requirements are very important to increase the system trust, acceptance and safety: Trust leads to acceptance, acceptance leads to safety (since automated safety features are not deactivated or overridden). To achieve this we need to understand the humans, their behavior, how they would react in certain scenarios and what they expect from the system in certain situations.

For instance, to communicate with pedestrian, human factors requirements provide guidelines about communication strategies. A report [16] shows that currently people would not feel safe while crossing AV because they do not trust when they do not see any driver on the driving seat.

On the other hand, for requirements elicitation, engineers are also using statistics to understand specific driver behavior. Sometimes with the availability of large data sets, it seems that we know how humans will react under certain conditions but in reality, it is not always in a way we anticipate. People can possibly behave in strange ways, which a particular set of data fails to comprehend. Therefore, to ensure the success of the system, we need to determine the right system behavior in situations where a person is doing something unexpected. To define such system behavior we need a good requirements process. Our preliminary research shows that today, we are not yet very good at managing such requirements efficiently.

### 4. Solution

For enabling continuous deployment, automotive companies have initiated working on vehicles using agile approaches. But it is hard to systematically describe the requirements for agile system development [17]. This is particularly true for AI parts, due to their inductive training nature.

In summary, it is very difficult for human factors experts to communicate their knowledge as requirements to developers. One solution could be, to modify agile interventions [18] to address human factors aspects or to include human factors experts in development teams. But given the shortage on human factors experts in the field, there is no defined procedure about how and where the human factors should be optimally placed in the team or how to train the agile teams so that they can learn and include the human factors aspects during development. Therefore, the first step is to come up with a solution about where we can properly introduce human factors in AV development cycle.

We need to address and integrate human factors knowledge throughout the agile AV development cycle for continuous software development. Aiming to propose a framework for agile teams to provide guidelines to include human factors knowledge and define their roles and responsibilities during AV development. A framework that allows engineers (AI/SE/Automotive) to leverage human factors perspective when building AI intense systems, to facilitate the

understanding, communication and V&V of human factors requirements.

## 5. Novelty

Requirements engineering focuses much on socio-technical requirements, but human factors knowledge also considers other aspects such as distractions and behaviors which are important to consider for the successful deployment of AV. For example, consider there is a driver in AV and the control lies with AV. As AV is in control, the driver can be relaxed and therefore can be distracted by other things or she might feel sleepy. We are also aware of the fact that AV still require intervention of human driver. Because of this, we have driver monitoring system (DMS). Hence, if the DMS functionality detects that the driver is distracted or sleepy, then how should it behave? Such kind of requirements are provided by human factors experts. I notice that human factors relate to the most difficult requirements, those which are tacit and users would not be able to describe them in their own words.

Many researchers are performing research on different perspectives of human factors in AV development. For example, Merat et al. [19] conduct a study on communication procedure between vehicles and other objects without human to human correspondence. Schoettle and Sivak [20] present a study about peoples acceptance of AV, it has reported that as the level of automation increases, peoples' acceptance of AV decreases. Van Maanen et.al. [21] discuss how human factors can be integrated in AI for the better human machine cooperation (HMC). Chen et al,[22] also present a model for AV transparency considering AI and humans as integral part. Kirsten [23] developed a method for interface design to include human factors before the system development.

In summary, the gap between human factors and design or development of automated vehicles has also been identified in research. But it is unclear how HF knowledge can be included throughout the development life cycle of AV.

## 6. Research Method

Within the interdisciplinary research environment of this work, we will use a mixture of research methods.

The goal of my PhD studies is to create a method to bridge the communication gap between human factors experts, requirements engineers, and AV developers to communicate human factors requirements.

In our first study, we interviewed 10 professionals including both human factors experts and AV engineers. We did a qualitative analysis on these semi-structured interviews and address the following research questions in context of AV development:

1. Definition of human factors in relation to agile.
2. Properties of human factors and agile.
3. Implications for agile developers.
4. Implications for human factors.
5. Implications for requirements.

Based on this interview study, we formulated the problem statement for the design science research.

During the course of my doctoral studies, I have two secondments: one in automotive company and one at another university. These secondments will support my research. While working in an automotive company (which work with agile development of AV), I will analyse the problem in practice. I will then attempt to build a solution based on a literature review as well as discussions with practitioners to solve the problem. I aim to re-evaluate and iterate the process if required. Overall, I am planning to use the design science research method, and to conduct several studies in accordance to this method. I aim to evaluate a proposed methodology for including HF knowledge in AV engineering through a case study at an automotive company, in which I will use interviews or a questionnaire to collect data.

My purpose of visiting another university is to work on the concept in detail and to ensure its usefulness for human factors experts and researchers.

Within the design science research framework, we may use other research methods to support the study such as surveys and case studies.

## 7. Progress

Within the broad topic of reducing the communication gap between human factors experts and AV developers in agile development, our first study particularly focused on discovering how human factors knowledge can be captured as requirements in agile development.

Our findings present several challenges and implications for agile developers, requirements engineers and for human factors experts, who are engaged in AV development.

While addressing research question one, it was observed that everyone has different human factors definition depending upon different aspects, particularly in the context of AV development. But it could be problematic, while communicating human factors requirements to others. So it is important to have one common understanding of basic concepts. That is why, we have synthesized one definition of human factors for AV development, considering our interviewees perspective and established a definitions of human factors.

Here, we provide an overview of our findings for above mentioned research questions 2-5. We have found properties of human factors and agile methods in AV development. Properties of agile methods are highlighted as iterative nature and responsiveness to changing requirements. Further, agile methods shift responsibility to autonomous teams, which often dislike static, detailed requirements. Instead, they prefer to explore requirements just-in-time by themselves.

We find that both agile methods and human factors focus on quality in use. We learned that to remove the communication gap of human factors requirements with AV developers, it would be desirable to have a human factors expert in each team. Human factors experts then can provide the basic knowledge related to human factors requirements and guide developers in which direction to look for system test and experiments. We believe that requirements engineering can support this by managing the knowledge gained from experiments effectively and by expressing design decisions in relation to human factors requirements in system requirements.

With this qualitative study being almost concluded, we will now focus on the secondment with the industry partner next.

## 8. Conclusion

Due to the agile development and fast increments, it is unclear how human factors fit into the current practice of AV development. We need to develop a strong setup with protocols where we can support an environment for human factors' experiments and user-studies, so that developers can actually create knowledge and data with good reliability when needed for their design decisions. We expect that such a setup can provide a good conceptual framework that guides engineers in all relevant disciplines on how to manage human factors knowledge and to balance the role of human factors for AV development in scaled-agile setups.

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