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A Theoretical Framework for Trust in Automation Considering Its Relationship to Technology Acceptance and Its Influencing Factors

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ABSTRACT

We propose a theoretically derived framework on the relationship between trust in automation (TiA) and technology acceptance considering influencing factors of TiA for the application context of automated driving. The impact of trust on the acceptance of automated systems seems to be empirically proven. Nevertheless, acceptance models often do not consider the concept of trust or neglect the influencing factors of trust. To provide a more holistic perspective on these issues, we conducted a structured literature analysis. Scientific papers which consider the relationship between TiA and acceptance as well as factors influencing trust in the context of automated driving were included. Based on the identified literature, a theoretical framework was derived. The framework is intended to serve as a complement to existing sound acceptance and trust models as well as a starting point for empirical verification of the theoretical assumptions in the course of further research.

Keywords: Trust in automation, Technology acceptance, Autonomous driving, Theoretical framework

INTRODUCTION

Automated cars are about to bring substantial changes in mobility (Milakis, 2018). While functions and systems of lower automation levels have already become part of series production, the implementation of higher automation levels such as SAE Level 4 and 5 is still in its infancy (Milakis, 2018). The advantages of automated vehicles, e.g. improved safety (National Highway Traffic Safety Administration, 2018) and increased convenience (Endsley, 2019), are supposed to be manifold. However, there are some factors, which could affect the breakthrough of this technology. Especially user acceptance is a mandatory premise for technology adoption (Davis, 1989). If a technical system is not accepted by potential users, it will most likely not be used. But which factors are decisive for whether a technology is accepted or not?

Technology acceptance models usually equate acceptance with technology usage or the intention to use it. Looking at Davis's Technology Acceptance Model (TAM, 1989) two factors seem to be decisive for the acceptance: perceived usefulness and perceived ease of use. Both factors lead to usage

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intention, which predicts actual system usage. Although well elaborated, it is important to consider that the TAM was developed for the context of information systems. Since its publication, the TAM has been further developed, adopted to new contexts, and extended to include additional influencing factors. Particularly relevant for the context of the present work is, for example, the car technology acceptance model (CTAM) by Osswald, Wurhofer, Trösterer, Beck, and Tscheligi (2012). Osswald et al. (2012) identified variables influencing acceptance in the vehicle information context. These include the TAM factors as well as perceived safety, anxiety, self-efficacy, and attitude towards using technology. Another relevant model for the present work is the autonomous vehicle acceptance model (AVAM) developed by Hewitt, Politis, Amanatidis, and Sarkar (2019) which includes all factors of the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003), another extension of the original TAM, as well as the factor perceived safety of the CTAM.

Interestingly, one factor not considered in the aforementioned models relevant to the application context of automated driving is trust. This is remarkable since the relationship between trust and acceptance has been demonstrated (see e.g., Choi & Ji, 2015; Kaur & Rampersad, 2018; Lee & See, 2004; Pavlou, 2003; Tussyadiah et al., 2017) and is taken into account in acceptance models of rather generic application contexts, e.g. in the Automation Acceptance Model (AAM; Ghazizadeh, Lee, & Boyle, 2012).

Taken together, it could be worthwhile to review, analyse, and expand previous models for the automated driving context. We assume that trust has a particularly relevant, but so far neglected, role in acceptance models for automated vehicles. Therefore, we strive to provide a theoretical framework that focuses on trust in this context and its relationship to acceptance. In models such as the AAM, trust is considered, but the factors influencing trust are not further described or are roughly grouped under external variables. However, we assume that to meaningfully discuss and understand the interplay between trust and acceptance or implement it for research, it is additionally important to understand the factors influencing trust. The latter will, therefore, also be considered in this paper to broaden our understanding of trust in automation. In a nutshell, the goal of the present paper is to derive a theoretical framework on TiA regarding its relationship to technology acceptance and its influencing factors in the automated driving context. The added value of the framework is that existing theoretical and empirical work on both sides of TiA (influencing and influenced) are summarised while TiA is in the focus of consideration.

METHODOLOGY AND PROCEDURE

In developing the framework, literature on the relationship between trust and acceptance was researched during the months of January and February of 2021. Theoretical acceptance models and/or empirical work, which include trust as a factor or have been developed for the application context driving and/or automation and/or automated driving, were selected. Google Scholar, PubMed, PubPsych, and Web of Science were accessed for the research.

Search terms were e.g., the following keywords or combinations of these: trust in automation, (technology) acceptance models, perceived safety, (automated) driving context, influencing factors, driverless cars, TAM, (empirical) correlation model, determinants, influencing factors. N = 35 papers were deemed relevant and considered for the elaboration of the framework.

RESULTS

Relationship Between TiA and Acceptance

In the context of automated systems, one often refers not only to trust, but to trust in automation (TiA). Lee and See (2004; p. 54) define TiA as "[…] the attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability". A somewhat more recent but very similar definition characterises TiA as "[…] the attitude of a user to be willing to be vulnerable to the actions of an automation based on the expectation that it will perform a particular action important to the user, irrespective of the ability to monitor or to intervene" (Körber, Baseler, & Bengler, 2018; p. 2). In the further course of this paper we follow and combine these definitions and similarly understand TiA as a subjective attitude of the user that an automated system will act in a desirable manner in situations characterised by uncertainty for and/or vulnerability of the user. The relevance of TiA as a key determinant for the acceptance of automation/automated technology is often postulated (see e.g., Kaur & Rampersad, 2018; Lee & See, 2004; Pavlou, 2003; Tussyadiah et al., 2017). However, there is no clear agreement on the direction of the relationship and there is few literature which has considered TiA as a component of acceptance models. Of these, some are introduced in the following.

As described beforehand, Ghazizadeh et al. (2012a) postulate a theoretically derived model (AAM) in which trust is related to the components of the TAM. They hypothesise that trust has both a direct influence on behavioural intention to use and acts on perceived usefulness thereby also influencing behavioural intention to use indirectly. In a subsequent study, Ghazizadeh et al. (2012b) empirically tested some of their hypothesised correlations and showed that trust has a direct influence on behavioural intention. However, the predicted indirect influence could not be shown. Further evidence on the relationship between TiA and acceptance is provided by Choi and Ji (2015). By means of an online study on the acceptance of autonomous driving, they investigated the relationship between trust, the TAM factors, and the additional factors perceived risk, external locus of control, and sensation seeking. Unlike Ghazizadeh et al. (2012b) they found that trust has both a direct influence on behavioural intention and an indirect effect on acceptance via perceived usefulness and perceived risk. This finding replicates results of Numan (1998) and Pavlou (2003). A similar pattern on the relationship between trust and acceptance is shown by Hegner, Beldad, and Brunswick (2019). They proved an empirical relationship between trust and the TAM factors in an online study on fully automated vehicles. Their results likewise demonstrated the direct effect of trust on acceptance, as well as the indirect effect of trust on acceptance via perceived usefulness. Finally, Montamedi et al. (2020)

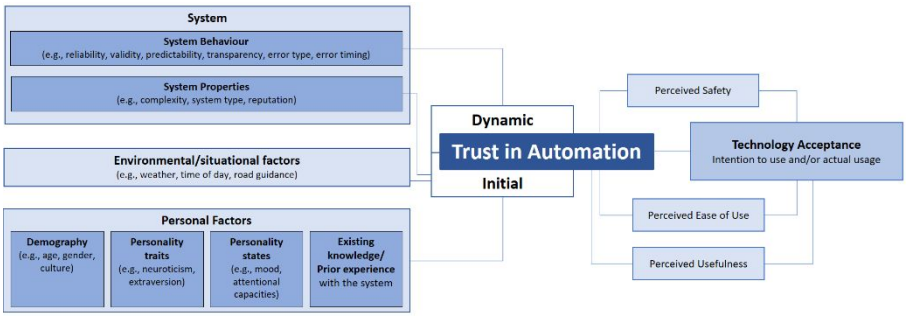

Figure 1: Theoretically developed framework on the influencing factors on and the relationship between TiA and technology acceptance. Note: (Potential) interdependencies between the (acceptance-relevant or trust influencing) factors as well as feedback loops or directions are not considered in this figure.

could not show a direct influence of trust on acceptance, but they also found an indirect effect of trust on acceptance via the factor perceived safety.

Based on this literature, our understanding of the relationship between TiA and technology acceptance expands as follows: there appears to be both a direct and indirect relationship between TiA and acceptance of automation technology (see Figure 1). With regard to the indirect relationship, the TAM components perceived usefulness and perceived ease of use (see e.g., Ghazizadeh et al., 2012a; Ghazizadeh et al., 2012b; Hegner et al., 2019; Choi & Ji, 2015; Montamedi et al., 2020) but also the factor perceived safety (see e.g., Montamedi et al., 2020; Choi & Ji; 2015) seem to be of particular importance.

Factors Influencing TiA

When researching the influencing factors of trust, particular consideration was given to those that seemingly have relevance to the automated driving context. A particularly relevant work in this context is the model of Hoff & Bashir (2015), who conducted a literature review on TiA and interdependencies with it.

Like many other researchers, Hoff and Bashir (2015) identified individual personal factors such as gender, age, culture, and personality traits (see e.g., Lee & See, 2004; Chien et al., 2014; Sanchez, Rogers, Fisk, & Rovira, 2014; Schaefer et al., 2014) as relevant determinants that primarily contribute to one facet of TiA, dispositional trust. Dispositional trust thereby means the enduring overall tendency of a person to trust automation, independent of context or a specific system. Besides these rather stable personal traits and characteristics influencing trust, Hoff and Bashir (2015) list other internal but rather variable personal factors, such as self-confidence, subjective expertise, mood, and attentional capacities, which influence trust dependent on the context. While Hoff and Bashir (2015) differ between dispositional and situative personal factors, we propose a more detailed subdivision into the rather dispositional categories demographics and personality traits and the rather

situative categories personality states and existing knowledge/prior experience. All four categories are subsumed under the term personal factors (see Figure 1).

In addition to personal factors, there are also external factors influencing TiA, including system properties, system performance, and environmental factors (Perkins et al., 2010; Rajaonah et al., 2008; Hoff & Bashir, 2015). System properties include characteristics such as type of system, design, or system complexity. System performance can be described by e.g., the reliability, validity and predictability of a system, as well as by the timing of potential errors and their nature (false alarms vs. misses). While Hoff and Bashir (2015) suggest to assign system properties to situational factors and consider system performance separately, we propose to subsume them for simplification purposes under the term system factors (see Figure 1). By environmental factors, we summarise factors external to the vehicle and the user, e.g., weather, time of day and road guidance (Dautzenberg et al., 2021). Environmental factors often receive little detailed consideration and are assigned to general situational factor groups, similar to Hoff and Bashir (2015). In contrast, we would consider the environmental factors as a third separate source of influence alongside the personal and system factors (see Figure 1).

Another distinction that Hoff and Bashir (2015) made based on their literature review, which we adopt for our theoretical framework, is that between initial and dynamic trust (see Figure 1). In accordance with Hoff and Bashir (2015), we hypothesise that especially the personal and environmental factors as well as users' evaluation of system properties determine an initial trust level towards an automated system. Is a potential user open to new things or rather neurotic? Is the driving situation rather complex or manageable? Is the system considered reliable based on previous experience or reputation? Actual system performance determines whether and how trust dynamically adapts or evolves. Does the system act comprehensibly, transparently and/or according to previous expectations?

CONCLUSION AND FUTURE WORK

In this paper, we developed a theoretical framework for the interaction between TiA and acceptance of automated driving (SAE Level4/5), including further relevant influencing factors related to trust and acceptance. The framework proposed here goes beyond existing models, by providing a more holistic picture of the interrelationships between trust and acceptance. Nevertheless, the framework presented in this paper has been developed theoretically. A validation of the relationships is pending and indispensable. Of particular interest are correlation directions and potentially existing feedback loops between the framework components. Moreover, some surveys that assess TiA, such as the Trust in Automation Scale (TAS; Jian, Bisantz, & Drury, 2000), assess not only trust but also distrust. Therefore, the subdivision of trust and distrust could be interesting - both with regard to the correlations with acceptance and with regard to the mode of action of the postulated influencing factors.

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