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Understanding Trust in Automation: A Consideration of Human Factors and Context

Hannah Biermann, Sophia Otten, and Martina Ziefle

Chair of Communication Science, RWTH Aachen University, 52074 Aachen, Germany

ABSTRACT

The understanding of trust decisions in human-automation interaction is crucial for acceptance modelling. To fully understand trust in automation, it is important to understand what trust and distrust actually mean to different groups of people, what associations they share, and what ideas and meanings the two concepts evoke. We conducted a two-step empirical research approach using qualitative and quantitative methods to identify the narratives underlying trust and distrust and to evaluate relationships with human factors (demography, personality) and contextual factors (mobility and medicine). Exploratory factor analyses revealed distinct dimensions for trust and distrust in cognition, condition, affection, and semantics. Correlations were found between the identified trust and distrust dimensions and trust in autonomous mobility, but not trust in medical technology. In addition, the trust and distrust dimensions were correlated with human factors, including trust disposition, risk perception, innovativeness, gender, and age. Our research shows the intricate relationships and situational conditions of (dis)trust perceptions. Underlying narratives of the two concepts differ in relevance for the respective contexts whereas the relations to human factors are equally important and validate previous findings.

Keywords: Trust in automation, Distrust, Autonomous driving, Ambient assisted living, User diversity

INTRODUCTION

People are increasingly interacting with modern technology in different areas of their lives, both personally and professionally. A great advantage can be the relief of the user through technical devices that gradually take over tasks and perform them independently. However, increasing system automation is often accompanied by uncertainty among users, expressed for example in concerns about loss of control (Jaschinski and Allouch 2015, Schmidt et al. 2015). Trust can help overcome perceived uncertainties and is seen as a key driver for the acceptance and successful implementation of novel technologies (Ghazizadeh and Lee 2012).

In the research literature, there are numerous descriptions and classifications of trust that vary depending on the setting (organisational, interpersonal, etc.) in which trust decisions are made (Söderström 2009). With regard to human-automation interaction, trust is defined as "the attitude that an agent

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will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee and See 2004). It is assumed that trust as an attitude is related to reliance on someone or something and thus has behavioral implications (Lee and See 2004). In real life, misconceptions, such as trusting a technical system that acts faulty or unforeseen (i.e., overreliance), or distrusting a technical system that functions flawlessly (i.e., underreliance), can have dramatic consequences, as past aviation and maritime accidents have shown (Parasuraman and Riley 1997). By understanding how trust and distrust are formed, strategies can be derived for managing technology innovation and developing trustworthy applications for successful human-automation interaction.

Characteristics of the trust giver, such as disposition and knowledge, and characteristics of the trust receiver, such as performance, are important for the evaluation of trust and for trust decisions; a detailed description and classification of influencing factors for trust in automation can be found in Hoff and Bashir (2015). The perception of trust also seems to be influenced by the type of trust receiver (human or machine), which is reflected in the scientific tools used to measure trust. A recent textual analysis of trust measures showed that in the context of automation technology, system- and task-related attributes are often used (e.g., "reliable", "function"), whereas in the context of interpersonal trust (i.e., person-to-person), emotional aspects are more often asked about (e.g., "feeling", "honesty") (Alsaid et al. 2022). We would like to follow this up with an empirical study to better understand what trust and distrust actually mean to different people, and how these fundamental ideas and understandings are related to trust in automation. We distinguish conceptually between trust and distrust, assuming that they are related but individual attitudes. This assumption is supported by theoretical considerations (Muir 1994; Lewicki et al. 1998) and empirical research (Biermann et al. 2022).

We designed a two-step empirical, exploratory research approach using qualitative and quantitative methods. First, we explored the narratives underlying trust and distrust, i.e., how they are perceived and described, what associations and attributions exist, etc. (method: interview). In a second step, the obtained facets of trust and distrust were operationalised and measured in an online questionnaire survey to identify distinct dimensions and to assess relationships with human factors and trust in automation. As trust varies depending on the technical system and application field (Brell et al. 2019), we considered two different scenarios to identify context-independent and specific evaluation patterns. The areas chosen were mobility (autonomous driving) and medicine (ambient assisted living, short AAL), as in both cases risk perception, trust in technology, and the perceived value of an innovation play an important role in the willingness to use it.

METHOD

The procedure and methods used, as well as the samples of the two studies are described below.

Interview study: In a preliminary qualitative study, guided interviews (language: German) were conducted to identify conceptual facets of trust and distrust. Participants were asked what trust and distrust mean to them, what they associate with these terms, and to what extent their conception of trust and distrust changes when they think specifically about the use of technology. In sum, 21 adults of different age groups (21 to 86 years) participated, thereof 12 women and 9 men. The average age of the participants was 49.9 years (SD = 20.1). The interviews were transcribed verbatim and analyzed using content analysis.

Questionnaire survey: Interview results were operationalized and measured in an online questionnaire survey. Initially, participants were asked about demographic information (age, gender, education), their trust disposition (Beierlein et al. 2014, Otten and Ziefle 2022), innovativeness, and risk perception (Beierlein et al. 2015). Subsequently, participants evaluated items describing trust (e.g., "Trust is a gut feeling or instinct") and distrust (e.g., "Distrust is something negative"). A semantic differential was used to assess associations with trust and distrust in the form of counterword pairs (e.g., "affection" vs. "aversion"). All itmes used for the evaluation of general trust and distrust perceptions were self-developed based on the interview findings. Then, two scenario descriptions were presented to the participants in randomized order. One scenario pertained to medical video-based AAL (VAAL) technology, focusing on movement recognition and fall detection. The other scenario pertained to autonomous driving, focusing on a self-driving shuttle service. Following the scenarios, participants were asked to rate the extent to which they would trust and intend to use the technologies described (e.g., "I would only use this technology if I felt I could trust it"). The items were developed on the basis of the results of preliminary qualitative studies.

We used 6-point Likert scales ranging from "totally disagree" to "totally agree". Cronbach's alpha (α) was checked for scale reliability which was good (>.7), except for the self-developed scale measuring distrust perception (.660) which was included for analysis, though, due to the exploratory nature of the overall research design. Descriptive and inferential statistical methods were used for data analysis. A significance level of.05 was used.

In total, N = 90 data sets were included in the analysis. There were slightly more male (55.6%) than female participants (44.4%). The sample was highly educated with 61.2% university graduates. The mean age was 36.37 (SD= 11.25) with an age range from 20 to 73 years. The mean score on risk perception was M = 3.99 (SD = 1.24) and the mean score on dispositional trust was M = 4.04 (SD =.31). The mean score on innovation readiness was 3.89 (SD = .44). The mean score for trust in autonomous mobility was 4.81 (SD = .81), while the mean score for trust in VAAL technology was 4.66 (SD = .73).

RESULTS

First, interview results are presented. Second, results of the questionnaire survey are outlined.

Interview Study: Understanding the Narratives of Trust and Distrust

The aim of the interview study was to understand individual perceptions of trust and distrust in general and with regard to technology use. The obtained results are presented below regarding descriptions of and associations with trust and distrust, as well as contextual differences. Verbatim quotes from the interview transcripts are in quotation marks and marked in italics.

(Dis)trust descriptions: Trust and distrust were described as a personality trait, as an instinct, and a gut feeling that participants said was difficult to put into words. Trust was paraphrased with positive and distrust with negative attributions, such as "warm" and "vital" versus "discomfortable" and "corrosive". Descriptions of trust and distrust related to aspects of control, reliability, and safety. The participants stated that trust for them meant being able to give up control and rely on something or someone, keeping one's word, and not being hurt. In contrast, distrust was interpreted as the opposite of trust, expressed as having no control, not being able to rely on others, and being hurt.

(Dis)trust associations: Trust and distrust were generally associated with other people and social interaction. Table 1 shows an overview of all associations with the two terms mentioned by the participants and assigned categories. Associations with trust were predominantly positive and associations with distrust were negative. Besides, associations with trust and distrust often formed pairs of opposites. Values were associated only with trust, whereas distrust aroused attitude-related associations.

Interpersonal vs. technology trust: Asked to what extent their perception of trust and distrust changes when they think about technology, some of the

Table 1. Mentioned associations with trust and distrust and assigned categories (N = 21).

Category	Trust associations	Distrust associations
Feeling	Affection	Disappointment
	Wellbeing	Fear
	Love	Discomfort
	Comfort	
State and condition	Safety	Uncertainty
	Reliability	Doubt
	Intimacy	Panic
	Familiarity	Danger
	Breach of trust	Fraud
		Dispute
		War
Relationship	Family	Enmity
	Friendship	Job / Business
Value	Fidelity	
	Loyalty	
	Honesty	
Attitude		Prejudice
		Pessimism

participants stated no considerable differences and indicated that trustworthiness was determined by similar factors, such as experience and reliability. Not everyone saw it the same way. For others, trust generally involved emotional aspects, while trust in technology was related to functional aspects. One participant (female, age 54) stated: "*I mentioned the word love earlier, I don't love technology. There's a big difference. Technology has to work reliably for me.*" Also, technology-related trust was described less as a gut feeling and more a predictable risk. Another participant (male, age 73) stated: *"Well, you can be more objective about whether technology is really trustworthy. Whether a person is trustworthy cannot be determined objectively. [...] I rather know that I cannot believe a technology. So it's not about distrust, it's about having knowledge about a technology.*"

Questionnaire Survey: Quantifying Trust and Distrust Perceptions

The aim of the questionnaire survey was to measure the obtained narratives of trust and distrust to identify dimensions that can be used to describe them and to evaluate to what extent these are related to human factors and trust in automation.

Figure 1 shows associations with trust and distrust measured on a semantic differential. Associations with trust were positive, while associations with distrust tended to be negative. There were major differences in the evaluation of associated feelings. Distrust was also more strongly associated with perceived risk and the unknown, whereas trust was more strongly associated with familiarity and security. Social relationships also seem to influence perceptions, e.g., with trust being more associated with friendship and distrust with enmity. Smaller evaluation differences occurred in the association of trust and distrust with intuition and reasoning, knowledge and belief, and naivety and wisdom, which were near the middle of the scale (i.e., half/half).

Figure 2 visualizes response behaviors for items describing trust. There was unanimous agreement that trust is important for friendship. There was also a relatively high level of agreement with the idea of trust being associated with wellbeing, something positive, and reliability. There was a striking diversity of responses to the claim that trust is difficult to describe, suggesting the existence of individual perspectives on the issue of trust.

Figure 3 illustrates the response behaviour for items describing distrust, which was more diverse overall. While there was still a comparatively high level of agreement on the association of distrust with an uncomfortable feeling and a (bad) experience, participants were divided on the assumption that distrust is related to fear or insecurity or is something negative. There was also disagreement about whether distrust is the opposite of trust, and disagreement about the possibility that feelings of distrust and trust can exist in the same thing at the same time.

(Dis)trust dimensions: To further investigate dimensions of trust and distrust, exploratory factor analyses (EFA) using principal axis factoring and oblique rotation (direct oblimin) were conducted. Due to the sample size, only factor loadings above. 4 were considered.

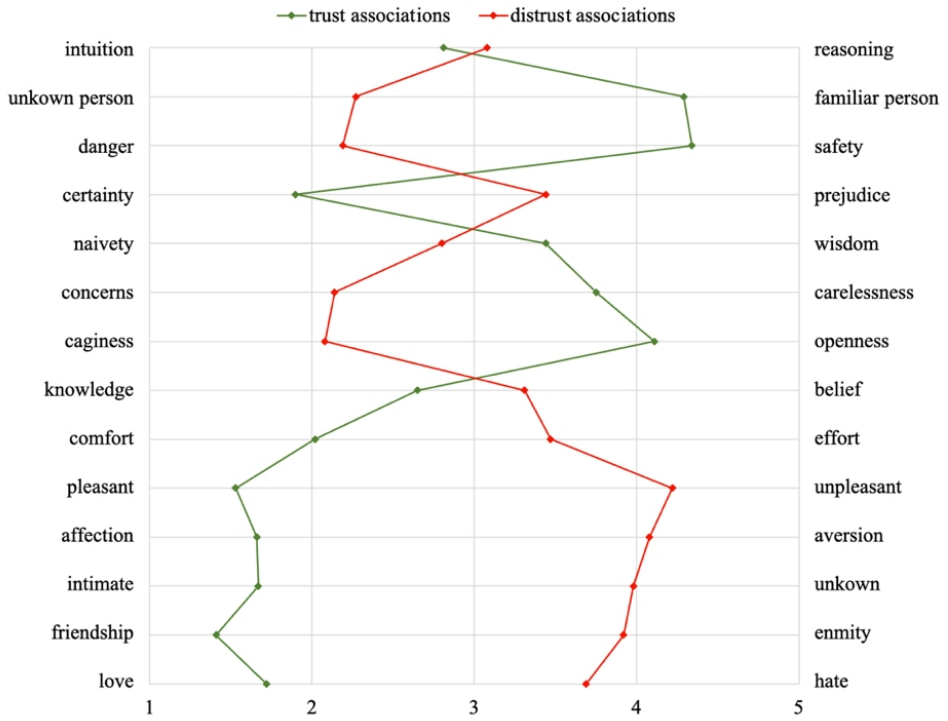

Figure 1: Associations with trust and distrust measured on a semantic differential (N = 90).

The EFA on the ***trust*** instrument revealed two distinct dimensions based on the factor loadings and examination of the scree plot. The Kaiser-Mayer Olkin score was.767 and Barthlett's test of sphericity was significant (p<.001). Factor one consisted of 8 items (α = .794) and factor two of 3 items (α = .556), see Table 2.[1] The two identified trust factors explained 44.05% of the variance (extraction sum of squared loadings). After careful examination, the first factor was named *conditional trust* and the second factor was called *affective trust*.

The EFA on the ***distrust*** instrument revealed three distinct dimensions based on the factor loadings and examination of the scree plot. The Kaiser-Mayer Olkin score was.635 and Barthlett's test of sphericity was significant (p < .001). The first factor consisted of 4 items (α = .649), while factor two (α = .547) and factor three (α = .652) consisted of 3 items.[2] The three identified distrust factors explained 39.83% of the variance (extraction sum of squared loadings). After careful examination, the first factor was named *affective distrust*, the second factor was named *cognitive distrust*, and the third factor was named *semantic distrust*.

[1] A third proposed factor consisted of only one item and was discarded whereas another item did not load on any of the factors and was discarded, too.

[2] Two items were excluded from the analysis due to insufficient factor loading.

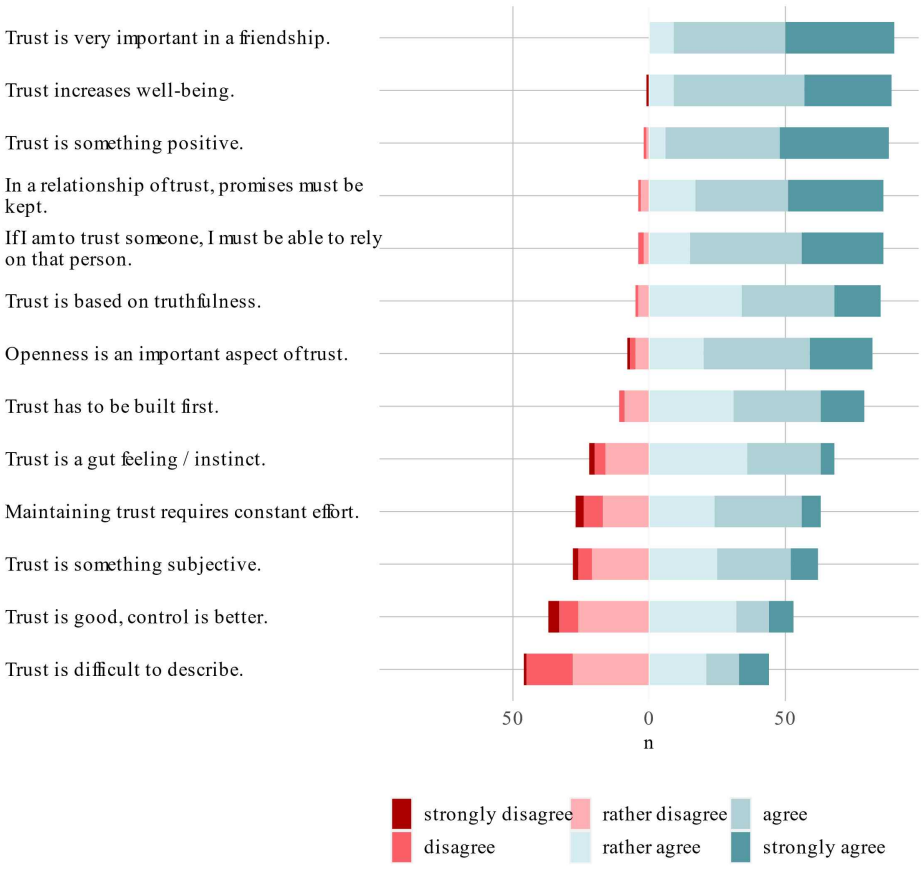

Figure 2: Trust perceptions (N = 90).

Relations between (dis)trust, human factors, and context: Correlation analyses were carried out to evaluate relations between the identified trust and distrust dimensions, human factors, and trust in automation (mobility vs. medicine). We found a moderate correlation between *conditional trust* and trust in autonomous mobility (ρ = .331, p = .001). Also, *cognitive distrust* and *semantic distrust* showed significant correlations with trust in autonomous mobility (ρ = .474, p<.001; ρ = .254, p = .016). The more likely respondents were to say that trust (in general) is something positive and important, conditioned by reliability, the greater their reported trust in autonomous mobility. Also, the more they were to say, for example, that distrust is based on disappointment and experience and needs to be built up, the greater their reported trust in autonomous mobility. No significant correlations were found between (dis)trust factors and medical trust in VAAL technology.

All identified (dis)trust factors were related to human factors: *Conditional trust* correlated with risk perception (ρ = -.227, p = .031), trust disposition (ρ = .265, p = .012), innovativeness (ρ = .346, p<.001), and gender (r = −.265, p = .011). *Affective trust* correlated with risk perception

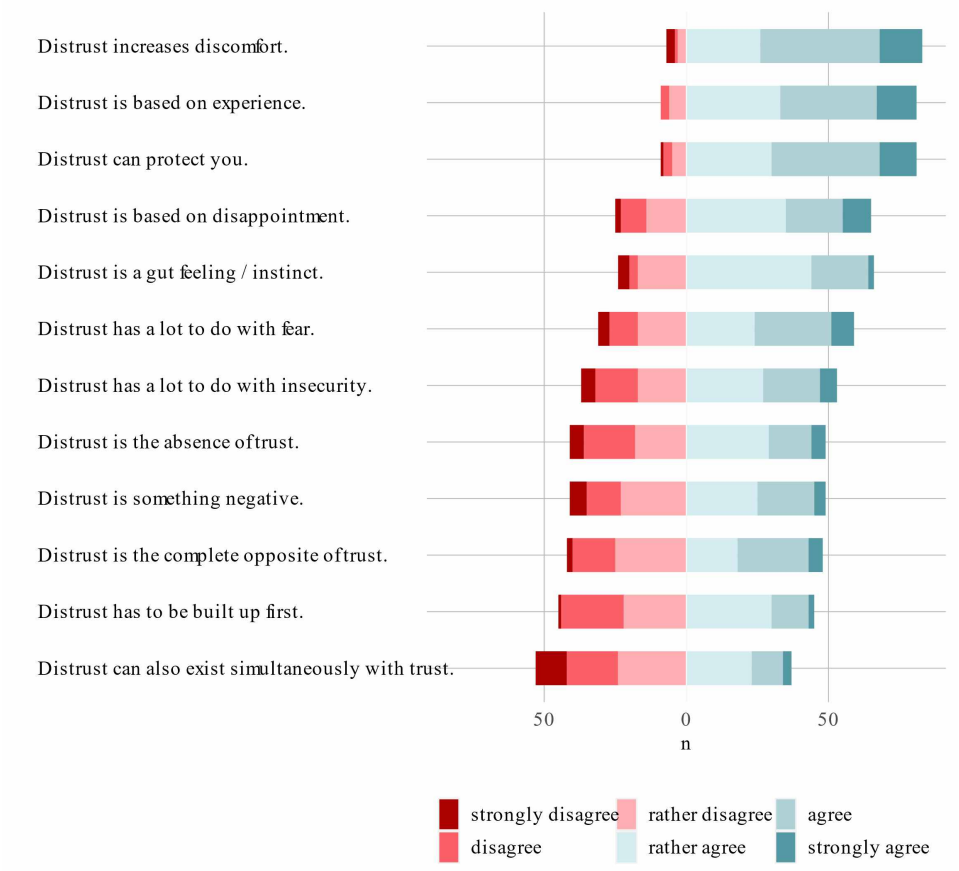

Figure 3: Distrust perceptions (N = 90).

Table 2. Pattern matrix for the trust instrument.

Items	Factor 1 "conditional trust"	Factor 2 "affective trust"
If I am to trust someone, I must be able to rely on that person.	.786	
Trust increases well-being.	.731	
Trust is something positive.	.684	
Trust is very important in a friendship.	.625	
In a relationship of trust, promises must be kept.	.61	
Trust is based on truthfulness.	.501	
Trust has to be built up first.	.466	
Maintaining trust requires constant commitment.	.427	
Trust is a gut feeling/instinct.		.574
Trust is difficult to describe.		.52
Trust is something subjective.		.438

Table 3. Pattern matrix for the distrust instrument.

Items	Factor 1 "affective distrust"	Factor 2 "cognitive distrust"	Factor 3 "semantic distrust"
Distrust has a lot to do with fear.	.917		
Distrust has a lot to do with insecurity.	.568		
Distrust is something negative.	.432		
Distrust is a gut feeling/instinct.	.404		
Distrust increases discomfort.		.771	
Distrust is based on experience.		.553	
Distrust is based on disappointment.		.448	
Distrust has to be built up first.			.813
Distrust is the complete opposite of trust.			.647
Distrust can exist simultaneously with trust.			.437

($\rho = -.254$, p = .016) and gender (r = −.248, p=.018). *Affective distrust* correlated with gender (r = −.208, p = .049), *cognitive distrust* correlated with innovativeness ($\rho = .336$, p = .001), and *semantic distrust* correlated with age (r = .242, p = .021).

DISCUSSION

The aim of our research was threefold: First, we identified narratives underlying trust and distrust. Second, we quantified different dimensions (i.e., trust and distrust factors). Third, we assessed relationships with human and contextual factors. The obtained results contribute to a more detailed description and explanation of trust and distrust in general and in automation, and help scientific research to measure corresponding constructs more precisely.

With regard to the obtained qualitative data, the basic descriptions of trust and distrust were similar, e.g., both were seen as personality traits and related to aspects of control, reliability, and safety. Semantic differences were found: trust had a positive connotation and distrust a negative connotation, expressed for example in opposite attributions. There were further differences in individual associations; values were exclusively associated with trust, whereas distrust implied attitudinal associations. Contextual differences were found: Technology trust was more associated with functional aspects, whereas interpersonal trust was more emotional. This is in line with the findings of Alsaid et al. (2022). The descriptive evaluation of trust and distrust showed different response behaviour: There was a high level of agreement, i.e., broad consensus, regarding the description of trust, whereas responses regarding the description of distrust were more diverse, indicating different opinions. The following conclusions can be drawn: First, trust and distrust are partly opposing concepts, but they also have conceptual similarities and overlaps, as well as unique features in terms of concrete associations and attributions. In other words, we can confirm the assumption that they are distinct but closely related concepts. Second, there seems to be a greater consensus on what

constitutes trust, while narratives of distrust are more divergent. This confirms previous studies (Biermann et al. 2022) and calls for follow-up studies to better understand, in particular, the formation of distrust.

The difficulty of finding a specific definition of what distrust actually means is illustrated by the allusion to the underlying semantics. Overall, five different dimensions of trust and distrust were found. The different facets reflected in them illustrate the complexity of how trust and distrust are perceived and how they arise. Correlation analyses revealed intriguing results. While there were significant correlations between (dis)trust factors and trust in autonomous mobility, there were no significant relations in the medical context. This is interesting since there are several studies showing that trust is an important predictor for perceptions of medical technology (e.g., Otten and Ziefle 2022; Wilkowska and Ziefle 2018). This, however, is often specified to conditional trust of specific technologies and less often about general trust perceptions and how these are related to the overall evaluation of medical technology. Thus, it is important to further investigate whether general (dis)trust perceptions influence trust in medical technology, like it influences trust in autonomous mobility, or whether the medical context is more context-dependent than initially thought.

Correlations between (dis)trust factors and trust in autonomous mobility showed that the conditional, cognitive, and semantic domains of (dis)trust are relevant whereas the affective domain shows no relationship. Thus, rational considerations and situational conditions seem to be more strongly related to trust in autonomous mobility than affective evaluations, which is in line with our pre-study findings, suggesting that trust in technology is driven by cognition rather than emotion, and reinforcing the two-stage research process of this study.

(Dis)trust factors were related to human factors. This confirms previous studies (e.g., Biermann et al. 2022) and adds to the literature. However, as not all dimensions of (dis)trust correlated with all human factors, it is crucial to deepen the understanding of these correlations. This would also clarify which dimensions of (dis)trust are more or less relevant for the relationships between trust and human factors. Future studies should extend and further validate these initial findings.

We continue to draw the following conclusions: Trust and distrust are based on different facets, which in this study could be mapped into five dimensions in affection, cognition, condition, and semantics. These distinct dimensions correlate with human factors, suggesting that perceptions and evaluations of trust and distrust are individual and may be determined by people's general attitude of trust (or scepticism) towards others, how risk-averse or risk-seeking they are, how willing they are to embrace innovation, and also their socio-demographic background. Secondly, there is a correlation between the identified (dis)trust dimensions with trust regarding autonomous mobility, but not with trust regarding VAAL technology. Therefore, a further conclusion is that the evaluation of trust or distrust in the case of technology use is context-dependent, which is also supported by the observation that trust in autonomous mobility is generally higher than trust in VAAL technology. It is assumed that trust does not always follow the same pattern, but

is determined by personal and situation-specific characteristics. This makes it necessary to carefully investigate trust in automation, taking into account user diversity and different application contexts. Our findings provide an empirical basis for future research projects.

The critical reflection of the study addresses both methodological and content issues. Firstly, the sample of our quantitative study (questionnaire) was rather small. Besides, the participants were relatively young and well educated. Follow-up studies should validate the results obtained in a larger and broader (i.e., more diverse) sample. Another point relates to the data collection, which took place in Germany or in German-speaking countries. As perceptions and attitudes may be conditioned by cultural influences, it would be both exciting and indispensable to mirror our results in a cross-national study in order to identify any cultural differences in the perception and evaluation of trust and distrust, which would then have to be incorporated into the management and design of technical innovation. A third point relates to the automation contexts considered in our study. With the knowledge gained in this study that there are context-specific evaluation patterns with regard to trust and distrust, it remains essential to consider further application scenarios (e.g., home automation, production contexts) and to describe the formation of trust and distrust regarding the scenarios considered here in more detail in follow-up studies, for example in a comparative study of factors influencing trust and distrust. Besides, the reliability of some of the identified (dis)trust factors was only sufficient, not adequate, which may be due to the comparatively small number of items per factor. Due to the exploratory research approach of this study, they were nevertheless included in the analyses. Nevertheless, further narratives of trust and distrust should be identified and measured in follow-up studies to complement and sharpen the identified factors.

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