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Exploring Trust in Human-Agent Collaboration

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Abstract. Collaborative ensembles will increasingly involve agents like robots in the near future. A key part of collaboration is trust. While trust has been mainly studied between humans in CSCW, trust in human-agent research has been mostly studied in dyadic formations divorced from the broader context. This exploratory paper critically discusses previous work on trust across CSCW and HCI-related areas, taking into account recent practice approaches in CSCW and what they can contribute for understanding trust in human-agent collaboration. To make better sense of how trust emerges in collaborative ensembles with agents, we suggest that concepts that have been proposed in the field of human-agent interaction need to be further explored in real-life settings, while concepts embraced in CSCW can lead to a more thorough understanding of the situatedness and dynamics of trust going beyond the attributes of the agent itself.

1 Introduction

Understanding key aspects of collaboration is an important part of CSCW and HCI research. In the near future, due to technological innovation, we can anticipate that collaborative ensembles will increasingly involve agents like robots. For example, as assistive robots are developed for care, collaborative care networks may involve at least patients, caregivers and robots. An agent, like the robot here, can be defined

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as “an object or technology that people interact with as if it is able to act with its own purposes, motivations, and intentions”¹ (Human-Agent Interaction, 2019).

Trust is a key aspect of collaboration, and it has been studied in both CSCW and in other research with agents. In the CSCW community, trust has been studied mainly with regards to human-human collaboration. In this context, technology is a tool through which interpersonal trust can be fostered, without being an artifact or even a perceived social actor to be trustworthy itself. In other communities, such as in Human-Agent Interaction (HAI) and Human-Robot Interaction (HRI), the agency and social role of agents has been taken into account. Given that trust is a key aspect of collaboration, the aim of this paper is to understand how trust is differently framed across disciplines, and what CSCW can contribute to trust in human-agent collaboration.

We consider human-agent collaboration, in accordance with Jung et al. (2018), as collaborative partnerships between humans and agents in completing tasks that typically focus on coordinating close, seamless joint activities. However, as also mentioned by Jung et al. (2018), up to now this research often only focused on human-agent dyad studies, but interaction scenarios are becoming more and more common in which one or several robots are deployed in social contexts that involve groups of people rather than individuals. In the simplest of collaboration scenarios that involve multiple people, an agent will have to make decisions about how to distribute resources (e.g. social attention, task support, or physical resources) and preliminary studies in HRI have already studied the effects of different types of collaboration formations on human-robot teaming (Brosnan and de Waal, 2014; Lee, 2018). Different collaboration formations are also likely to impact issues of trust in human-agent collaboration studies but to date this has not been well explored, especially in complex real world settings and collaborative formations.

In this exploratory paper, trust is critically reflected on as it is used both in CSCW and in other work on human-agent collaboration. Conceptualizations of trust as they are used in human-agent research are critically discussed, taking into account recently emerging practice approaches in HCI. Our aim is to outline broad directions for future research, which can then form the basis from which future studies can be defined and conducted.

The outline of this paper is as follows. In the next section, previous work on trust in CSCW and HCI will be critically reflected on. Subsequently, a section elaborating work on trust in agents will discuss agents as social actors and previous work on trust in human-agent interaction. We then discuss what building blocks are missing that need further research, and the contributions that CSCW can make to understanding and developing better human-agent collaboration, followed by a Conclusion section.

¹ <http://hai-conference.net/what-is-hai/>

2 Trust in CSCW

In CSCW, and related Human Computer Interaction (HCI) research, trust has been studied in various contexts and mainly on an interpersonal level. Technical artifacts can be seen as tools entailed in collaborative work or as mediums through which that work is conducted. In this context, interpersonal trust is either framed as a key part of collaboration between people, or as occurring between individuals and political or corporate institutions. For the most part, collaboration is interwoven with its broader social context.

Trust has been particularly identified as important in computer-mediated communication (CMC) (Zheng et al., 2002) and virtual work teams (Al-Ani et al., 2013b; Robert, 2016; Quan-Haase and Wellman, 2005; Bos et al., 2001). In a study on globally distributed computer-supported work, trust was framed as expectations of other human parties (Al-Ani et al., 2013a). Individuals' baseline trust and its effect on the diffusion of trust in cooperation has been explored (Wang and Redmiles, 2016), as well as inter-group trust formation (Nguyen and Canny, 2007) and interpersonal conflict in technologically-mediated settings (Billings and Watts, 2007). In computer-supported crisis management, psychological and social factors were taken into account, and trust was related to information sharing behaviour in a crisis response system (Linot, 2018). Lampinen et al. (2016) have also worked on trust in the context of the sharing economy.

Besides collaboration in work teams, institutional trust has been studied, such as in e-governance and related to e-participation (Corbett and Le Dantec, 2018; De Cindio et al., 2007). Further, Wang and Mark (2013) explored trust in online news, where they compared social media to official news to study trust in institutional practices. Other interesting work showed how people in a political conflict zone were able to create a context of trust (Semaan and Mark, 2011). The use of ICTs helped people to manage their public identity, to conduct background checks, and to develop collaborative practices. Social interaction through technology added to the formation of a context of trust, where trust was framed as a practice. Trust in an institution was also studied in the context of e-commerce (Kim et al., 2017; Greenspan et al., 2000; Egger, 2000; Garnik, 2004), where trusting an online supplier is a crucial part of the trust relationship. In related work, cultural backgrounds have been taken into account (Garnik, 2004), and prepurchase knowledge besides interface properties and informational content (Egger, 2000), as well as interpersonal cues to measure affective reactions related to trust (Riegelsberger, 2003). Other related work has linked privacy and trust (Crabtree et al., 2017; Hong, 2009). E.g. Crabtree et al. (2017) conducted an ethnomethodological study of digital privacy practices in homes, and they found that people were concerned with the impact of the networked world on interpersonal affairs in their daily lives.

Besides a focus on trust in humans or institutions, properties of computers have been studied and how they can also foster interpersonal trust. For example, trust can be affected by choices in the design of a web interface (Marsh and Meech,

2000), and Kostakos and Oakley (2009) explored this through using locative images. Also, design principles have been proposed to foster trust between interacting human parties in collaborative work, drawing from ethnographic fieldwork (Knowles et al., 2015).

In CSCW, contextual knowledge and practices have been taken into account as essential for trust, and this has methodological implications. The use of qualitative research methods such as ethnography and ethnomethodology is thus common in the study of trust, also with an increasing focus on 'practices'. While early methods in HCI were inspired by psychological sciences involving controlled short-term, lab-oriented studies, which are according to Kuutti and Bannon (2014) embedded in the *Interaction paradigm*, this is not the case in the recently emerging *Practice paradigm*. In previous practice-oriented work, the practical accomplishment and "dynamic and situated 'interactional' aspects [...] to be accounted"(Fitzpatrick, 2003, p. 91) was highlighted. Generally speaking, practice approaches explore "[...] historical process and performances, longer-term actions which persist over time, and which must be studied along the full length of their temporal trajectory[,][...] situated in time and space"(Kuutti and Bannon, 2014, p. 3543). Further, the broader context is taken into account, and it is "intervoven within the practice" (Kuutti and Bannon, 2014, p. 3543).

Qualitative studies have shown how trust is enacted through ongoing practices, where it is for example operationalized by public officials (Corbett and Le Dantec, 2018). Trust as a practice itself has been worked on in CSCW already in the early days (Van House et al., 1998), being one of many representatives of the *turn to practice* (Kuutti and Bannon, 2014) in HCI.

3 Trust in Agents

Trust has also been explored in situations involving agents. As agents are becoming part of collaborative ensembles, previous research has shown that some agents can be treated and seen as social beings (Coeckelbergh, 2012). In the process of anthropomorphizing agents, some authors argue that it is possible to associate human-like characteristics to agents such as benevolence, competence and integrity. From this point of view, an agent can be perceived as a social actor (Waytz et al., 2014).

Based on the assumption that agents can be perceived as social, studies have explored how interpersonal trust occurs in human-robot interaction. In short-term child-robot interactions for example, van Straten et al. (2018) showed that interpersonal trust occurred with robots, where interpersonal trust was distinguished by the children from technological trust. Technological trust can be defined as "the attitude that an agent will help [to] achieve an individual's goal in a situation characterized by uncertainty and vulnerability" (Lee and See, 2004, p. 51). Further, an agent's technical properties was one of the reasons for children to trust robots interpersonally (van Straten et al., 2018).

When reviewing the literature of human-agent collaboration, there are two integrative models of trust by Mayer et al. (1995) and Rousseau et al. (1998) that mostly occur (e.g. Martelaro et al., 2016). In the Mayer et al. (1995) model of trust, trust is defined as the “willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party” (Mayer et al., 1995, p. 712). Trust arises referring to another party’s ability (i.e. competence), integrity (i.e. adherence to honesty and truthfulness), and benevolence (i.e. the willingness to protect and support without an egocentric motive) (Mayer et al., 1995). The model of trust by Rousseau et al. (1998) gives a definition for organizational contexts that comes up slightly later, where the notion of social trust is defined as a “psychological state comprising the intention to accept vulnerabilities based upon positive expectations of the intentions or behaviour of another” (Rousseau et al., 1998).

Human-agent trust was modeled by Gulati et al. (2018), who take several properties of both the agent the person into account. A person’s motivation and willingness are identified as factors having an impact on trust, along with the perceived agent’s competence, benevolence, honesty, predictability and reciprocity. In a study with Siri, they show that trust can be affected by how helpful (or benevolent) an agent is, how competent (or reliable) it is, and how reciprocal it is to a person’s needs. However, trust is not significantly affected by motivation, predictability and honesty (Gulati et al., 2017).

Although focusing on dyadic relationships between trustor and trustee is very common, broader approaches have been proposed as well, i.e. on trust as reliance. Billings et al. (2012) proposed a three-factor model of trust in robots, including *human* characteristics such as ability and personality, *environmental* characteristics such as task and team, and *robot* characteristics such as performance and attributes (Billings et al., 2012). These three factors have also been identified in a meta-analysis on trust (Hancock et al., 2011), where the authors stressed that too few studies have yet been conducted on environmental and human-related factors, although robot-related factors have been shown to affect trust the most. The conclusion that robot-related factors are more “influential” on trust is however not convincing, given the few studies on human-related and environment-related factors, where the impact is not yet known. Moreover, identifying and adding the interplay of these factors on one another for trust is still open to research.

Drawing on the model from organizational contexts by Mayer et al. (1995) and the model on trust in automation by Lee and See (2004), Wagner et al. (2018) propose a trust model based on risk. They define trust as “a belief, held by the trustor, that the trustee will act in a manner that mitigates the trustor’s risk in a situation in which the trustor has put its outcomes at risk” (Wagner et al., 2018, p.26:4). Trust is modeled in game-theoretic terms, and similar to what Hancock et al. (2011) proposed, they highlight three important factors that influence trust-based decisions, namely the trustee, the trustor, and the situation. The model was also tested in an emergency experiment by Robinette et al. (2016), where

people tended to overtrust the robot despite half of them observing the same robot performing poorly in a navigation guidance task minutes before.

Based on the three-factor model by Hancock et al. (2011), Hoff and Bashir (2015) have also suggested a three-layered model in which these factors contribute to *dispositional*, *situational* and *learned* trust (Hoff and Bashir, 2015). They pointed out that age, gender, culture and personality differences are components of dispositional trust, where they reflect an individual's overall tendency to trust in automation. Situational trust is shaped by internal and external variability, such as self-confidence, mood, type of system, perceived risks, task difficulty and organizational setting. Learned trust includes an operator's evaluation of a system based on past experience or the current interaction, and it is shaped by preexisting knowledge, system performance and design features. The three factors add to a person's reliance on a system, where they can change with the course of a single interaction (Hoff and Bashir, 2015). According to this model, trust affects a person's willingness to rely on a system, which can potentially change through dynamically learned trust, i.e. interaction experience. The latter is affected by system performance and design features. Furthermore, it is acknowledged that situational factors that are not related to trust also affect perceived reliance. What is however not acknowledged is how other factors may change over time, and how they affect one another not only through interaction, but also through other everyday life practices.

A limitation to many studies on trust in human-agent interaction and human-robot interaction so far is that they have mainly been performed in laboratory or experimental settings (e.g. Rossi et al., 2017; Agrawal and Yanco, 2018). This is understandable due to technology readiness levels to date. However, there are some studies that are starting to be performed in real-life settings, such as with senior citizens in care facilities and domestic environments (de Graaf et al., 2015; Klamer and Allouch, 2010; Tsiourti et al., 2014; Wada and Shibata, 2007; Wada et al., 2005, 2004; Broadbent et al., 2016). These studies mainly focus on agents as companions indicating positive effects on health and psychological well-being of people with respect to mood, loneliness and social connections with others. To our knowledge though, none of these studies focused on trust or collaboration per se, instead focussing mainly on acceptance aspects of the agents and derived implications for design.

4 Discussion

CSCW has a body of research on trust, focusing on computer-supported collaboration between humans. However, agents will increasingly become part of collaborative ensembles in the near future, such as in mixed human-robot teams in care contexts. Therefore, both taking into account agents as collaborative actors in different group formations, and exploring trust in agents in various collaborative settings, are important for understanding current and future collaboration.

As summarized in Table 1, we can broadly characterize some key differences in research on trust across different communities. For trust in CSCW when taking into account the broader context, trustees are mostly humans or institutions such as companies or governmental organizations, whereas in HAI and HRI, the trustee is the agent. A research gap for trust is the incorporation of agents as part of collaborative ensembles, where humans and institutions as well as agents can be trustees. For collaboration, trust in CSCW mostly refers to trust in human-human collaboration, often as part of larger ensembles, whereas in HAI and HRI, the focus is on human-agent collaboration, often as part of dyadic interactions. It is likely that different group formations with agents will have a different impact on trust, which is yet open for research. Regarding the study context and focus, trust in agents has so far largely been conducted in lab-based experiments asking questions around interactions, acceptance and so on, while CSCW research on trust has been conducted via field studies of everyday settings, trying to understand everyday practices and situated actions in complex contexts.

	Trust in Context	Trust in H-A Interaction
Trustee	Humans, Institutions	Agents
Collaboration	Human-Human	Human-Agent
Study Context	Field studies	Lab Experiments
Focus	Practices, Contextual Knowledge	Interactions, Acceptance

Table I: A broad characterisation of trust across different research communities.

As agents such as robots are likely to increasingly become part of collaborative ensembles in real-world settings, we argue that the CSCW field has much to contribute to HAI/HRI research, to take into account the complexity of dynamic environments for trust in agents. While lab-based studies can be fruitful for studying an interaction itself, we would gain important practical knowledge from taking contextual aspects and changes over time into account and how these relate to trust. For example, starting with the model proposed by Billings et al. (2012), we could make use of taking several aspects like environmental, person-related and agent-related factors into account and study how they dynamically affect trust. Furthermore, the three-factor model proposed by Hoff and Bashir (2015) involves temporal trajectories, where trust is dynamically co-shaped by interaction experiences. However, this approach has to our best knowledge not yet been applied to real-life settings with agents with regards to how everyday practices interrelate with *learned trust* and other factors that are part of the model. The many years of CSCW research studying collaborations over time and exploring notions of trajectories Fitzpatrick (2003) may have much to contribute here. We also argue that CSCW can broaden its concerns to also consider the role of agents in collaboration.

In support of our argument to include contextual knowledge in future research on trust in agents, theoretical work has pointed out that trust is not a “dyadic phenomenon between two isolated actors; there is usually always a context and a history, and there are also other actors that matter” (Möllering, 2006, p. 9). This relates to more recent HCI research, where practice-oriented approaches have been emerging (Kuutti and Bannon, 2014). Framing trust as it is enacted through ongoing practices as proposed by Corbett and Le Dantec (2018) or as a practice itself (Van House et al., 1998) is also a possible direction to go in to better understand the situatedness and dynamics of trust in collaborative ensembles that involve agents.

5 Conclusion

CSCW has a body of research on trust in computer-supported collaboration and relationships. However, agents will increasingly become part of collaborative ensembles in the near future, which should be taken into account in future research on collaboration. As trust is a key aspect of collaboration, trust in agents must be further explored. Despite research on the topic in other fields such as HAI and HRI, there is no agreed concept of trust in agents, and trust has been studied mainly as a psychological state or intention divorced from its context. Opposed to earlier interaction approaches, CSCW and HCI are strong in understanding the importance of collaboration in context, also embracing more practice-oriented approaches in recent years. In order to understand the complexity, dynamics and situatedness of trust, trust in agents may be better framed as interwoven with everyday practices, where CSCW can have a key role in conceptualizing and exploring how trust is part of collaborative ensembles that include agents.

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