ALMOST HUMAN, BUT NOT REALLY

THE RELEVANCE OF THE HUMAN-TECHNOLOGY RELATIONSHIP FOR SOCIAL NEEDS AND INTERPERSONAL RELATIONSHIPS

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ABSTRACT

Technologies become increasingly present in people's daily lives and oftentimes adopt the role of social counterparts. People have conversations with their smart voice assistants and social robots assist with the household or even look after their users' mental and physical health. Thus, the human-technology relationship often resembles interpersonal relationships in several ways. While research has implied that the human-technology relationship can adopt a social character, it needs to be clarified in what ways and regarding which variables the human-technology relationship and interpersonal relationships are comparable. Moreover, the question arises to what extent interaction with technology can address users' social needs similar to a human counterpart and therefore possibly even affect interpersonal interaction. In this, the role of technology anthropomorphism, that is, the attribution of humanlike qualities to non-human agents or objects needs to be specified.

This thesis is dedicated to the relevance of the human-technology relationship for interpersonal relationships with a focus on social needs. In the frame of this overarching research aim, the studies included in this thesis focus on the dynamics of the human-technology relationship and their comparability to interpersonal relationships (RQ1), the potential of human-technology interaction to address users' social needs or substitute their fulfillment through interpersonal interaction (RQ2) as well as the role of technology anthropomorphism regarding these relationships (RQ3).

First, focusing on trust, which is integral for the relationship with a technology that is experienced as a counterpart, two consecutive experimental studies (study 1.1/1.2) were conducted. Based on a human-robot interaction, they explored trust development in the human-technology relationship as well as to what extent determinants known to affect interpersonal trust development are transferable. Moreover, they focused on the role of technology anthropomorphism in this relationship. In this, a positive effect of technology competence, that is, its ability to achieve intended goals (study 1.1), as well as technology warmth, that is, its adherence to the same intentions and interests as the trustor (study 1.2), on trust in the technology emerged. Thus, relevant determinants for trust development in the human-technology relationship were highlighted, also implying a transferability of essential dynamics of trust development from interpersonal relationships. Furthermore, perceived technology anthropomorphism appeared to affect the positive interrelation of perceived technology competence and trust in the technology (study 1.1) as well as the interrelation of perceived technology warmth and trust in the technology (study 1.2). These insights support a relevance of perceived technology anthropomorphism in trust dynamics within the human-technology relationship, but also in the transferability of corresponding dynamics from interpersonal relationships.

Similarly, in another study (study 2) the transferability of dynamics was explored for the variable of social connectedness, also key for relationship development and potentially relevant for the effect of interaction with technology on users' social needs. Therefore, a two-week human-technology interaction with a conversational chatbot was investigated. In this, possibly relevant characteristics of the technology, such as its perception as anthropomorphic or socially present, and the user, for example, the individual tendency to anthropomorphize or the individual need to belong, were focused. Moreover, a possible effect of social connectedness to the technology on the desire to socialize with other humans was explored. As findings showed that duration and intensity of participants' interaction with the technology throughout the two-week study-period positively predicted felt social connectedness to the technology, similarities to dynamics of interpersonal relationship development were highlighted. Furthermore, the relevance of technology anthropomorphism in the development of a human-technology relationship as well as its comparability to dynamics of interpersonal relationships was underlined. Namely, the more intense individuals interacted with the technology, the more anthropomorphic they perceived it, and therefore felt more socially connected to it. Similarly, the longer and more intense individuals interacted with the technology, the more socially present they perceived it, and in turn felt more socially connected to it. While contrary to expectations, no interrelation between the felt social connectedness to the technology and the desire to socialize with other humans emerged, this relationship was explored further within studies 3.1, 3.2 and 4.

Two consecutive experimental studies (study 3.1/3.2) explored the potential of anthropomorphic technologies to fulfill social needs as well as how individually perceived anthropomorphism correlates to these needs. While in both studies social exclusion and technology anthropomorphism were manipulated, we applied a different manipulation of anthropomorphism for each study. Whereas in one study (study 3.1) participants answered anthropomorphic (vs. non-anthropomorphic) questions regarding their own smartphone, in the other study (study 3.2) they were confronted with smartphone designs with anthropomorphic (vs. non-anthropomorphic) design cues. In both studies, no effects of anthropomorphism and social exclusion on behavioral intention or willingness to socialize were found. Yet, study 3.1

showed a positive correlation between willingness to socialize and perceived technology anthropomorphism. Results of study 3.2 further supported this relationship and additionally showed that this relationship was particularly strong for individuals with a high tendency to anthropomorphize, when the technology came with anthropomorphic design cues regarding its appearance. Thus, findings imply a relationship between social needs and anthropomorphism and further hint at a relevance of individual and contextual strengthening factors.

To complement these findings and foster a deeper understanding of the human-technology relationship as well as its potential to address users' social needs, a qualitative interview study was conducted (study 4). Findings highlight a potential of anthropomorphic technologies to address users' social needs in certain ways, but also underline essential differences between the quality of human-technology interaction and interpersonal interaction. Examples are the technology's missing reactions in interaction with the user on a content, physical, and emotional level as well as the absence of satisfaction of users' social needs through interaction with technology. Additionally, insights hint at a social desirability bias, as interaction with technology that resembles interpersonal interaction appears to often be subject to rather negative reactions by third parties.

After an overview of the empirical studies included in this thesis and their brief summaries, their research contribution is discussed. This is followed by an elaboration of overall theoretical and practical implications of this thesis. Theoretical implications focus on how this work contributes to but also extends theoretical and empirical work in the frame of the "computers are social actors" paradigm and particularly highlights the role of technology anthropomorphism as a phenomenon in this regard. Beyond the exploration of a social character of the human-technology relationship, this thesis offers insights on the potential of the human-technology relationship to address users' social needs to an extent that interpersonal relationships can be affected. Implications for practitioners involve insights on design examples to support the development of essential determinants of the human-technology relationship. They also offer a more abstract invitation to reflect on the design and application contexts of technologies to foster a responsible handling with technology in peoples' daily lives. Finally, the thesis concludes with a discussion of general limitations and directions for future research.

ZUSAMMENFASSUNG

Technologien werden zunehmend präsent im Alltag der Menschen und nehmen häufig die Rolle eines sozialen Gegenübers ein. Menschen unterhalten sich mit ihren technischen Sprachassistenten und soziale Roboter unterstützen im Haushalt und kümmern sich sogar um das psychische und physische Wohlbefinden ihrer Nutzer und Nutzerinnen. Entsprechend ähnelt die Mensch-Technik Beziehung in verschiedenen Aspekten häufig zwischenmenschlichen Beziehungen. Im Einklang damit spricht bisherige Forschung dafür, dass die Mensch-Technik Beziehung einen sozialen Charakter annehmen kann. Es gilt jedoch zu erforschen, auf welche Art und Weise und in Bezug auf welche Variablen die Mensch-Technik Beziehung und zwischenmenschliche Beziehungen vergleichbar sind. Darüber hinaus stellt sich die Frage, inwiefern durch Interaktion mit Technik soziale Bedürfnisse der Nutzer und Nutzerinnen auf eine ähnliche Art und Weise adressiert werden können wie durch die Interaktion mit einem anderen Menschen, und infolgedessen möglicherweise ein Effekt auf zwischenmenschliche Interaktion entstehen kann. Dabei gilt es zu spezifizieren, welche Rolle Anthropomorphismus, das heißt, die Zuschreibung menschenähnlicher Qualitäten in Bezug auf nicht-menschliche Agenten oder Objekte, spielt.

Die vorliegende Dissertation widmet sich der Relevanz der Mensch-Technik Beziehung für zwischenmenschliche Beziehungen, mit einem Fokus auf soziale Bedürfnisse. Im Rahmen dieses übergreifenden Forschungsvorhabens erforschen die Studien dieser Arbeit die Dynamiken der Mensch-Technik Beziehung und deren Vergleichbarkeit mit zwischenmenschlichen Beziehungen (Forschungsfrage 1), das Potential der Mensch-Technik Interaktion, soziale Bedürfnisse der Nutzer und Nutzerinnen zu adressieren oder die Befriedigung dieser durch zwischenmenschliche Interaktion zu substituieren (Forschungsfrage 2) sowie die Rolle des Anthropomorphismus von Technik in Bezug auf diese Zusammenhänge (Forschungsfrage 3).

In zwei konsekutiven, experimentellen Studien (Studie 1.1/1.2) wurde Vertrauen in der Mensch-Technik Beziehung als essentielle Grundlage einer Beziehung zu einer Technik, die als Gegenüber wahrgenommen wird, fokussiert. Mittels einer Mensch-Roboter Interaktion wurde die Entwicklung von Vertrauen in der Mensch-Technik Beziehung untersucht. Dabei wurde erforscht, inwiefern Determinanten, welche die Entwicklung von zwischenmenschlichem Vertrauen beeinflussen können, auf die Mensch-Technik Beziehung übertragbar sind. Darüber hinaus wurde die Rolle des Anthropomorphismus von Technik

untersucht. Es zeigte sich ein positiver Effekt der Kompetenz der Technik, das heißt der Fähigkeit, beabsichtigte Ziele zu erreichen (Studie 1.1), und der Wärme der Technik, das heißt des Verfolgens der gleichen Intentionen und Interessen wie jeweilige Nutzer und Nutzerinnen (Studie 1.2) auf das Vertrauen in die Technik. Entsprechend wurden relevante Determinanten der Vertrauensentwicklung in der Mensch-Technik Beziehung beleuchtet und eine Übertragbarkeit essentieller Dynamiken der Vertrauensentwicklung aus zwischenmenschlichen Beziehungen aufgezeigt. Außerdem zeigte sich ein Effekt des wahrgenommenen Anthropomorphismus der Technik auf die positiven Zusammenhänge zwischen wahrgenommener Kompetenz und Vertrauen in die Technik (Studie 1.1) sowie wahrgenommener Wärme und Vertrauen in die Technik (Studie 1.2). Diese Einsichten unterstützen die Relevanz des wahrgenommenen Anthropomorphismus der Technik hinsichtlich der Vertrauensdynamiken in der Mensch-Technik Beziehung sowie der Übertragbarkeit entsprechender Dynamiken aus zwischenmenschlichen Beziehungen.

In einer weiteren Studie (Studie 2) wurde die Übertragbarkeit der Dynamiken von zwischenmenschlichen Beziehungen auf die Mensch-Technik Beziehung in Bezug auf die Variable der sozialen Verbundenheit untersucht. Diese kann ebenso relevant für die Beziehungsentwicklung und einen möglichen Effekt von Interaktion mit Technik auf soziale Bedürfnisse der Nutzer und Nutzerinnen sein. Hierfür wurde eine zweiwöchige Mensch-Technik Interaktion mit einem dialogfähigen Chatbot exploriert. Dabei wurden potentiell relevante Charakteristika der Technik, beispielsweise, ihre Wahrnehmung als anthropomorph oder sozial präsent sowie der Nutzer und Nutzerinnen, beispielsweise, die individuelle Tendenz zu anthropomorphisieren sowie das individuelle Bedürfnis nach Zugehörigkeit, fokussiert und ein möglicher Effekt der sozialen Verbundenheit zur Technik auf den Wunsch mit anderen Menschen zu sozialisieren untersucht. Die Ergebnisse zeigten, dass Interaktionsdauer und Interaktionsintensität mit der Technik über die zweiwöchige Studiendauer hinweg die empfundene soziale Verbundenheit zu dieser positiv voraussagten. Entsprechend wurden Ähnlichkeiten der Dynamiken der Beziehungsentwicklung zu zwischenmenschlichen Beziehungen hervorgehoben. Des Weiteren wurde die Relevanz von Anthropomorphismus der Technik für die Entwicklung einer Mensch-Technik Beziehung und die Vergleichbarkeit mit Dynamiken zwischenmenschlicher Beziehungen unterstrichen. Denn je intensiver Menschen mit der Technik interagierten, umso menschenähnlicher nahmen sie diese wahr und fühlten sich infolgedessen umso stärker sozial verbunden mit ihr. Ebenso, je länger und intensiver Menschen mit der Technik interagierten, umso sozial präsenter nahmen sie diese wahr und fühlten sich infolgedessen umso stärker sozial verbunden mit ihr. Während sich wider Erwarten kein Zusammenhang zwischen der sozialen Verbundenheit zur Technik und dem Wunsch, mit anderen Menschen zu sozialisieren, zeigte, wurde dieser Zusammenhang im Rahmen der Studien 3.1, 3.2 und 4 näher exploriert.

Im Rahmen zweier konsekutiver, experimenteller Studien (Studie 3.1/3.2) wurde das Potential von anthropomorphen Technologien, soziale Bedürfnisse zu erfüllen untersucht sowie der Frage nachgegangen, inwiefern individuell wahrgenommener Anthropomorphismus mit sozialen Bedürfnissen korreliert. In beiden Studien wurden soziale Exklusion und Anthropomorphismus der Technik manipuliert, Anthropomorphismus jedoch in den Studien jeweils unterschiedlich. In einer Studie (Studie 3.1) beantworteten Versuchspersonen anthropomorphe (vs. nicht anthropomorphe) Fragen über ihr eigenes Smartphone. In der anderen Studie (Studie 3.2) wurden sie mit Smartphone-Designs mit anthropomorphen (vs. nicht anthropomorphen) Merkmalen konfrontiert. In beiden Studien zeigten sich keine Effekte von Anthropomorphismus und sozialer Exklusion auf die verhaltensbezogene Intention oder die Bereitschaft mit anderen zu sozialisieren. Jedoch zeigte sich in Studie 3.1 übergreifend eine positive Korrelation zwischen der Bereitschaft mit anderen Menschen zu sozialisieren und dem wahrgenommenen Anthropomorphismus der Technik. Ergebnisse der Studie 3.2 unterstützten diesen Befund und implizierten zusätzlich, dass dieser Zusammenhang für Menschen, die eine hohe Tendenz zu anthropomorphisieren aufwiesen und gleichzeitig mit einer Technik mit anthropomorpher Gestaltung in Bezug auf deren Erscheinung konfrontiert waren, besonders ausgeprägt war. Insgesamt sprechen diese Einsichten für einen Zusammenhang zwischen sozialen Bedürfnissen und Anthropomorphismus und deuten auf eine Relevanz von individuellen und kontextuellen Faktoren hin, die verstärkend wirken können.

Als Ergänzung der erläuterten Befunde sowie zur Unterstützung eines tiefgründigen Verständnisses der Mensch-Technik Beziehung und des Potentials dieser, soziale Bedürfnisse der Nutzer und Nutzerinnen anzusprechen, wurde eine qualitative Interviewstudie durchgeführt (Studie 4). Die gewonnenen Einsichten unterstützen das Potential anthropomorpher Technik, soziale Bedürfnisse der Nutzer und Nutzerinnen auf bestimmte Wege anzusprechen, aber zeigten auch essentielle Unterschiede in der Qualität der Mensch-Technik und zwischenmenschlichen Interaktion. Zu Beispielen gehören fehlende Reaktionen der Technik auf Nutzer und Nutzerinnen auf einer inhaltlichen, emotionalen und physischen Ebene sowie das Ausbleiben der Befriedigung sozialer Bedürfnisse durch die Interaktion mit Technik. Zusätzlich weisen die Studieneinsichten auf einen Effekt sozialer Erwünschtheit diesbezüglich hin, zumal die Interaktion mit Technik, die zwischenmenschlicher Interaktion ähnelt, häufig mit eher negativen Reaktionen Dritter assoziiert wurde.

Im Anschluss an einen Überblick und die kurze Zusammenfassung der empirischen Studien dieser Dissertation wird deren Beitrag in Hinblick auf bisherige Forschung diskutiert. Darauf folgt eine Erläuterung übergreifender theoretischer und praktischer Implikationen dieser Arbeit. Theoretische Implikationen fokussieren hauptsächlich wie die vorliegende Dissertation das Verständnis theoretischer und empirischer Arbeiten im Rahmen des „computers are social actors“ Paradigmas vertieft und zusätzlich erweitert. Darüber hinaus wird die diesbezügliche Rolle von Anthropomorphismus der Technik als Phänomen beleuchtet. Über die Exploration des sozialen Charakters der Mensch-Technik Beziehung hinaus, liefert die vorliegende Arbeit Einsichten zum Potential der Mensch-Technik Beziehung soziale Bedürfnisse der Nutzer und Nutzerinnen insofern zu adressieren, dass Konsequenzen für zwischenmenschliche Beziehungen entstehen können. Implikationen für die Praxis beziehen sich auf Einsichten in Hinblick auf Design-Beispiele, welche die Entwicklung von Faktoren, die zentral für die Mensch-Technik Beziehung sein können, unterstützen können. Darüber hinaus laden die Implikationen ein, über das Design und die Anwendungskontexte von Technologien zu reflektieren, um einen verantwortungsvollen Umgang mit Technologien im Alltag der Menschen zu fördern. Abschließend werden allgemeine Limitationen der vorliegenden Arbeit diskutiert und mögliche Richtungen für zukünftige Forschung aufgezeigt.

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1. INTRODUCTION

Nowadays, technologies play an increasing role within people's daily lives. Every day, individuals spend a significant amount of time interacting with such. The smartphone represents a very prominent example (Statista, 2021). Moreover, chatbots, smart voice assistants or even personal robots assist in the household, consult in shopping, and support with mental and physical health issues. Accordingly, many technologies do not simply function as tools, which extend users' abilities, but are more and more perceived as interaction partners. Users might, for example, have conversations with chatbots, smart voice assistants or even social robots. They might cooperate with them, delegate tasks or command them (Hassenzahl et al., 2020).

In parallel to technologies being designed and perceived as interaction partners, people's schedules are getting busier and individuals often do not manage to socialize with other people within their daily routine. On some days, people might even end up having spent more time interacting with a technology as a counterpart than with another human being. In this context, the question arises to which extent human-technology interaction might affect users, for example, by addressing their needs, in a way that their desire to interact with other humans is reduced. Could a conversation with a smart voice assistant offer satisfaction of users' social needs to an extent that their need to talk with their partner about their day might be reduced? Or could the companionship of a social robot telling jokes counteract boredom or loneliness of the user and therefore dampen the need to go out and interact with other humans?

To look deeper into this general research question, it seems important to explore the human-technology relationship and investigate similarities and differences to interpersonal relationships. Indeed, in the context of the "computers are social actors" (CASA) paradigm, Nass et al. (1994) have long ago highlighted parallels between the two and found that individuals transfer social rules from interpersonal interaction to interaction with technologies (Nass & Moon, 2000; Reeves & Nass, 1996). Thus, human-technology interaction may resemble interpersonal interaction in several ways. Still, research needs to specify which dynamics play a role in the development of the human-technology relationship. Moreover, there is only little research regarding the possible ways human-technology interaction can address human needs in a similar way to interpersonal interaction, and in turn potentially affect interpersonal interaction.

Comparing the human-technology relationship to interpersonal ones and considering a possible effect of human-technology interaction on interpersonal interaction, technology anthropomorphism, namely the attribution of "humanlike properties, characteristics, or mental states to real or imagined nonhuman agents and objects" (Epley et al., 2007, p. 865), appears as a possible influential factor. If human-technology interaction resembles and possibly even affects interpersonal interaction, the degree of perceived humanlikeness in a technology could play an essential role in these relationships. Although anthropomorphism is generally recognized as a possible relevant factor in human-technology interaction (e.g., Hancock et al., 2011; Kiesler et al., 2008) as well as specifically in interrelation with users' social needs (e.g., Epley et al., 2007; Epley et al., 2008a; Epley et al., 2008b; Niemyjska & Drat-Ruszczak, 2013), underlying mechanisms need to be further specified.

In sum, this thesis aims at exploring the human-technology relationship as well as its relevance for social needs and interpersonal relationships and understanding the role of technology anthropomorphism in this regard. Besides insights on the user experience of technologies, findings bear broader relevance, referring to individual wellbeing as well as societal changes of social interaction. Namely, findings could offer insights on how to make use of a possible potential of technology to elicit an overall positive experience, for example, by addressing certain needs of users. On the other hand, insights could shed light on whether and to what extent interaction with technology could possibly compete with interpersonal interaction and therefore come with probably far-reaching societal consequences.

2. RESEARCH RATIONALE AND RESEARCH QUESTIONS

This thesis aims at exploring the main research question: How does the human-technology relationship affect interpersonal relationships with regard to social needs. Given this, the studies presented in this thesis follow three subordinate research questions. First, to what degree is the human-technology relationship comparable to interpersonal relationships? Second, how does the human-technology relationship affect users' social needs? And third, what role does technology anthropomorphism play in these relationships? In the remainder of this section, the research gaps that the questions address as well as previous theoretical and empirical work that offers the groundwork for their derivation is outlined.

Technologies become increasingly present in our daily lives and, amongst others, based on design trends such as humanlike features, we oftentimes interact with technologies as we would with a social counterpart. Examples are smart home solutions, chatbots or even social robots. Mostly, these technologies are not perceived as simple tools, they become other (Ihde, 1990). In line with this, the embodied relationship with technology that represents a tool becomes one of alterity (Hassenzahl, 2021). Hassenzahl et al. (2021) define this class of interactive systems as "otherware". This thesis focuses on technology as otherware. In line with this, users' personal relationship to such technologies can become more multi-faceted. Therefore, the nature of the human-technology relationship as well as relevant dynamics of its development represent an essential research objective for current human-computer interaction (HCI) and human-robot interaction (HRI) research.

Based on previous literature in the context of the CASA paradigm (Nass, 1994), individuals transfer social rules from interaction with other humans to interaction with non-human agents (Nass & Moon, 2000; Reeves & Nass, 1996). For example, it was found that people judge a computer's performance more positively than it is (Nass et al., 1994), presumably because they do not want to insult the computer when typing their judgment into its interface. In line with this, various HCI and HRI studies imply that humans can form as well as maintain relationships with non-human agents (e.g., Bickmore & Pickard, 2005; Edwards et al., 2016; Kim et al., 2013; Sundar et al., 2017). Kim et al., (2013), for example, found that the effect of the caregiving role of the robot on users' relationship satisfaction was mediated by the perceived benefit of being in a relationship with a robot. Such findings imply that dynamics of relationship development in the human-technology relationship might resemble dynamics known from interpersonal relationships in certain ways. Yet, this assumed transferability of dynamics needs systematic exploration.

Previous research, which has followed the approach of transferring theories and models of interpersonal interaction to HCI and HRI, has, for example, focused on the subjects of personality (e.g., Aly & Tapus, 2016) or affect (e.g., Gockley et al., 2006). Yet, studies in this regard have mainly explored transferring models known from psychological theories by means of design and have not evaluated their fit for human-technology interaction.

Moreover, focusing on variables relevant for the human-technology relationship (cf., Hancock et al. 2011), recent studies have followed a similar approach for trust (de Visser et al., 2016; Kulms & Kopp, 2018). In their study, Kulms and Kopp (2018), for example, explored the transferability of interpersonal trust dynamics in the field of intelligent computers. In this, their study focused on competence and warmth as possible determinants of trust in computers. The authors found that competence and warmth were positively interrelated with trust in computers and therefore highlight a relevance as well as transferability of trust determinants known from interpersonal trust to trust in HCI. Yet, the above-presented studies have barely included systematic manipulations of these determinants.

In sum, research needs to clarify dynamics in the development of the human-technology relationship on a broader level and systematically explore whether and to what extent dynamics known from interpersonal relationship development are applicable to the human-technology relationship. Thus, the following research question emerges.

RQ1: Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship?

Psychological needs represent qualities of experience that individuals need to thrive (Deci & Ryan, 1985; Sheldon et al., 1996). Despite the general lack of consensus regarding which needs are most central or primary, prominent need theories acknowledge social needs, that is, the need for love or belongingness (Baumeister & Leary, 1995; Maslow, 1943) as well as relatedness (Deci & Ryan, 1985; Sheldon et al., 2001), as integral for the human experience. Moreover, according to the social production function theory, besides physical integrity, individuals perceive their social well-being to be an omnipresent goal in life (Ormel et al., 1999). In consequence, according to the social reconnection hypothesis, when social needs are not satisfied, individuals are motivated to search for alternative fulfillment of such (DeWall &

Baumeister, 2006). As technologies increasingly act as social counterparts in our daily lives, the question arises whether and to what extent technology has the potential to offer alternative fulfillment of social needs.

Previous literature in consumer psychology offers groundwork for such an assumption as it implies that individuals can be invested in their digital possessions, similar to physical ones (Belk, 1988, 2013). According to Clayton et al. (2015), this can result in an intense feeling of connectedness to digital possessions. Furthermore, Kang and Kim (2020) have explored a human-Internet of Things interaction. Their findings support that users can build a connected, social relationship with smart devices. Moreover, first studies have investigated whether interaction with technology has the potential to address users' social needs. Mourey et al. (2017), for example, conclude that after interacting with anthropomorphic consumer products, individuals' social needs were satisfied to a certain extent. Namely, participants who were socially excluded exaggerated the number of their social connections less. At the same time their anticipated need to engage with close individuals as well as their willingness to show prosocial behavior were reduced (Mourey et al., 2017). Results of another study by Krämer et al. (2018) show that participants with a high need to belong stated a lower willingness to participate in social activities after interacting with the agent, when the agent demonstrated socially responsive behavior. In line with these findings, technologies might bear the potential to address individuals' social needs and therefore diminish the innate desire to seek social connections to human others. Yet, single study findings have not been integrated and systematically explored. Research needs to clarify to what extent human-technology interaction can address social needs, and further systematically explore effects on interpersonal interaction. Thus, the second research question is formulated.

RQ2: To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction?

Comparing the human-technology relationship to interpersonal ones and exploring a potential effect of human-technology interaction on users' social needs, technology anthropomorphism could be a relevant variable. In line with the CASA paradigm (Nass & Moon, 2000; Nass et al., 1994), previous study results (e.g., Jia et al., 2012; Kim & Sundar, 2012) support that anthropomorphic design cues such as humanlike agents on interfaces, lead users to attribute a more social and interpersonal character to the interaction with the technology. Thus, the perception of anthropomorphism in a technology could play a decisive role in the transferability of dynamics from interpersonal relationships to the human-technology relationship.

Regarding the potential relationship between anthropomorphism and social needs, previous research has found that a feeling of chronical disconnection from other individuals or current loneliness is often accompanied by the attribution of anthropomorphic qualities to objects and entities (e.g., pets, religious agents, imaginary creatures; Epley et al., 2007; Epley et al., 2008a; Niemyjska & Drat-Ruszczak, 2013). Bartz et al. (2016) have further replicated this connection between loneliness and anthropomorphism, also demonstrating that reminding individuals of a close and supportive relationship dampened their tendency to anthropomorphize. Moreover, studies that imply a potential effect of technology on users' social needs and in turn on interpersonal interaction, have found a relevance of technology anthropomorphism in this. For example, Mourey et al. (2017) observed the above-mentioned effect that participants who were socially excluded exaggerated their number of social connections less and their anticipated need to engage with close individuals as well as their willingness to show prosocial behavior were reduced only in the condition where participants interacted with an anthropomorphic (vs. non-anthropomorphic) product. In a similar manner, in the above-discussed study by Krämer et al. (2018), participants who had a high need to belong stated a lower willingness to participate in social activities after interacting with the agent only when the respective agent demonstrated socially responsive (vs. non-responsive) behavior (Krämer et al., 2018). In sum, it appears that technology anthropomorphism could play an essential role in the relationship of human-technology interaction and users' social needs as well as potential consequences for interpersonal interaction.

Overall, research needs to further specify the role of anthropomorphism for the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on social needs of users and explore underlying mechanisms. In consequence, the third research question concerns the following interrelations.

RQ3: What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?

3. RESEARCH APPROACH AND THEORETICAL BACKGROUND

This section provides an overview of the research approach of this thesis. Furthermore, it presents the most relevant theoretical and empirical work that contributed to the studies included in this thesis.

3.1. RESEARCH APPROACH

Aiming to explore how the human-technology relationship can affect interpersonal ones with a focus on social needs, this thesis considers technology as otherware as defined by Hassenzahl et al. (2021). First, a part of the studies included in this thesis focuses on the exploration of the human-technology relationship. These studies explore the development of essential constructs of the human-technology relationship, such as trust (study 1.1/1.2) and social connectedness (study 2) as well as the fulfillment of social needs (study 4). In this, they consider relevant characteristics of the technology (e.g., technology competence and warmth in study 1.1/1.2) as well as interindividual differences (e.g., individual tendency to anthropomorphize in study 1.1/1.2 & study 2) and situational factors (e.g., duration and intensity of interaction with technology in study 2) that could be influential. These studies go beyond the mere exploration of dynamics within the human-technology relationship and focus on the comparability of dynamics known from interpersonal relationships with regard to the development of trust (study 1.1/1.2), social connectedness (study 2) and the fulfillment of social needs (study 4).

Moreover, most studies included in this thesis explore a potential effect of the human-technology relationship on interpersonal relationships, focusing on users' social needs (study 2., study 3.1/3.2 & study 4). To do so, they consider variables such as the willingness to socialize with other humans (e.g., study 2 & study 3.1/3.2) or assess behavioral intentions (e.g., study 3.1/3.2).

An aspect that all studies have in common is an overarching consideration of the role of technology anthropomorphism in the relationships of interest, as previous literature suggests its relevance when comparing the human-technology relationship to interpersonal ones (e.g., Kulms & Kopp, 2018) and focusing on a potential effect of interaction with technology on users' social needs (e.g., Krämer et al., 2018; Mourey et al., 2017). Figure 1 illustrates the described research approach and demonstrates how the single studies aim at addressing its components.

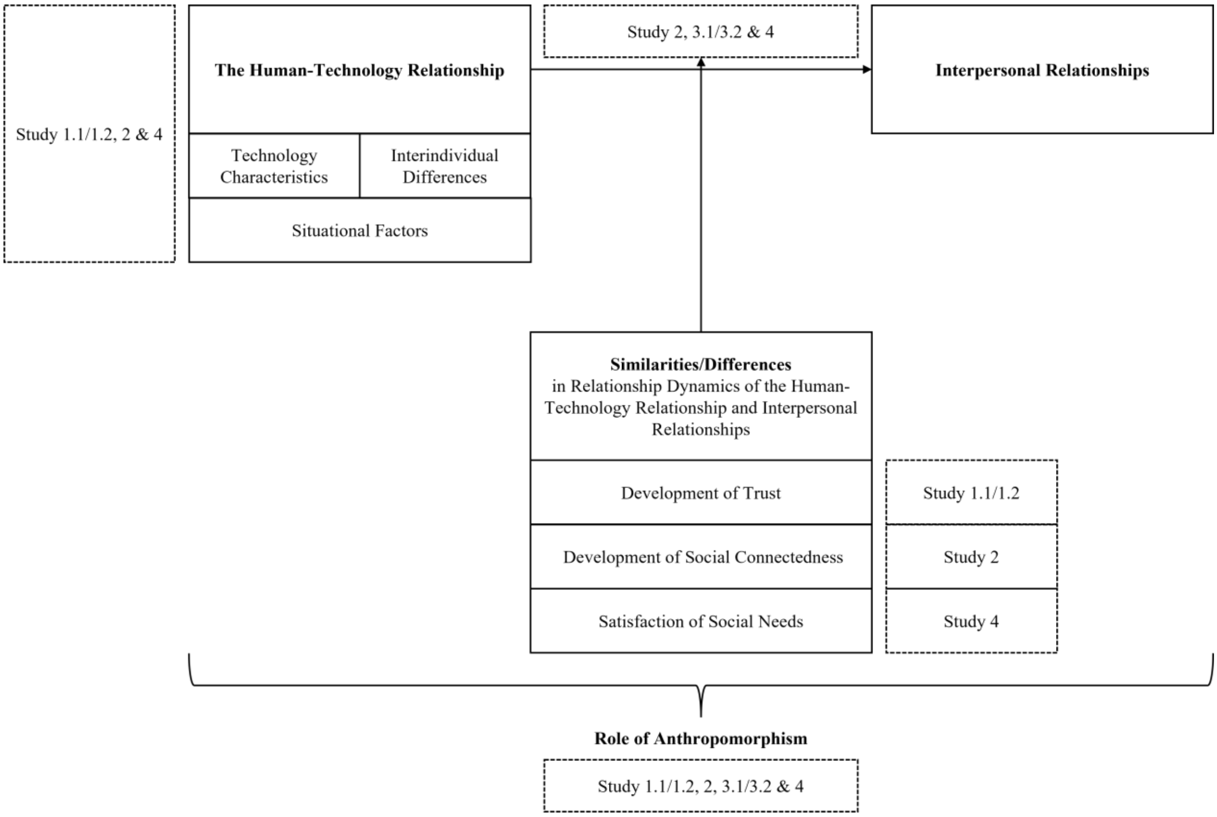

Figure 1. Illustration of the research approach of this thesis including the single studies allocated with regard to the addressed subordinate research objectives

Finally, the studies included in this thesis explore the above-elaborated relationships by means of various methodological approaches. Whereas studies 1.1 and 1.2 follow an experimental, cross-sectional design and use videos of specific HRI for their manipulations, study 2 explores the relationships of interest based on a two-week period of regular human-technology interaction with a conversational chatbot. Further, both study 3.1 and 3.2 follow an experimental, cross-sectional design, focusing on a one-time human-technology interaction regarding a smartphone. Finally, study 4 is a cross-sectional interview study based on a phenomenological approach, exploring past experiences of relevant human-technology interactions, in this, considering different technologies. Table 1 presents the studies included in this thesis along with their addressed research questions and central characteristics of their methodology.

Table 1. Overview of study characteristics of empirical studies included in this thesis

Study	Addressed Research Questions	N	Design	Data	Considered Technology	Anthropomorphism Manipulation
Study 1.1	RQ1, RQ3	155	Experimental, Cross-Sectional	Quantitative	Humanoid Robot	Anthropomorphic Verbal and Non-Verbal Cues (voice, movement, name) vs. Non-Anthropomorphic Verbal and Non-Verbal Cues (presentation of statements on tablet, no movement, no name)
Study 1.2	RQ1, RQ3	157	Experimental, Cross-Sectional	Quantitative	Humanoid Robot	
Study 2	RQ1, RQ2, RQ3	58	Prospective, Longitudinal	Quantitative	Conversational Chatbot on Smartphone	-
Study 3.1	RQ1, RQ2, RQ3	159	Experimental, Cross-Sectional	Quantitative	Smartphone	Anthropomorphic vs. Non-Anthropomorphic Questions about Personal Smartphone
Study 3.2	RQ1, RQ2, RQ3	236	Experimental, Cross-Sectional	Quantitative	Smartphone	Anthropomorphic vs. Non-Anthropomorphic Visual Design of a Smartphone
Study 4	RQ1, RQ2, RQ3	8	Interview, Cross-Sectional	Qualitative	Various	-

3.2. THEORETICAL BACKGROUND

This section is structured according to the above-presented research approach (Figure 1) and presents relevant theoretical and empirical background regarding each component of the research approach. The attached manuscripts present a more detailed theoretical introduction regarding their specific research questions.

3.2.1. HUMAN-TECHNOLOGY RELATIONSHIP

The exploration of the human-technology relationship within this thesis is based on the presumption that human-computer relationships can adopt a social character, as Nass et al. (1994) long ago postulated in the frame of the CASA paradigm. Namely, the authors' research shows that computer users apply social rules from interpersonal interaction to their interaction with computers, even though users might report such attributions to be inappropriate. According to the CASA paradigm, these social responses are neither based on some sort of deficiency nor on sociological or psychological dysfunction. Instead, they are described as natural responses to social situations, which according to the authors are easy to generate, ordinary and commonplace, as well as persistent (Nass et al., 1994). Based on these findings, it has been established within HCI research that various principles drawn from the research fields of social psychology, sociology and communication are generally relevant to study HCI.

In line with this, recent studies suggest that humans can form and maintain a sort of relationship with non-human agents (e.g., Bickmore & Pickard, 2005; Cassell, 2001; Edwards et al., 2016; Kim et al., 2013; Moon & Nass, 1996; Sundar et al., 2017). Yet, such studies have not focused on similarities and differences of such relationships to interpersonal ones.

When exploring the human-technology relationship with regard to certain dynamics, technology characteristics, such as specific design cues (cf., Kang & Kim, 2020), interindividual differences, such as tendencies to anthropomorphize (cf., Waytz et al., 2010), and situational factors, for example, referring to the duration of technology use (cf., Granovetter, 1973), could be influential. These need to be considered in a systematic manner.

3.2.2. TRANSFERABILITY OF DYNAMICS FROM INTERPERSONAL RELATIONSHIPS TO THE HUMAN-TECHNOLOGY RELATIONSHIP

To explore the human-technology relationship, this thesis focuses on comparing such to interpersonal relationships and evaluating the transferability of dynamics. First, the development of trust in technology is explored as it is integral for the human-technology relationship (e.g., Hancock et al., 2011; Van Pinxteren et al., 2019), especially when technology is experienced as a counterpart (e.g., Saßmannshausen et al., 2021). Second, the development of social connectedness in the human-technology relationship is focused, as it could affect social needs of humans, and in turn possibly even have an effect on their interpersonal relationships.

3.2.2.1. TRUST

Trust represents a central variable within the human-technology relationship, as it builds an essential precondition for effective human-technology interaction (e.g., Hancock et al., 2011; Van Pinxteren et al., 2019). Moreover, according to Saßmannshausen et al. (2021), while control might be essential for a successful relationship with a technology that represents a tool, trust appears to be integral for the relationship with a technology that is experienced as a counterpart.

In the context of human-technology interaction, trust can be defined as “the attitude that an agent will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability” (Lee & See, 2004, p. 54). Therefore, trust offers a basis for dealing with uncertainty or risk (Deutsch, 1962; Mayer et al., 1995) and enhances cooperative behavior (Balliet & van Lange, 2013; Corritore et al., 2003). Although trust generally develops over a period of time and is built upon numerous interactions (Rempel et al., 1985), especially in short-time interactions or first encounters, certain attributes of the trustee may be influential with regard to attributed trustworthiness (e.g., Mayer et al., 2003). According to literature on central determinants of trust development in the context of interpersonal interaction, perceiving the trustee to be competent, that is, being capable of achieving intended goals, and warm, that is, cohering with the intentions and interests of the trustor, can positively affect the development of trust (Fiske et al., 2002, 2007; Mayer et al., 1955).

Focusing on the transferability of dynamics known from interpersonal relationships to the human-technology relationship, various parallels can be found in literature regarding determinants influencing trust development. For example, studies found that a robot’s perceived competence rooted in facial expressions (Calvo-Barajas et al., 2020), a robot’s reputation, referring to knowledge regarding its reliance (Bagheri & Jamieson, 2004), or its past performance (Chen et al., 2010; Lee & See, 2004), as well as its current performance (Chen et al., 2010) can affect the user’s trust. Similarly, in their study, Robinette et al. (2017) found bad robot performance to be interrelated with a drop in individuals’ self-reported trust in the robot, which was in turn associated with their choice to use the robot for guidance.

Furthermore, in their meta-analysis, Hancock et al. (2011) showed that performance-based factors related to a robot, such as false-alarm rate, reliability, as well as failure rate predict the development of trust in robots. Therefore, perceiving the trustee (here: the robot) as competent, that is, being able to achieve intended goals, seems crucial for trust development in human-technology interaction. Moreover, Kulms and Kopp (2018), examined the transferability of interpersonal trust dynamics in the field of intelligent computers, focusing on competence and warmth as potential determinants of trust. Based on their results, both competence and warmth were positively associated with trust in computers, supporting a relevance and similarity to trust determinants in interpersonal interaction. In sum, literature on the transferability of dynamics with regard to trust development from interpersonal relationships to the human-technology relationship, implies a certain comparability of dynamics. Yet, studies have mainly focused on single determinants that can affect the development of trust and barely manipulated these determinants in a systematic manner.

Furthermore, comparing dynamics of the human-technology relationship and interpersonal relationships, technology anthropomorphism might be a potentially relevant factor. The perception of technologies as humanlike could, for example, facilitate or even enhance the transferability of dynamics from interpersonal relationships. So far, the role of technology anthropomorphism has not been considered in interplay with other potentially relevant determinants of trust development known from interpersonal interaction.

3.2.2.2. SOCIAL CONNECTEDNESS

An essential determinant of perceived companionship as one form of relationship between user and technology is the social connectedness perceived by the user (Lee et al., 2017). Referring to interpersonal relationships, van Bel et al. (2009) describe social connectedness as an experience of relatedness and belonging, rooted in relationship salience as well as quantitative and qualitative social evaluations. In accordance with the assumed transferability of dynamics from interpersonal interaction to human-technology interaction (e.g., Nass & Moon, 2000), literature in consumer psychology supports that individuals can be invested in digital possessions in a similar manner they are with regard to physical ones (Belk, 1988, 2013). According to Clayton et al. (2015), this can foster a strong sense of attachment to digital possessions. Yet, technologies considered in these studies are not necessarily experienced as counterparts and the connectedness to such barely appears comparable to the social connectedness within interpersonal relationships.

Focusing on technologies that are experienced as counterparts, Kang and Kim (2020) highlight the relevance of perceived connectedness to technology as a central determinant in the context of the human-technology relationship. In particular, the authors could show that with an increase of sense of connectedness, technology anthropomorphism was associated with more positive user responses, such as an increased intention to learn from the technology or a generally more positive attitude towards it (Kang & Kim, 2020). Still, the extent to which this sense of connectedness is actually comparable to interpersonal relationships and can affect users' social needs as well as possibly their interpersonal relationships remain to be explored.

In sum, based on theoretical and empirical findings, social connectedness could play a role in the human-technology relationship, which might to a certain extent be comparable to the role it plays within interpersonal relationships. Yet, the extent of this comparability needs to be explored in a systematic manner, especially focusing on the potential of connectedness to be of social kind, and thus possibly affect interpersonal relationships. Moreover, factors that could potentially influence the development of social connectedness, including characteristics of the technology and the interaction as well as interindividual differences of the user, have not been considered in light of the assumed transferability of dynamics from interpersonal relationships to the human-technology relationship in previous research.

3.2.2.3. SOCIAL NEEDS AND INTERPERSONAL RELATIONSHIPS

Regarding the transferability of dynamics from interpersonal relationships to the human-technology relationship apart from social connectedness and trust, this thesis focuses on whether interaction with a technology can address social needs in a similar manner to interpersonal interaction. Moreover, this thesis explores to which extent interpersonal interaction could be affected in turn.

Various need theories state that social needs, that is, the need for love or belongingness (Baumeister & Leary, 1995; Maslow, 1943) as well as relatedness (Deci & Ryan, 1985; Sheldon, et al., 2001), are essential for humans. Accordingly, individuals are predisposed to seek connections to other individuals (Baumeister & Leary 1995; Maslow 1943). Moreover, the social production function theory states that besides physical integrity, individuals perceive their social well-being as an omnipresent goal in life (Ormel et al., 1999). In consequence, according to the social reconnection hypothesis (DeWall & Baumeister, 2006), individuals are motivated to search for alternative fulfillment when social needs are not satisfied. For example, according to study results of DeWall et al. (2009), individuals with threatened need for social belonging were faster at identifying smiling faces in a crowd as well as focusing on positive, social faces (vs. unhappy faces or positive but nonsocial images). Based on the assumption that human-technology interactions can adopt a social character (e.g., Nass et al., 1994), it is thus possible that, humans could seek alternative fulfillment of their social needs in interaction with technology when their social needs remain unfulfilled.

Furthermore, study results highlight a connection between social needs and interaction with technology. For example, Mourey et al. (2017), found that after the interaction with anthropomorphic technologies, participants who were socially excluded exaggerated the number of their social connections less and their anticipated need to engage with close others as well as their willingness to show prosocial behavior were dampened. The authors assume some sort of satisfaction of participants' social needs to be causal (Mourey et al., 2017). Based on results of another study by Krämer et al. (2018), participants who had a high need to belong stated a lower willingness to engage in social activities after interacting with a digital agent when this agent performed socially responsive behavior. According to these findings, interaction with technology might bear the potential to partly address individuals' social needs in a certain way, and therefore possibly even dampen the innate desire to search for social connections to other humans. Yet, some of the found effects are based on rather indirect measures of social needs and their fulfillment (cf., Mourey et al., 2017). Moreover, it has not been specified whether such effects could have the potential to affect interpersonal relationships in a sustainable manner or just offer a temporary stopgap for unsatisfied social needs as also discussed by Krämer et al. (2018).

Overall, research needs to clarify in what way social needs can be addressed by interaction with technology compared to other humans. In addition, it is yet to explore, to what extent social needs can be addressed by interaction with technology, referring to a temporary vs. more sustainable manner. A potential effect on the desire to interact with humans also needs further systematic investigation.

3.2.3. ANTHROPOMORPHISM

Exploring the transferability of dynamics known from interpersonal relationships to the human-technology relationship as well as its potential effect on users' social needs, technology anthropomorphism could be a possible influential factor. Anthropomorphism describes the attribution of human characteristics, motivations, emotions, and intentions to non-human agents that can involve animals, spiritual entities, or any other kind of object (Epley et al., 2007).

As a phenomenon, anthropomorphism per se is not new. Xenophanes (6^{th} century B.C., as cited in Lesher, 2001) long ago referred to this phenomenon, considering analogies between religious agents and believers. Namely, the term anthropomorphism is rooted in the Greek words "Anthropos" (gr., άνθρωπος; meaning human) and "Morphe" (gr., μορφή; meaning form or shape). In early work, anthropomorphism was referred to as an embodied aspect of human judgment that is evolutionary and invariant to situations and therefore similar for all individuals (Guthrie, 1993; see also Mitchell et al., 1997). More recently, HCI research has focused on anthropomorphism as well as its determinants and consequences, as technologies of daily use are increasingly designed with humanlike characteristics. Although research generally agrees on the above presented definition of anthropomorphism (cf., Epley et al., 2007), it is rather general and leaves room for different interpretations of the concept. In line with this, different researchers refer to different subsets of humanlike characteristics that can be attributed to a non-human agent or object, and thus apply different measures for the assessment of anthropomorphism. For example, according to Ruijten et al. (2019), these characteristics can be categorized into appearances, thoughts, or emotions that are humanlike. According to the authors (Ruijten et al., 2019), while appearance involves characteristics that reflect humanlike behavior, including physical shapes as well as abilities, thoughts stand for characteristics that imply cognitive states and processes that are humanlike. Furthermore, emotions describe characteristics that imply subjective conscious experiences (cf., Ruijten et al., 2019).

Accordingly, while some researchers have applied measures that solely focus on appearance (e.g., Godspeed Questionnaire; Bartneck et al., 2009), and for example, assess the extent to which a technology looks humanlike, others have measured anthropomorphism by asking individuals to indicate to what extent they perceive an agent to have cognitive abilities, such as consciousness or a free will (e.g., Waytz et al., 2010). Moreover, referring to emotions as humanlike characteristics, Eyssel et al. (2010), for example, have assessed anthropomorphism by asking individuals to rate to what extent a technology can experience primary as well as secondary emotions. While researchers themselves have been consistent with regard to their respective conceptualizations of anthropomorphism, the different focuses and corresponding measures that have been applied in HCI and HRI research come with the challenge of a restricted comparability of insights regarding the phenomenon of anthropomorphism. In this regard, Rujten et al. (2019) has proposed a one-dimensional scale to measure anthropomorphism with the goal of comparing various agents and robots across different studies with regard to their humanlikeness. While its fit for various technologies and interactions with such is still to be explored, it highlights the complexity of the current state of research regarding the conceptualization and measurement of anthropomorphism in human-technology interaction.

Further, research has also focused on when and why individuals "see human" in non-human agents. The SEEK (Sociality, Effectance, and Elicited Agent Knowledge) model by Epley et al. (2007), that refers to the above-presented definition of anthropomorphism by Epley et al. (2007) for example, considers three central determinants of anthropomorphism. It predicts that humans are more prone to anthropomorphism when "anthropocentric knowledge is accessible and applicable, when motivated to be effective social agents, and when lacking a sense of social connection to other humans" (Epley et al., 2007, p. 1). Furthermore, apart from research on when and why individuals might anthropomorphize, there is increasing work on individual differences in this regard. Namely, Waytz et al. (2010) have developed a measure to assess stable individual differences in anthropomorphism, the "Individual Differences in Anthropomorphism Questionnaire". The authors suggest that these individual differences further predict the extent to which moral care, responsibility, concern, and trust is attributed to a certain agent, as well as to what extent the agent in question might socially affect the self (Waytz et al., 2010).

Generally, in line with the CASA paradigm (Nass et al., 1994), research supports that anthropomorphic design cues in technologies, such as humanlike faces on technology interfaces, foster the perception of users that an interaction with a certain technology has a social and interpersonal character (Jia et al., 2012; Kim & Sundar, 2012). Thus, when exploring the extent to which dynamics known from interpersonal relationships are transferable to the human-technology relationship, technology anthropomorphism might play a role.

Furthermore, specifically concerning social needs, studies have implied an interrelation of the attribution of humanlike characteristics to non-human agents or objects and individuals' social needs. For example, research has shown that individuals who were threatened in their need for social belonging were faster in detecting smiling faces in a crowd and focused on social, positive faces in comparison to positive non-social images or unhappy faces (DeWall et al., 2009). In a similar manner, prior studies have found that the feeling of chronical disconnectedness from others or current loneliness is often associated with attributing anthropomorphic qualities to objects and entities (e.g., religious agents, pets, imaginary creatures; Epley et al., 2007; Epley et al., 2008a; Niemyjska & Drat-Ruszczak, 2013). Offering further support for such a relationship between anthropomorphism and social needs, Bartz et al. (2016) found that reminding individuals of a close, supportive interpersonal relationship reduced their tendency to anthropomorphize. Thus, deprived social needs might be a motivator to seek social cues in non-living objects and attribute anthropomorphic characteristics to such.

Moreover, first studies have gone beyond the mere identification of this relationship and have aimed at exploring the potential of anthropomorphic technologies to satisfy users' social needs. For example, based on results of Mourey et al. (2017), after individuals interacted with anthropomorphic technologies, their social needs were partly satisfied. Additionally, experimentally generated effects of social exclusion were diminished. Specifically, after the interaction with anthropomorphic (vs. non-anthropomorphic) technologies, participants who were socially excluded exaggerated the number of their social connections less. In a similar manner, their anticipated need to engage with close others and their willingness to show prosocial behavior were reduced. In another study by Krämer et al. (2018), after the interaction with a virtual agent that showed socially responsive (vs. not socially responsive) nonverbal behavior, no main effect of socially responsive behavior on participants' connectedness with the agent or on their experience of rapport, referring to a short time liking and responsiveness of the agent, was found. Yet, participants who had a high need to belong stated a lower willingness to engage in social activities after interacting with the agent only when the agent demonstrated socially responsive behavior. While both studies have applied different manipulations, they have not further considered the specific role of perceived humanlikeness regarding their stimuli. Thus, it is unclear to what extent, and which perceived humanlike characteristics might have played a role in the found effects.

In sum, existing theoretical and empirical work implies an overall relevance of anthropomorphism for the comparison of relationship dynamics in the human-technology and interpersonal relationships as well as the potential of interaction with technology to address social needs of users. Yet, research still needs to clarify in what way anthropomorphism affects these relationships. Moreover, it needs to be systematically explored whether technology anthropomorphism plays a role for the effect of interaction with technology on interpersonal relationships of users. Finally, the interplay of anthropomorphism with other influential variables, including characteristics of the technology in question, the user, as well as the context of technology use regarding the relationships of interest, needs to be investigated.

4. OVERVIEW OF STUDIES AND PUBLICATIONS

The following chapter provides an overview of the empirical studies conducted in the frame of this dissertation, that is, four main studies with two of them consisting of two subordinate studies (study 1.1/1.2, study 2, study 3.1/3.2 & study 4). These studies correspond to four published papers. All papers are included in the appendix.

Table 2 presents an overview of the studies and papers addressing the subordinate research questions of this dissertation. Furthermore, their respective publication status as well as involved authors and their contribution according to the Contributor Roles Taxonomy (CRediT; Brand et al., 2015) are included in the table.

All research was conducted in line with the "Ethical Principles of Psychologists and Code of Conduct" of the American Psychological Association (2021) and the according study designs were reviewed by the ethics committee of the faculty for mathematics, computer science, and statistics of the Ludwig-Maximilians-Universität München.

Table 2. Overview of papers corresponding to the studies included in this thesis along with authors and their contributions, the publication status, and the addressed research questions

Study	Paper Title	Authors	Contributions	Status	Addressed Research Questions
Study 1.1 Study 1.2	Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI.	Lara Christoforakos, Alessio Gallucci, Tinatini Surmava-Große, Daniel Ullrich, & Sarah Diefenbach	**Lara Christoforakos** Conceptualization Formal Analysis Investigation Methodology Writing – Original Draft & Review **Allesio Gallucci, Tinatini Surmava-Große** Formal Analysis Investigation Methodology **Daniel Ullrich** Conceptualization Formal Analysis Investigation Methodology **Sarah Diefenbach** Conceptualization Writing – Review & Editing Supervision	Published Article; *Frontiers in Robotics and AI*	**RQ1:** Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship? **RQ3:** What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?
Study 2	Connect With Me. Exploring Influencing Factors in a Human-Technology Relationship Based on Regular Chatbot Use.	Lara Christoforakos, Nina Feicht, Simone Hinkofer, Annalena Löscher, Sonja F. Schlegl, & Sarah Diefenbach	**Lara Christoforakos** Conceptualization Formal Analysis Investigation Methodology Writing – Original Draft & Review **Nina Feicht, Simone Hinkofer, Annalena Löscher, Sonja F. Schlegl** Investigation	Published Article; *Frontiers in Digital Health*	**RQ1:** Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship? **RQ2:** To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction?

			Methodology **Sarah Diefenbach** Conceptualization Writing – Review & Editing Supervision		**RQ3:** What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?
Study 3.1 Study 3.2	Technology as a Social Companion? An Exploration of Individual and Product-Related Factors of Anthropomorphism.	Lara Christoforakos & Sarah Diefenbach	**Lara Christoforakos** Conceptualization Formal Analysis Investigation Methodology Writing – Original Draft & Review **Sarah Diefenbach** Writing – Review & Editing Supervision	Published Article; *Social Science Computer Review*	**RQ2:** To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? **RQ3:** What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?
Study 4	Fulfilling Social Needs Through Anthropomorphic Technology? A Reflection on Existing Research and Empirical Insights of an Interview Study.	Lara Christoforakos & Sarah Diefenbach	**Lara Christoforakos** Conceptualization Formal Analysis Investigation Methodology Writing – Original Draft & Review **Sarah Diefenbach** Writing – Review & Editing Supervision	Published Article; *Zeitschrift für Arbeitswissen-schaft*	**RQ1:** Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferrable to the human-technology relationship? **RQ2:** To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? **RQ3:** What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?

5. EMPIRICAL STUDIES

This section summarizes the empirical studies according to the corresponding papers. Each study is presented along with its research motivation, research questions, general hypotheses, and study paradigm. This is followed by a short description of the sample and procedure, a summary of results, and the corresponding research contribution.

5.1. STUDY 1.1 & 1.2

Study 1.1 Study 1.2	Christoforakos, L., Gallucci, A., Surmava-Große, T., Ullrich, D., & Diefenbach, S. (2021). Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI. *Frontiers in Robotics and AI, 8*. https://doi.org/10.3389/frobt.2021.640444

In line with the CASA paradigm, various studies have followed the approach of transferring theories and models known from interpersonal interaction to HCI and HRI (e.g., Aly & Tapus, 2016; Gockley et al., 2006). First studies have explored this approach focusing on trust in HCI (de Visser et al., 2016; Kulms & Kopp, 2018) as a variable crucial for a successful human-technology interaction (e.g., Hancock et al., 2011; Van Pinxteren et al., 2019). Yet, these studies have mostly focused on single determinants and barely manipulated the relevant determinants. Moreover, technology anthropomorphism as a possibly influential factor was not systematically considered within these studies.

Studies 1.1 and 1.2 address this research gap and focus the research question: (RQ1) Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship? Moreover, they add to the question: (RQ3) What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship?

5.1.1. RESEARCH QUESTIONS, GENERAL HYPOTHESES AND STUDY PARADIGM

Study 1.1 and study 1.2 explored whether determinants known to influence interpersonal trust development can affect trust development in the human-technology relationship as well as what role anthropomorphism plays in this relationship. Overall, we assumed that within a human-technology interaction, technology competence and warmth as determinants known to be substantial for interpersonal trust (e.g., Fiske et al., 2007; Mayer et al., 1995) would enhance trust in the technology. We further hypothesized that this relationship would be mediated by individual perceptions of competence and warmth. In addition, comparing trust development in the human-technology relationship to parallel dynamics of interpersonal relationships, we assumed that technology anthropomorphism would moderate and could strengthen the effect of technology competence and warmth on trust. These hypotheses were investigated in two consecutive experiments, each manipulating one possible trust determinant (competence in study 1.1, warmth in study 1.2) on the example of the humanoid service robot Pepper by SoftBank Mobile Corp. (Pandey & Gelin, 2018). Both studies further included a manipulation of anthropomorphism as they also focused on a possible moderating role of anthropomorphism. In both studies, the same general study paradigm was applied, where a particular video of a certain HRI was presented to participants in an online setting. Based on this, participants filled out an online survey with relevant measures as described in the section below (section 5.1.2.).

Specifically, in study 1.1, where competence and anthropomorphism were manipulated, the videos show a robot and a human who are playing a shell game. In this, the human player covers an object and the robot guesses its placement for four playthroughs. The manipulation of robot competence concerned the robot's skills in the game. In the condition competence high, the robot's judgment is correct three out of four times. In contrast, in the condition competence low, the robot's judgment is correct only one out of four times. Furthermore, robot anthropomorphism was manipulated by means of verbal (voice) and non-verbal (gestures) design cues as well as mentioning the robot by its name within the introduction of the study. In the condition anthropomorphism high, the robot named "Pepper" shows the chosen shell with its hand and moves its head in the corresponding direction. In the condition anthropomorphism low, the robot does not have a name nor make any gestures or speak. Instead, answers are written on its tablet.

In study 1.2, where warmth and anthropomorphism were manipulated, the videos show a robot and two human players who are playing a shell game. This time, human player 1 covers an object and human player 2 guesses its location for three playthroughs. The robot, that stands next to human player 2, observes the game. In the first playthrough, human player 2 does not consult the robot and guesses wrongly. In the subsequent playthroughs, human player 2 guesses loudly and the robot consults the human on the accuracy of the guess. The manipulation of robot warmth concerned the intentions of the robot. In the condition warmth high, the robot and human player 2 have the same intentions (human player 2 winning). Thus, the robot shows compassion following the first lost playthrough and offers help. In the subsequent playthroughs, the robot gives the correct advice and cheers after each win of human player 2. In the condition warmth low, the robot shows opposed intentions and interests compared to human player 2 (human player 2 losing). Thus, the robot depreciates human player 2 after the first failure but offers help for the next playthroughs. Despite accepting the robot's help, the player loses in the second playthrough due to the robot's misleading advice and the robot cheers afterwards. In the third playthrough, the robot advises human player 2 one more time, but the player chooses not to follow the advice and wins. The robot gets miffed at this outcome. In study 1.2, robot anthropomorphism was also manipulated by means of verbal (voice) and non-verbal (gestures) design cues as well as mentioning the robot by its name within the introduction of the study. While in the condition anthropomorphism high, the robot named "Pepper" verbally expresses advice and turns its head towards the player as it speaks, in the condition anthropomorphism low, the robot does not have a name nor make any gestures or speak. Its advice is presented on its tablet. Figure 2 and 3 show screenshots of the videos presented in each condition within study 1.1 (Figure 2) and 1.2 (Figure 3).

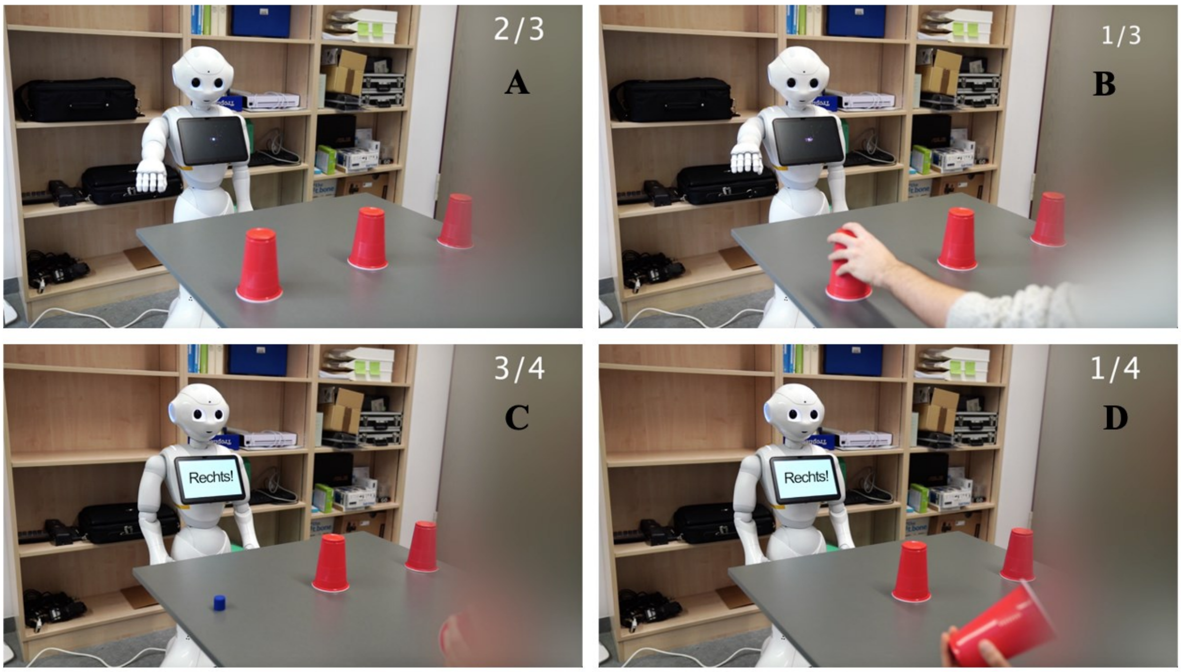

Figure 2. Screenshots of the videos in study 1.1, displaying HRI during a shell game in the conditions (A) anthropomorphism high x competence high, (B) anthropomorphism high x competence low, (C) anthropomorphism low, competence high and (D) anthropomorphism low, competence low. Game scores are presented in the upper right corner of each screenshot. From "Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI." By L. Christoforakos, A. Gallucci, T. Surmava-Große, D. Ullrich, and S. Diefenbach, 2021, *Frontiers in Robotics and AI, 8*, (79), p. 5.

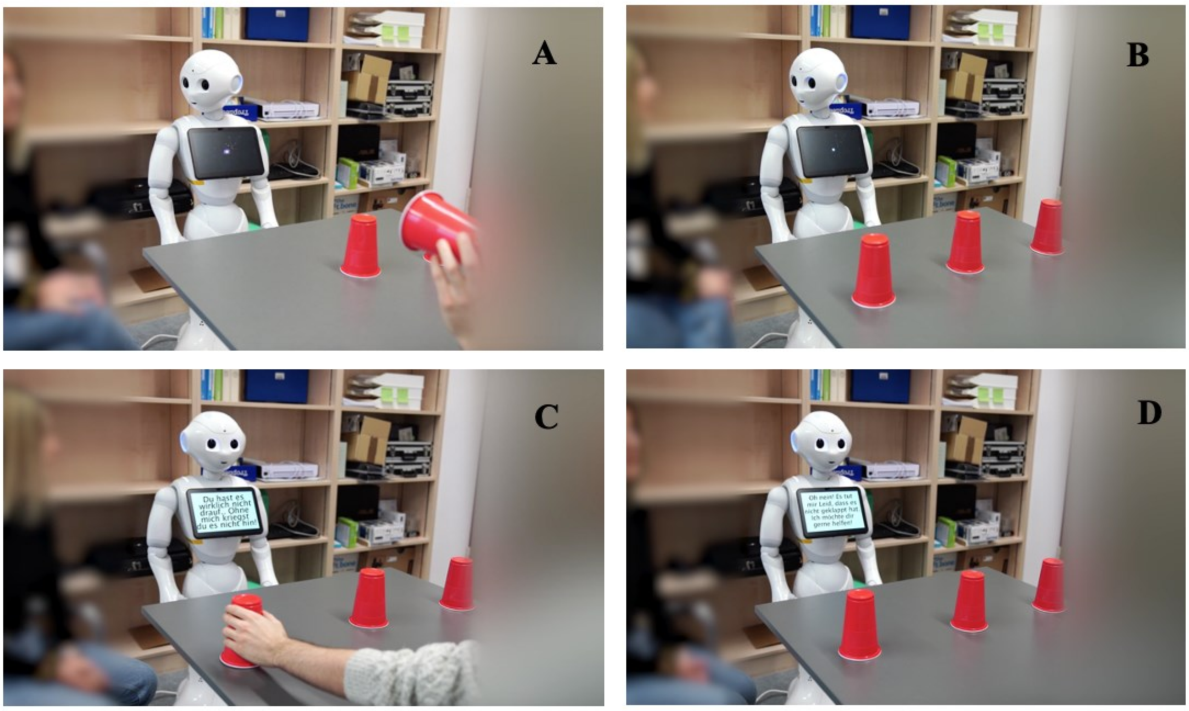

Figure 3. Screenshots of the videos in study 1.2, displaying HRI during a shell game in the conditions (A) anthropomorphism high x warmth high, (B) anthropomorphism high x warmth low, (C) anthropomorphism low, warmth high and (D) anthropomorphism low, warmth low. From "Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI." By L. Christoforakos, A. Gallucci, T. Surmava-Große, D. Ullrich, and S. Diefenbach, 2021, *Frontiers in Robotics and AI, 8*, (79), p. 10.

5.1.2. SAMPLE AND PROCEDURE

155 participants between 18 to 77 years (*M* = 33.50, *SD* = 15.00; 64% female, 36% male, 1% diverse) took part in study 1.1. 157 participants between 18 to 67 years (*M* = 34.53, *SD* = 13.88; 61% female, 39% male) took part in study 1.2.

In both studies, the interactions between the service robot and human player that were shown on video, differed for each experimental condition. In each condition, participants were presented the video of the HRI. Afterwards, participants provided their judgment regarding anticipated trust in the robot as well as attributed trustworthiness to such. Moreover, perceived competence, warmth, and anthropomorphism of the robot as well as other measures related to users' characteristics were assessed.

5.1.3. SUMMARY OF RESULTS

Overall, in line with our hypotheses, results showed a positive effect of technology competence (study 1.1) as well as technology warmth (study 1.2) on trust development in robots on an anticipatory as well as attributional level, that is, anticipated trust in the robot and attributed trustworthiness to the robot. Thus, these determinants appear relevant for trust development in HRI and imply a transferability of central dynamics of trust development from interpersonal interaction (Fiske et al., 2007; Mayer et al., 1995) to human-technology interaction.

Contrary to our hypotheses, based on the manipulations applied in the studies, anthropomorphic cues did neither influence the relationship of robot competence and trust (study 1.1) nor robot warmth and trust (study 1.2) on an anticipatory and attributional level. Yet, when considering the measurements of perceived robot competence, warmth and anthropomorphism instead of the applied manipulations, an according effect was found. Namely, perceived anthropomorphism moderated the effect of perceived competence (study 1.1) as well as perceived warmth (study 1.2) on trust on an attributional level. These explorative insights support a potential role of the perception of anthropomorphism for the transferability of interpersonal trust dynamics to HRI.

5.1.4. RESEARCH CONTRIBUTION

Results of study 1.1 and 1.2 emphasize the relevance of specific determinants for trust development as an essential component of the human-technology relationship. They further shed light on the transferability regarding determinants of trust development known from interpersonal relationships to the human-technology relationship. Namely, according to findings, competence (study 1.1) and warmth (study 1.2) of a technology appear to be possible determinants of trust development in the human-technology relationship. These determinants are also known to affect trust development in interpersonal relationships (e.g., Fiske et al., 2007; Mayer et al., 1995). Such findings are compatible with previous HCI research (e.g., Hancock et al., 2011; Kulms & Kopp, 2018; Robinette et al., 2017), implying a positive effect of computer competence and warmth on trust in computers.

However, anthropomorphism, which was varied on the level of appearance, referring to the categorization of Ruijten et al. (2019), between the respective conditions of each study, did not moderate the effect of manipulated competence (study 1.1) or warmth (study 1.2) on the trust ratings. This finding could possibly root in a rather restricted variance of anthropomorphism, amongst others, due to the manipulation based on the same technology in both conditions of both studies. Previous results that have implied an effect of anthropomorphic agent design have applied stronger manipulations, for example, by comparing different agent types, such as avatars vs. computers (e.g., de Visser et al., 2016). Yet, based on exploratory analyses an anthropomorphic perception of the robot may still play a role. Namely, individually perceived anthropomorphism, assessed regarding the general impression of humanlikeness of the technology, moderated the effect of perceived competence (study 1.1) and perceived warmth (study 1.2) on attributed trustworthiness of the technology. Despite the exploratory character of this finding, it generally highlights the relevance of individual perception for the development of psychological judgments such as trust in human-technology interaction. It also supports the consideration of anthropomorphism as a potential determinant of trust development in the human-technology relationship, especially combined with other known essential determinants such as competence and warmth.

More specifically, focusing on the combination with competence, this finding could be considered in line with previous study results implying that humans lose confidence in erring computers quicker compared to erring humans (Dietvorst et al., 2015). Such results underline the role of competence for trust in the human-technology relationship but also indicate a potential interaction of competence and anthropomorphism in this context (Dietvorst et al., 2015). Similarly, de Visser et al. (2016) found that an increase in (feedback) uncertainty about a robot's performance regarding a task strengthened the effect of technology anthropomorphism on trust resilience, that is, a higher resistance to trust breakdowns. The authors propose that "increasing anthropomorphism may create a protective resistance against future errors" (de Visser et al., 2016, p. 13), also indicating a possible interaction of technology competence and anthropomorphism. Similar interactions remain to be explored more closely with regard to technology warmth.

Thus, the studies discussed above address the research questions of (RQ1) transferability of dynamics known from interpersonal relationships to the human-technology relationship as well as (RQ3) the role of anthropomorphism in this relationship. In sum, it appears that regarding the development of trust, determinants known to be influential in interpersonal relationships (here: competence and warmth) also play a comparable role in the human-technology relationship. Technology anthropomorphism appears relevant when focusing on its perception through users, and in this seems to play a certain role in the relationship of perceived competence and trust as well as perceived warmth and trust within the human-technology relationship. Still, underlying mechanisms of interaction regarding the role of anthropomorphism for the transferability of dynamics from interpersonal relationships to the human-technology relationship need to be further specified with regard to trust and investigated for other variables relevant to the human-technology relationship. In study 2 this was applied for social connectedness.

5.2. STUDY 2

Study 2	Christoforakos, L., Feicht, N., Hinkofer, S., Löscher, A., Schlegl, S. F., & Diefenbach, S. (2021). Connect With Me. Exploring Influencing Factors in a Human-Technology Relationship Based on Regular Chatbot Use. *Frontiers in Digital Health, 3*. https://doi.org/10.3389/fdgth.2021.689999

Previous research implies that users can develop a sense of connectedness to their digital possessions (Clayton et al., 2015). Furthermore, findings of Kang and Kim (2020) imply that individuals might be able to develop a connected, social relationship with technology that is perceived as a counterpart. In addition, their results support an enhancing effect of anthropomorphic cues on the users' feeling of connectedness to the technology. Yet, underlying mechanisms regarding the development of social connectedness including the role of technology anthropomorphism, as well as their similarity to interpersonal relationships have not been systematically investigated so far. Moreover, a possible effect of social connectedness to a technology on interpersonal interaction, for example, by affecting users' social needs, has not been explored yet.

Thus, study 2 addresses this research gap and focuses on the research question: (RQ1) Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship? Moreover, it follows the question: (RQ2) To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? Finally, it addresses the overall research question: (RQ3) What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?

5.2.1. RESEARCH QUESTIONS, GENERAL HYPOTHESES AND STUDY PARADIGM

Study 2 explored the human-technology relationship with a focus on participants' felt social connectedness to the technology. In this, it explored possibly related characteristics of technology (e.g., perceived anthropomorphism and social presence) and user (e.g., individual tendency to anthropomorphize, individual need to belong) as well as their similarity to dynamics known from interpersonal relationships. Moreover, a possible effect of social connectedness to the technology on the desire to socialize with other humans was investigated.

Based on theoretical work on the development of interpersonal relationships (e.g., Altman et al., 1973; Carpenter & Greene, 2015; Granovetter, 1973), we assumed that the time spent in interaction with a conversational technology as well as the perceived interaction intensity could promote the development of the human-technology relationship. Moreover, based on findings that imply a role of technology humanlikeness regarding the transferability of dynamics known from interpersonal interaction to HCI (e.g., Jia et al., 2012; Kim & Sundar, 2012), we hypothesized that the perception of anthropomorphism or social presence in a technology would affect how users appraise their relationship to the technology, and thus how socially connected they feel to it. In this context, we further assumed that interindividual differences, such as the individual tendency to anthropomorphize or the individual need to belong, might play a moderating role in the relationship between interaction duration or intensity and perceived anthropomorphism or social presence of the technology. Finally, based on first study results implying that interaction with humanlike technology could affect user's social needs (e.g., Krämer et al., 2018; Mourey et al., 2017), we assumed that the felt social connectedness to the technology in question might partly satisfy individuals' social needs, and therefore diminish the innate desire to seek social connections to other individuals.

These general hypotheses were explored in the frame of a regular interaction with the conversational chatbot of the mobile application "Replika – My AI 207 Friend" (Luka Inc., 2020) over a two-week period. Replika represents a sort of chatbot companion that gathers information from its user and comments on various social topics beyond practical purposes through written conversation. Participants were asked to download the application and communicate with their personal chatbot for at least five minutes daily over the two-week study-period. All relevant measurements as described in the section below (section 5.2.2.) were assessed online by means of surveys.

5.2.2. SAMPLE AND PROCEDURE

58 participants between 18 to 56 years (M = 27.21, SD = 8.27; 47% female, 52% male, 2% did not indicate gender) took part in the study. The two-week study involved 15 separate occasions of measurement. Measures of users' technology perception, users' psychological states, and their felt social connectedness to the technology were assessed at the end of the two-week study-period. Potentially relevant trait variables (i.e., individual tendency to anthropomorphize, individual need to belong) were assessed prior to the interaction with the chatbot, as baseline

measures. In addition, the average interaction duration and average interaction intensity were measured daily over the two-week study-period and analyzed over time.

5.2.3. SUMMARY OF RESULTS

In line with our hypotheses, results showed that the duration and intensity of participants' interaction with the chatbot throughout the two-week study-period positively predicted social connectedness to the chatbot. Moreover, perceived anthropomorphism partially mediated the relationship of interaction intensity and social connectedness to the chatbot. Perceived social presence (partially) mediated the relationships of interaction duration, respectively interaction intensity, and social connectedness to the chatbot. Furthermore, contrary to our hypotheses, individual tendency to anthropomorphize as a user characteristic did not have a moderating effect on the relationship of interaction duration, respectively interaction intensity, and perceived anthropomorphism of the chatbot. In a similar manner, individual need to belong did not have a moderating effect on the relationship of interaction duration, respectively interaction intensity, and perceived anthropomorphism or perceived social presence of the chatbot. Additionally, no negative relationship between the felt social connectedness to the chatbot and the desire to socialize with other humans emerged.

5.2.4. RESEARCH CONTRIBUTION

Results of this study deliver insights on the development of social connectedness in the human-technology relationship as well as the transferability of dynamics from interpersonal relationships in this regard. Namely, it seems that regular interaction with a technology, referring to duration and intensity, can promote felt social connectedness to the technology. The perception of technology anthropomorphism, referring to characteristics of technology appearance, and social presence appear to mediate this relationship. Namely, the more intense participants’ interaction with the chatbot was, the more anthropomorphic as well as socially present they perceived it, and in turn felt more socially connected to the technology.

Accordingly, our findings imply that factors influencing the development of interpersonal relationships, that is, amount of time as well as emotional intensity of interaction (e.g., Granovetter, 1973), may be transferable to the human-technology relationship to a certain extent, as interaction duration and intensity affected the felt social connectedness to the technology. Based on our findings as well as previous CASA research (e.g., Nass & Moon, 2000), social cues such as anthropomorphic technology design might facilitate this transferability of dynamics known from interpersonal relationship development to the human-technology relationship.

Moreover, contrary to our assumption, study results showed no negative correlation between social connectedness to the technology and the desire to socialize with other humans. Although recent studies support that technologies including humanlike design cues might, to a certain extent, satisfy social needs of users, and therefore possibly diminish their desire to interact with other humans (e.g., Krämer et al., 2018; Mourey et al., 2017), this study's results did not show such an interrelation. The studies that found such an effect focused on the comparison of anthropomorphism vs. no anthropomorphism in technologies (Mourey et al., 2017) or socially responsive vs. non-socially responsive behavior of virtual agents (Krämer et al., 2018). Within our study, technology anthropomorphism was not manipulated and solely the perceived anthropomorphism of the chatbot was considered as a potentially relevant factor for the felt social connectedness to such. Moreover, studies which found a relationship in this regard, did not explore the direct interrelation of felt social connectedness to a technology and desire to interact with other humans, but focused on the interaction with the technology and its relationship to the desire to interact with other humans (Mourey et al., 2017; Krämer et al., 2018). Based on our findings, it appears worthwhile to further explore which underlying psychological mechanisms such results rely on.

Overall, the two-week study-period supports the external validity of the insights, as they do not merely root in a novelty effect or initial participant engagement. This also implies that the examined interrelations are already detectable in a two-week period of technology use.

Thus, the study discussed above addresses the research questions of (RQ1) transferability of dynamics known from interpersonal relationships to the human-technology relationship as well as (RQ2) the possible effect of human-technology interaction on users' social needs. Additionally, it refers to the question regarding (RQ3) the role of anthropomorphism in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs. In sum, it appears that determinants of relationship development in interpersonal interaction can be transferred to the human-technology relationship to a certain extent, referring to single determinants affecting the development of social connectedness in the human-technology relationship. Moreover, based on results of study 2, the perception of social cues, such as humanlikeness in characteristics of technology appearance, might facilitate this transferability. Yet, no effect of this social connectedness to the technology on interpersonal interaction with regard to social needs was found. This interrelation was further explored in studies 3.1, 3.2 and 4.

5.3. STUDY 3.1 & 3.2

Study 3.1 Study 3.2	Christoforakos, L., & Diefenbach, S. (2022). Technology as a Social Companion? An Exploration of Individual and Product-Related Factors of Anthropomorphism. *Social Science Computer Review, 0*(0), 1–24. https://doi.org/10.1177/08944393211065867

Previous research has implied a possible interrelation of the interaction with technology and users' social needs, highlighting a relevance of technology anthropomorphism. For example, Kang and Kim (2020) found that anthropomorphism fosters the sense of connectedness between user and technology. Moreover, first studies support that interaction with anthropomorphic technology can even affect interpersonal interaction to a certain extent. Mourey et al. (2017), for example, found that after interacting with anthropomorphic (vs. non-anthropomorphic) products, individuals who were socially excluded exaggerated the number of their social connections less. Additionally, their anticipated need to engage with close others and their willingness to show prosocial behavior were diminished (Mourey et al., 2017). Similarly, Krämer et al. (2018) found that individuals with a high need to belong stated a lower willingness to engage in social activities after interacting with an agent showing socially responsive behavior. Still, results of single studies have scarcely been considered in an integrative manner. Moreover, in the above-mentioned studies different manipulations were applied and it is unclear to what extent, and which perceived humanlike characteristics might have played a role in the found effects. Overall, systematic research on the interrelation of interaction with technology and users' social needs, focusing on technology anthropomorphism as well as specific preconditions and interindividual factors that might be relevant within this relationship, is lacking.

Addressing this research gap, study 3.1 and 3.2 refer to the research question: (RQ2) To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? They also focus on the question: (RQ3) What role does anthropomorphism play regarding the possible effect of human-technology interaction on users' social needs?

5.3.1. RESEARCH QUESTIONS, GENERAL HYPOTHESES AND STUDY PARADIGM

Study 3.1 and 3.2 explored whether anthropomorphic technologies have the potential to fulfill users' social needs and how individually perceived anthropomorphism correlates to social needs. In this, we aimed at systematically comparing the interaction with anthropomorphic vs. non-anthropomorphic technology and assessing social needs on an intentional as well as behavioral level.

Based on theoretical work, such as the social reconnection hypothesis, implying that when individuals' social needs remain unsatisfied, they are consequently motivated to seek alternative fulfillment of such (DeWall & Baumeister, 2006), we assumed that social exclusion would increase the urge to fulfill social needs. Moreover, as previous single studies could show that after individuals interacted with anthropomorphic products, their social needs could be satisfied to an extent that, experimentally induced effects of social exclusion were mitigated (e.g., Mourey et al., 2017), we generally assumed that interaction with an anthropomorphic technology would diminish the enhancing effect on social needs induced by social exclusion. In addition, we hypothesized that the relationship between interacting with anthropomorphic technologies and expressing lower social needs would be particularly pronounced for socially excluded individuals. On an exploratory level, we studied the relationship of individual perceptions of anthropomorphism and social needs as well as the role of individual differences in anthropomorphism in this.

Therefore, two consecutive experimental online studies were conducted. In both studies, technology anthropomorphism as well as social exclusion were manipulated. While anthropomorphism was manipulated differently in the studies, both studies followed the same study paradigm.

In study 3.1, anthropomorphism was manipulated rather implicitly (cf., Mourey et al., 2017) by asking participants to imagine their own smartphones and answer numerous questions which were formulated in an anthropomorphic vs. non-anthropomorphic manner (e.g., "How well would you say does your smartphone work?" vs. "How would you rate the functionality of your smartphone?"). Social exclusion was manipulated by asking participants to describe a situation, where they felt socially excluded within a group vs. to describe their kitchen, including furniture, colors, floors, etc.

In study 3.2, a more explicit manipulation of anthropomorphism by means of design-cues was used. There, participants were confronted with an anthropomorphic vs. non-anthropomorphic smartphone design. Figure 4 shows the two smartphone designs. For the anthropomorphic condition, a design similar to Apple's iPhone was altered in a way that the combined design and placement of the menu-button, the front camera and the microphone resembled a human face. For the non-anthropomorphic condition, the design was not altered and simply resembled Apple's iPhone. Social exclusion was manipulated in the same manner as in study 3.1. In both studies, participants were confronted with these manipulations in an online setting and afterwards filled out questionnaires with regard to the variables of interest, as specified in the next section (section 5.3.2.).

Figure 4. Anthropomorphic (left) vs. non-anthropomorphic (right) smartphone designs applied for the manipulation of anthropomorphism within study 3.2. From "Technology as a Social Companion? An Exploration of Individual and Product-Related Factors of Anthropomorphism." by L. Christoforakos and S. Diefenbach, 2022, *Social Science Computer Review, 0*(0), p. 11.

5.3.2. SAMPLE AND PROCEDURE

159 participants between 18 to 75 years (*M* = 26.18, *SD* = 9.56; 73% female, 26%, 1 % diverse) took part in study 3.1. 236 participants between 17 to 71 years (*M* = 30.37, *SD* = 11.17; 60% female, 40% male) took part in study 3.2.

Procedures of both studies were parallel. After the manipulations of social exclusion and then anthropomorphism, participants played a self-constructed non-competitive sentence completion game as a measure of behavioral intention to socialize with others. In this, participants filled out parts of a given sentence which thereafter was (presumably) completed by another player or the computer. The game content was not crucial for our measure. We rather focused on participants' reported preference for playing the game alone or with another participant. Thereafter, participants' social needs on an intentional level were assessed by a scale measuring willingness to socialize with others and perceived anthropomorphism, referring to a general humanlike impression of the technology, regarding the participants' own smartphone (in study 3.1) or the presented smartphone design (in study 3.2). In study 3.2, further person variables such as individual tendencies to anthropomorphize were assessed.

5.3.3. SUMMARY OF RESULTS

Contrary to our hypotheses, in both studies, none of the assumed main or interaction effects of anthropomorphism and social exclusion on behavioral intention and willingness to socialize were found. Yet, in study 3.1 an overall positive correlation between willingness to socialize and perceived anthropomorphism emerged. Results of study 3.2 further supported this relationship and additionally showed that this relationship was especially pronounced for individuals who reported a high tendency to anthropomorphize, given the fact that the product fosters a humanlike perception due to its visual design. In sum, our results imply a relationship between social needs and anthropomorphism and further hint at a relevance of individual and contextual strengthening factors regarding this interrelation.

5.3.4. RESEARCH CONTRIBUTION

Results of the presented studies offer insights on the relationship of the interaction with technology and users' social needs and the role of technology anthropomorphism in this relationship. Namely, it appears that perceived anthropomorphism regarding a technology and user's willingness to socialize with other humans are positively correlated. Although our results do not suggest any causality, considering previous research on this interrelation (e.g., Bartz et al., 2016; Eyssel & Reich, 2013), our findings could imply that the higher individuals' need to socialize with others is, the more they attribute a general humanlikeness to non-human entities. Thus, our insights stand in line with the SEEK model (Epley et al., 2007), which supports that individuals are more likely to anthropomorphize when they feel the need for social connection to others.

Furthermore, our research underlines a relevance of individual differences in anthropomorphism. Namely, based on our results, the positive relationship of perceived anthropomorphism and willingness to socialize with others is particularly pronounced for individuals with a high tendency to anthropomorphize, who at the same time are confronted with a technology with anthropomorphic design cues regarding its appearance. In sum, it appears that there is a certain relationship between technology anthropomorphism and users' social needs, and that individual and contextual factors can affect the strength of this relationship. Still, interrelations as well as causalities regarding these variables require further systematic investigation.

Moreover, both studies could generally hint at the relevance of individual perception regarding anthropomorphism of technologies. Namely, besides the above-elucidated relevance of individual differences in anthropomorphism for the relationship in question, individually perceived anthropomorphism of non-human agents or objects seems to be interrelated to individuals' willingness to socialize. Therefore, explicitly considering perceived anthropomorphism as a measure when focusing on the potential of interaction with technology to address social needs of users, could be rather insightful for future research in this regard.

Furthermore, due to the missing effects of the experimental manipulations of anthropomorphism in both studies, the question whether interaction with anthropomorphic technology comes with the potential to dampen negative effects of social exclusion, as implied by previous studies (e.g., Mourey et al., 2017), remains unclear. Still, these missing effects could potentially indicate that in the case of a smartphone, manipulating technology anthropomorphism by referring to it in an anthropomorphic (vs. non-anthropomorphic) manner or manipulating simple visual design cues might not be sufficient to affect individuals' behavioral intention or willingness to socialize with others. Furthermore, this finding could also root in the short period of time for which participants were confronted with the technology. Respectively, the anthropomorphism manipulation of these two studies might have not been long enough to affect participants' behavioral intention or willingness to socialize with others.

Thus, both study findings contribute to the research question regarding (RQ2) the possible effect of human-technology interaction on users' social needs, as well as (RQ3) the role of anthropomorphism regarding the possible effect of human-technology interaction on users' social needs. In sum, it appears that interaction with technology and users' social needs could be interrelated in a certain way when technology anthropomorphism is involved. Yet, our findings support the complexity of this issue, as various factors such as individual differences, that is, the individual tendency to anthropomorphize, or contextual factors such as anthropomorphic design cues could play a role in this relationship. Still, the question, whether interaction with technology that is anthropomorphic or perceived as such can affect or even satisfy individuals' social needs, demands further research. Study 4 further investigated this relationship and complemented existing findings by means of an alternative research approach.

5.4. STUDY 4

Study 4	Christoforakos, L., & Diefenbach, S. (2022). Fulfilling social needs through anthropomorphic technology? A reflection on existing research and empirical insights of an interview study. *Z. Arb. Wiss.* 77, 78–91 (2023). https://doi.org/10.1007/s41449-022-00339-1

Single study results have implied a possible "social saturation" by means of interaction with technologies when they include humanlike qualities (e.g., Mourey et al., 2017; Krämer et al., 2018). Our above-presented studies, which investigated the potential of technology to affect the willingness to socialize with others, did not find any similar effect (Christoforakos et al., 2021; Christoforakos & Diefenbach, 2022b). Naturally, it appears challenging to compare study results due to the different manipulations of technology anthropomorphism that were applied as well as the different means of assessing perceived technology anthropomorphism and social needs of individuals. Still, this state of research could, amongst others, potentially also root in the challenging assessment of variables involved in the interrelation in question. For example, while it might be advisable to consider an explicit measurement of perceived anthropomorphism besides the mere manipulation of such, previous findings suggest that such an explicit measurement could also cause psychological reactance in participants (cf., Kim and Sundar, 2012), potentially leading to invalid measurement.

Similarly, the assessment of social needs through measures, such as the scale on willingness to socialize (Krämer et al., 2018), could be affected by contextual factors, for example, the physical distance to one's friends and family or other plans, potentially impairing insight validity. In comparison, more indirect measures, such as planned prosocial behavior as applied by Mourey et al. (2017), rely on the assumption that ratings have been affected by a satisfaction of social needs. This could also lead to a rather vague interpretation of results. Moreover, in general, it seems challenging to measure satisfaction of social needs after a short-term interaction with technology within a cross-sectional study. Thus, further research is required to broaden the view on this relationship and grasp the potential of technology to address humans' social needs, and therefore potentially affect their willingness to interact with other human counterparts.

Study 4 addresses this research gap and focuses on the research question: (RQ1) Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship? Additionally, it focuses the question: (RQ2) To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? Moreover, it follows the overall research question: (RQ3) What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?

5.4.1. RESEARCH QUESTIONS AND STUDY PARADIGM

Study 4 explored the potential of technology to address users' social needs and what role anthropomorphism plays in this relationship. Based on the equivocal character of previous findings in this regard as well as the above-elaborated assessment challenges, we complemented existing research by means of an alternative approach. To broaden the understanding of whether and based on which psychological mechanisms the interaction with technology has the potential of addressing social needs, we conducted a qualitative interview study. We chose an explorative approach to support an unbiased exploration of our research question and capture an extensive image of people's experience when they interact with technology.

Specifically, we followed the approach of psychological phenomenology in accordance with Moustakas (1994), aiming to reduce individual experiences of a phenomenon to a universally suitable essence. The interviews followed three main guiding questions concerning (1) similarities and differences in interaction with technology that resembles interpersonal interaction vs. humans regarding users' social needs, (2) technology characteristics that could play a role for an effect of interaction with technology on users' social needs and (3) third party reactions to human-technology interaction which resembles interpersonal interaction. The interviews were conducted online via the Zoom Video Communications software (Zoom Video Communications, 2021).

5.4.2. SAMPLE AND PROCEDURE

Eight participants between 25 to 61 years (M = 36.88; SD = 12.24; 50% female, 50% male) took part in the interview study. In the interviews, participants were given the option to talk about any product within the field of technology or consumer electronics which they found suitable to answer the questions. Most of them mentioned different products and afterwards focused on one. In a short introduction to get acquainted with the topic, participants were asked to elaborate on their interactions with technologies that are similar to interactions with other human interaction partners as well as general effects of any technology on their social needs.

Thereafter, the main part of the interview focused on the above-described three overarching guiding questions. Participants were asked to reflect one those.

5.4.3. SUMMARY OF RESULTS

Following the approach of a phenomenological analysis, general themes and clusters of meaning regarding participants' experiences emerged for each guiding question. Our findings showed many differences regarding the perceived quality of interaction with technology resembling interpersonal interaction compared to interpersonal interaction. In sum, regarding the general theme "descriptions of interaction content with a technology or human counterpart", participants most frequently described how interaction with technology represents a simple exchange of orders or instructions, as well as answers in return. In accordance with this, they often mentioned that technology does not offer any feedback or support on an emotional, informative or haptic level. Concerning the second general theme of "personal feelings or evaluations regarding interactions with technology vs. a human counterpart", participants mostly stated that they did not experience a satisfaction of social needs in interaction with technology. Furthermore, they explained that an interaction with technology could help counteract temporary boredom, frustration or loneliness and described perceived interaction with technology as more superficial or distant in comparison to interpersonal interaction.

Regarding technology characteristics that can be relevant for addressing users' social needs, within the general theme of "characteristics resembling (interaction with) humans or animals", participants most frequently named technology intelligence and (im)perfection or (un)predictability of the technology. In the same frequency, a general technology humanlikeness was mentioned as potentially relevant for technology to address users' social needs. Less frequently, participants named technology interaction with users (by means of speech) as well as visual design cues fostering humanlikeness as relevant for an effect on users' social needs. Furthermore, they explained how a combination of various humanlike characteristics (e.g., visual design cues combined with empathy expression) would be necessary in this regard. Regarding the theme of "other technology characteristics", participants most frequently mentioned modern, appealing, or aesthetic design as possibly influential. In the same frequency they named a certain frequency of use or timeframe of possession of a technology.

Finally, referring to third party reactions to an interaction with technology that resembles interpersonal interaction, concerning the theme of "rather negative reactions", participants most frequently mentioned irritation or lack of understanding from the third party. Less frequently, participants described situations where the third party was uncomfortable or annoyed.

Regarding the theme of “rather neutral or positive reactions”, participants most frequently named situations where the third party did not disapprove or even approved of the interaction with the technology resembling an interpersonal one. Less frequently, participants mentioned interest or enthusiasm about the interaction or involvement of the third party in the interaction with the technology. Finally, in the same frequency, participants mentioned situations where the third party appeared surprised or their attention was steered.

5.4.4. RESEARCH CONTRIBUTION

Findings of study 4 offer insights on the relationship of interaction with technology and users’ social needs as well as the relevance of technology anthropomorphism in this regard. While participants’ statements concerned different technologies and according interaction modalities, insights on the comparison of human-technology and interpersonal interaction regarding social needs show that, although modalities of interactions might oftentimes be similar, a crucial perceived difference refers to the monotonous character of interaction with technology and the absence of reactions to the user on a content, physical, and emotional level. This finding could serve as one possible explanation for the missing effect of interaction with or social connectedness to a technology on willingness to socialize with other human counterparts, as implied by results of this study and previous research (e.g., Christoforakos et al., 2021; Christoforakos & Diefenbach, 2022b).

Additionally, insights hint at a necessity to combine humanlike technology characteristics, such as characteristics referring to appearance and cognitive states (e.g., visual design cues combined with empathy expression), in order for interaction with technology to address users’ social needs. This could also serve as one reason for the non-observable effect of anthropomorphic technology on users’ social needs within prior research, that focused on manipulating only characteristics of appearance (i.e., visual design of a smartphone) with regard to technology anthropomorphism (e.g., Christoforakos & Diefenbach 2022b).

Moreover, results suggest that interaction with technology, that resembles interpersonal interaction, could be an effective countermeasure for temporary negative user states such as boredom, frustration or loneliness. These results offer further support for previous study findings that imply a relationship between loneliness and anthropomorphism (e.g., Epley et al. 2007; Epley et al. 2008a; Niemyjska & Drat-Ruszczak 2013). Furthermore, based on such findings, found effects of interaction with anthropomorphic technologies on users’ social needs (e.g., Krämer et al. 2018; Mourey et al. 2017) could possibly root in a counteraction of temporary negative user states such as loneliness.

Furthermore, referring to technology characteristics that can be relevant for addressing users' social needs, most of the found clusters of meaning concerned different characteristics that resemble humans and interaction with them. These findings stand in line with study results, supporting the relevance of anthropomorphism for the effect of interaction with technology on users' social needs (e.g., Krämer et al. 2018; Mourey et al. 2017). Moreover, many of the mentioned characteristics such as technology intelligence or imperfection appear rather abstract. This observation could emphasize the complex character of the relationship between interaction with technology and users' social needs as well as the challenge to observe this relationship based on a classical experiment.

Finally, the frequently mentioned irritation or lack of understanding of third parties, found as a reaction to human-technology interaction resembling interpersonal reaction, could speak for the novelty of this type of interaction, but also hint at a social desirability bias regarding the general research question. Namely, when individuals repeatedly experience a rather negative reaction of third parties towards an interaction with technology that resembles an interpersonal one, they might feel self-conscious regarding the social acceptability of the topic in question. Consequently, they might have inhibitions about explaining whether and in what way interaction with technology might address their social needs.

Overall, as this study followed a qualitative approach, insights generally foster a deeper understanding regarding the potential of interaction with technology to address users' social needs as well as the role of technology anthropomorphism in this regard. These exploratory insights furthermore hint at potential explanations for previous research findings and underline mechanisms that should be explored in future studies in a systematic manner.

Study 4 thus contributes to the research questions with regard to (RQ1) the transferability of dynamics known from interpersonal relationships to the human-technology relationship, (RQ2) the possible effect of human-technology interaction on users' social needs, and (RQ3) the role of anthropomorphism in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs. In sum, it appears that the human-technology relationship can resemble the interpersonal one in certain ways, as it could, for example, come with the potential of temporarily addressing facets of users' social needs, especially when technology anthropomorphism is involved. Yet, findings also underline limits of technology in this context by highlighting essential perceived differences to interpersonal interaction and suggesting that a complete satisfaction of social needs might not be achievable through the interaction with technology.

6. GENERAL DISCUSSION

We increasingly interact with technologies which we view as social counterparts. Thus, our interactions with such oftentimes resemble interactions with human counterparts in many ways. For example, we might catch ourselves having random conversations with our smart voice assistants. Moreover, social robots slowly but surely support us with daily activities, like shopping but also more intimate matters like our physical and mental health. Sometimes we even end up spending more time of the day interacting with a technology than with another human. Therefore, it appears important to look closer into the human-technology relationship, its similarities, and differences to the interpersonal one, as well as its potential to affect the extent to which we feel the need to interact with other humans. Thus, this thesis addresses the overarching research aim of exploring how the human-technology relationship might affect interpersonal relationships with regard to social needs. Moreover, it focuses on the role of technology anthropomorphism in this relationship.

Technological development will continue in an exponential manner and technologies will be increasingly able to affect their users in ways we have not experienced to date. Yet, understanding the potential of technology to address users' social needs and potentially even affect interpersonal relationships might offer valuable insights to facilitate a responsible and sustainable handling in this regard, from the perspective of technology users, developers, and society in general.

6.1. SUMMARY OF RESEARCH FINDINGS

Subsidiary to the overarching research question of how the human-technology relationship might affect interpersonal relationships with a focus on social needs, the present work focuses three research questions; (RQ1) Which dynamics play a role in the human-technology relationship and to what extent are dynamics known from interpersonal relationships transferable to the human-technology relationship?, (RQ2) To what extent does human-technology interaction affect users' social needs or substitute their fulfillment through interpersonal interaction? and (RQ3) What role does anthropomorphism play in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs?

The first question on dynamics of the human-technology relationship and their transferability form interpersonal relationships (RQ1) was addressed by quantitative studies, focusing on the development of trust (study 1.1/ 1.2) and social connectedness (study 2) as well as a qualitative interview study, focusing on the fulfillment of social needs. Results imply that essential dynamics regarding the development of trust within interpersonal relationships (e.g., Fiske et al., 2007; Mayer et al., 1995) are somewhat transferable to the human-technology relationship, as competence (study 1.1) and warmth (study 1.2) of the technology seem to positively affect trust development in such. Moreover, findings of study 2 imply that regular interaction with a technology, referring to duration and intensity, can promote social connectedness to the technology. Thus, it seems that factors known to affect interpersonal relationship development, that is, amount of time as well as emotional intensity of interaction (e.g., Granovetter, 1973), could be transferable to the human-technology relationship to a certain extent. Finally, findings of study 4 highlight similarities in the quality of human-technology and interpersonal interaction with regard to social needs. For example, participants often described how an interaction with technology could act as a countermeasure for temporary boredom, frustration, or loneliness which can also be experienced with a human counterpart. Yet, study findings also underline essential limits of human-technology interaction compared to interpersonal interaction. For example, findings imply that the interaction with technology mostly cannot offer feedback or support on a content, physical, or emotional level, and is often perceived not capable of satisfying users' social needs. Overall, insights highlight specific dynamics regarding central relationship variables, which are to a certain extent transferable from interpersonal relationships to the human-technology relationship, but also need further systematic exploration. Findings also underline limits of the interaction with technology in comparison to the interpersonal one, especially concerning the satisfaction of social needs.

The second question on the potential of human-technology interaction to affect users' social needs or substitute their fulfillment through interpersonal interaction (RQ2) was addressed by the prospective study exploring the interrelation of social connectedness to a technology and willingness to interact with other humans (study 2) as well as the experimental study on the effect of interaction with an anthropomorphic (vs. non-anthropomorphic) technology on willingness to socialize with other humans (study 3.1/3.2). It was also explored by the interview study focusing on the potential of interaction with technology to address users' social needs. Results of study 2 imply no interrelation of social connectedness to the chatbot and desire to socialize with other humans. Similarly, study 3.1 and 3.2 did not support an effect of interaction with anthropomorphic (vs. non-anthropomorphic) technology on the willingness to socialize with others. Qualitative findings of study 4 offer deeper insight in this relationship. They hint at the potential of interaction with technology that is similar to interpersonal interaction to be a countermeasure for temporary negative user states such as boredom, frustration, or loneliness. Yet, results also support an absence of satisfaction of users' social needs, amongst others, possibly because of the mentioned exchange of simple orders and answers in human-technology interaction and the non-existent feedback from the technology on a content, physical, and emotional level. Overall, based on the studies' findings, interaction with technology might have a certain potential of addressing social needs. Yet, this potential might be limited, for example, to temporary states such as loneliness. Interaction with technology might thus not be sufficient to actually satisfy social needs of users to an extent that the need to interact with other humans is affected.

The third research question on the role of anthropomorphism in the transferability of dynamics from interpersonal relationships to the human-technology relationship as well as regarding the possible effect of human-technology interaction on users' social needs (RQ3) was addressed by all studies included in this thesis. Results of study 1.1 and 1.2 imply a role of anthropomorphism for the transferability of dynamics of trust development known from interpersonal relationships to the human-technology relationship. Namely, exploratory analyses revealed that individually perceived anthropomorphism, referring to a general humanlike impression of the technology, moderated the effect of perceived technology competence (study 1.1) and perceived technology warmth (study 1.2) on attributed trustworthiness of the technology. In a similar manner, in study 2, perceived anthropomorphism played a role with regard to the similarity of dynamics of relationship development in interpersonal relationships and the human-technology relationship. Specifically, findings showed that perceived anthropomorphism, referring to characteristics of technology appearance, partially mediated the relationship of interaction intensity and social connectedness to the chatbot. The presented findings imply that perceived anthropomorphism of the technology can affect the extent to which dynamics known from interpersonal relationships are observable within the human-technology relationship. Still, specific mechanisms of interaction need further exploration.

Furthermore, studies 3.1 and 3.2 underline a positive relationship of perceived technology anthropomorphism, referring to a general humanlike impression of the technology, and the willingness to socialize with others (study 3.1). Findings imply that this relationship is especially strong for individuals who have a high tendency to anthropomorphize, and at the same time are confronted with anthropomorphic characteristics of technology appearance (referring to the visual design of a smartphone in study 3.2). Taken together, these results do not imply any causality. Yet, they hint at a certain positive relationship between users' social needs and technology anthropomorphism and further support a relevance of individual and contextual strengthening factors regarding this relationship. Moreover, qualitative findings of the interview study (study 4) support a role of technology anthropomorphism for an effect of interaction with technology on users' social needs. Namely, most of the participants' mentions with regard to technology characteristics that could be relevant for a potential effect of interaction with technology on users' social needs concerned characteristics resembling (interaction with) humans or animals. Rather frequently mentioned clusters of meaning included technology intelligence, (im)perfection, or (un)predictability, as well as a general technology humanlikeness to be potentially relevant for technology to address users' social needs. Based on the exploratory nature of findings, the role of anthropomorphism in this relationship is not conclusive from a methodological perspective. Yet, it becomes clear that it could be relevant for the potential of interaction with technology to address users' social needs.

6.2. THEORETICAL IMPLICATIONS

Findings of this thesis highlight specific dynamics within the human-technology relationship that are somewhat comparable to those known from interpersonal relationships. Specifically, this concerns integral relationship variables such as the development of trust or social connectedness. Thus, regarding these variables, theories and empirical findings on interpersonal interaction could be considered for research on human-technology interaction. For example, study 1.1 and 1.2 overall showed that competence and warmth, determinants known to influence trust development in interpersonal relationships (e.g., Mayer at al., 1995), are also relevant for the development of trust in technology. These findings stand in line with previous literature on the CASA paradigm, implying that individuals apply social rules known from interpersonal interaction to their interaction with computers (Nass et al., 1994). Such studies have generally underlined that numerous principles drawn from the research fields of social psychology, sociology, and communication are generally relevant to study HCI. The study findings of this thesis further extend this state of research, as they identify specific variables for which this holds true and point out technology, user, and situational characteristics that can be influential in this regard.

Moreover, the present work also hints at boundaries of the comparability of dynamics from interpersonal relationships and the human-technology relationship, especially when social needs and their satisfaction are considered. Whereas previous literature implies a potential of technology to affect the willingness of users to socialize with other humans (e.g., Krämer et al., 2018), studies considered in this thesis, which have explored the potential of technology or the social connectedness to such to affect users' willingness to socialize with other humans, did not find such an effect (Christoforakos et al., 2021; Christoforakos & Diefenbach, 2022b). While the comparison of study results is naturally challenging based on different manipulations and measures, the conducted qualitative interview study offers a deeper understanding of this relationship and first potential explanations for previous findings. Namely, findings of the interview study hint at a potential of technology to counteract negative user states such as boredom, frustration, or loneliness. Based on this, it seems that technology could rather act as a social snack, that is, something that can "provide a temporary stopgap for social hunger when a "social meal" (e.g., interaction with an accepting other) is unavailable" (Gardner et al., 2005, p. 232) and might not be able to fully satisfy social needs like a human interaction partner. The found potential of technology to counteract loneliness could also possibly be causal for previously found effects of technology on the willingness to socialize with others (Krämer et al., 2018), or, amongst others, the anticipated need to engage with close others and the willingness to perform prosocial behavior (Mourey et al., 2017). While this assumption has similarly been formulated by Krämer et al. (2018), it still needs systematic exploration. Moreover, it remains unclear, which kind of interactions with technology can act as a social snack and which contexts are suitable. For example, to what extent is social snacking by means of interacting with a social robot interchangeable with scrolling on Instagram or simply checking the news online?

Based on the studies included in this thesis, technology anthropomorphism seems to be relevant for the comparability of dynamics in interpersonal relationships and the human-technology relationship. It also seems to be interrelated with users' social needs and potentially even play a role for the effect of interaction with technology on social needs of users. Thus, our findings support previous results of CASA studies, implying that the humanlikeness of technology can affect the degree to which human-technology interaction adopts a social character (cf., Nass & Moon, 2000). Namely, findings imply that this could be particularly applicable for trust and social connectedness. Regarding these constructs, the perception of technology anthropomorphism played a role in the transferability of relevant dynamics known from interpersonal relationships to the human-technology relationship (study 1.1/1.2 & study 2). Still, it needs to be further explored in what way anthropomorphism precisely affects the transferability of such dynamics from interpersonal relationships to the human-technology relationship.

Furthermore, the SEEK model by Epley et al. (2007) predicts that humans are more likely to anthropomorphize when "lacking a sense of social connection to other humans" (Epley et al., 2007, p. 1), amongst others. Findings within this thesis offer additional support for this theoretical groundwork. Specifically, they show a positive relationship between perceived anthropomorphism and willingness to socialize with other humans. Our findings further extend such work by implying a general importance of individual factors, that is, the individual tendency to anthropomorphize (cf., Waytz et al., 2010) as well as contextual factors, that is, the availability of anthropomorphic cues in technology appearance, for this interrelation. Moreover, our exploratory interview study offers deeper insight in this relationship. Namely, based on its findings, most characteristics mentioned as potentially relevant for an effect of interaction with technology on users' social needs concerned characteristics that resemble behavior or interaction with humans. This stands in line with results of Mourey et al. (2017) and Krämer et al. (2018), which imply a potential of anthropomorphic technology to affect users' social needs. Interview insights also indicate that more than just appearance-based anthropomorphic characteristics of technology design could be relevant for such an effect as, amongst others, they imply a relevance of a combination of characteristics on the level of appearance but also cognitive states. In this, findings also highlight more abstract qualities such as technology intelligence as well as unpredictability and imperfection that might also be relevant for such an effect to be observed. Still, due to the exploratory nature of such insights, these different types of anthropomorphic technology characteristics need to be systematically evaluated with regard to their role for the potential of interaction with technology to address users' social needs.

Finally, findings of this thesis extend insights of Kim and Sundar (2012) who propose that anthropomorphism is a mindless process, that is, a non-conscious tendency to interact with computers similar to human beings, rather than a mindful one, that is, a conscious tendency to interact with computers similar to human beings. The authors base this assumption on their study insights, showing that participants who were confronted with the anthropomorphic version of a website deliberately denied treating the website in a human manner, particularly when the website was personified with simple labeling. Insights of our interview study complement such findings, but also hint at a possible social desirability bias in technology anthropomorphism. Namely, according to our findings, interaction with technology that resembles the interpersonal one is often subject to irritation or misunderstandings. Therefore, individuals could feel self-conscious about attributing human characteristics, emotions, motivations, and intentions to non-human agents (cf., Epley et al., 2007). While this issue generally makes anthropomorphism itself a difficult construct to measure in a valid manner, it should be considered in future studies focusing on technology anthropomorphism.

Overall, based on the variety and different quality of insights that the empirical studies within this thesis offer, a general theoretical implication that emerges is the value of different methodological approaches to shed light on the complex relationship of interaction with technology and users' social needs. Especially, when explicit measurement of central variables is challenging and social desirability comes into play, a combination of, for example, quantitative and qualitative approaches, but also cross-sectional and longitudinal studies could be of great added value.

6.3. PRACTICAL IMPLICATIONS

Insights of this thesis offer practical implications on how to foster the development of essential relationship variables in human-technology interaction, that is, trust and social connectedness. Namely, based on our findings, determinants that can affect the development of trust (i.e., competence and warmth; e.g., Fiske et al., 2002, 2007; Mayer et al., 1955) in interpersonal relationships can be relevant to foster similar dynamics in human-technology interaction. Similarly, central determinants of relationship development in interpersonal relationships can be essential for the development of social connectedness (i.e., interaction duration and intensity; e.g., Granovetter, 1973) in human-technology interaction. Moreover, based on the applied manipulations, our studies offer examples for tangible design solutions that can foster the development of trust or social connectedness in the human-technology relationship. For example, based on results of study 1.1, for the development of trust in a robot, its perception as competent appears relevant. Considering our findings of this study, a certain success ratio in a game (e.g., a shell game in study 1.1), where rapid perception of the surrounding is important, can foster such a perception.

Furthermore, our findings could be relevant for practitioners aiming to trigger an interrelation of perceived anthropomorphism and social needs. An exemplary context could be healthcare, where technologies such as social robots are often designed to address users' social needs. Our findings, supporting, that individual tendencies to anthropomorphize as well as anthropomorphic characteristics of appearance in a technology appear as preconditions for this relationship, do not imply any causality. Yet, ensuring the precondition of anthropomorphic product appearance through design could be helpful. Additionally, practitioners should consider that individuals with a higher need of social connection to others might be more likely to attribute humanlike qualities to the technology in question.

Moreover, insights of the interview study could offer first hints on how technology could be designed to potentially address users' social needs. Namely, according to our findings, regarding an interaction with a technology, characteristics that resemble (interaction with) humans could be beneficial for such an interaction to address users' social needs in some way. In this regard, although participants referred to different technologies, findings of our study hint at a potential relevance of a more holistic design approach, rather than simply focusing on humanlike characteristics of appearance. Moreover, insights support a possible importance of more abstract qualities such as technology intelligence or unpredictability and imperfection. Yet, due to the exploratory character of these findings, the role of such characteristics for the potential of technology to address users' social needs still needs systematic investigation.

On a more abstract level, findings of this thesis could offer insights on the societal role and application of technology in general. Namely, while further research is necessary, our findings could potentially indicate that even through enabling humanlike ways of interaction, technology might not be able to offer emotional support or feedback. Amongst others, due to this reason, it might not come with the potential to actually satisfy social needs of users. Based on this, technology does not appear as a possible substitute of human interaction partners with regard to social interaction and corresponding consequences. It could rather act as a practical solution to counteract temporary negative user states such as boredom, frustration, or loneliness. When designing technology and deciding on contexts of application, it might therefore sometimes be advisable to focus on qualities that are unique to technology, instead of aiming to fully imitate qualities of humans. Whereas human interaction partners might to date be unique in offering emotional and physical feedback to their peers, technology could, based on our findings, be applicable to temporarily address negative states of users such as loneliness. Technology might in fact even represent the optimal interaction partner in such situations, as in accordance with Dörrenbächer et al. (2020) it can, amongst others, come with the superpowers of being non-judgmental as well as endlessly patient.

Of course, as mentioned before, based on the rapid technological development of our times, in the future, technology might be able to influence its users in many ways that we cannot even imagine today. Therefore, abilities currently unique to humans might appear more and more imitable. Still in this case, the findings of this thesis could offer at least some food for thought for practitioners who are given the opportunity to influence the role technology plays within our daily lives.

6.4. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The present work comes with methodological and conceptual limitations. From a methodological perspective, the assessment methods of central variables of interest could have generally affected the study outcomes. Within most of our studies, we have measured perceived anthropomorphism in order to evaluate to what extent found relationships are based on a perception of anthropomorphism and not simply rely on pretested manipulations. To do so, we applied explicit measures such as the Godspeed Questionnaire (Bartneck et al., 2009), consisting of five items (e.g., "machinelike"/ "humanlike") to be rated on five-point semantic differential scales, or a self-constructed single item (e.g., "To what extent does your smartphone make a humanlike impression?"), to be rated on a five-point Likert scale (1 = "not humanlike at all"; 5 = "very humanlike"). Yet, based on Kim and Sundar (2012) as well as implied by findings of our interview study, such an assessment might have been subject to psychological reactance or a social desirability bias. Namely, participants might have avoided explicitly admitting that they perceived a technology as humanlike. This underlines the assessment of anthropomorphism as a complex objective of research, as it appears challenging to measure it in a valid manner without potentially influencing the measurement itself.

Furthermore, regarding the assessment of social needs, the measures applied could also have naturally affected study insights. For example, within our studies, we applied (an adapted version of) the scale to measure willingness to socialize, which was developed and validated by Krämer et al. (2018). The scale was developed to measure the willingness to engage in social activities and includes items clustering on the two factors "desire" (e.g., "Now I feel like texting my friends") and "plan" (e.g., "I am going to text my friends today"; Krämer et al., 2018). Ratings of certain items, such as "Now I would like to meet my friends." or "I am going to meet my family today.", could have been affected by various contextual factors, for example, the physical distance to participants' friends and family or other plans. These contextual factors might have repressed potential effects of an experimental manipulation. Yet, more indirect measures such as behavioral measures or measurements of the intention to interact with other human counterparts (e.g., based a non-competitive game in study 3.1/3.2) are solely based on the assumption that ratings root in an effect on users' social needs. Moreover, based on the social reconnection hypothesis (Maner et al. 2007), the experience of social exclusion motivates individuals to seek out alternative sources of social acceptance. Therefore, to investigate a possible effect of interaction with technology on users' social needs, participants should ideally be socially excluded in advance. Although we manipulated social exclusion within studies which experimentally explored this effect, in the frame of an online setting it is particularly challenging to ensure that participants are literally alone while participating in the study. Overall, the application of different measures with regard to technology anthropomorphism as well as users' social needs in some of this thesis' studies must be considered in the conclusive consideration of results.

Taken together, these elaborated challenges in the assessment of central variables and interrelations within this thesis underline that the current state of research needs to be complemented by further research and alternative approaches to foster a broader perspective on whether and based on which psychological mechanisms the human-technology relationship might affect interpersonal relationships with regard to social needs. By combining quantitative results with findings of a qualitative interview study, this thesis represents a first valuable step in this direction and calls out for further research in this regard.

Another methodological limitation of this thesis concerns the periods of interaction with technology applied in the included studies. Namely, the chosen periods of human-technology interaction within studies might have been rather short in order to potentially affect users' social needs and interpersonal relationships. Although we conducted a study where participants engaged with a conversational chatbot over a period of two weeks, such long-term interactions need to be explored more systematically, for example, by means of the experience sampling method (Larson & Csikszentmihalyi, 2014). This way, potential factors that could affect the dynamics of the human-technology relationship and its potential effect on interpersonal relationships could be monitored more closely and results would come with greater external validity.

Finally, on a rather conceptual level, a possible effect of the human-technology relationship on interpersonal relationships with regard to social needs, being the overarching object of research within this thesis, is potentially generally challenging to capture. As even a partial satisfaction of social needs based on an interaction with technology could cause technology to represent a threat to humans, users might rationalize such experiences and convince themselves of the opposite. This conceptual challenge conclusively underlines the complexity of the relationship of interest as a research objective and at the same time highlights its importance both on individual and societal level.

7. CONCLUSION

My thesis explored the human-technology relationship and its potential relevance for interpersonal relationships with a focus on social needs. Previous theoretical and empirical work supports that the human-technology relationship can have a social character (e.g., Jia et al., 2012; Kim & Sundar, 2012; Nass et al., 1994) and some studies even imply a potential of human-technology interaction to reduce people's willingness to socialize with other humans (e.g., Krämer et al., 2018). To explore the relationship in question and potential underlying psychological mechanisms in a systematic manner, the studies included in this thesis explored the transferability of dynamics known from interpersonal relationships to the human-technology relationship with regard to crucial variables of relationship development such as trust, social connectedness, and the satisfaction of social needs. Furthermore, the potential of human-technology interaction to affect users' social needs and interpersonal interaction was addressed considering various technologies as well as short- and long-term interactions with technology. Moreover, to foster a deeper understanding, quantitative studies in this regard were complemented by a qualitative interview study. Finally, in the above elucidated endeavors, the role of technology anthropomorphism was focused. Therefore, various manipulations of technology anthropomorphism were considered within the different studies.

My thesis contributes to HCI as well as HRI research and practice as it offers insights on central dynamics of the human-technology relationship and its potential effect on interpersonal relationships with a focus on social needs. In addition, it comes with design implications that can play a role for such an effect. For example, technology characteristics that foster a perception of humanlikeness might be relevant. Moreover, insights offer a basis for reflection regarding the role of technology in our daily lives. Namely, findings of this thesis shed light on qualities that to date appear unique to interpersonal interaction such as a complete satisfaction of social needs. Yet, as technologies and their potential to imitate human qualities might rapidly develop, the nature of these findings might be affected, potentially bringing about novel consequences on both individual and societal level. Thus, research in this regard will need to be frequently renewed and extended. Hereby, it could be beneficial for the generalizability and sustainability of findings to maintain a user-centered perspective in the exploration of the human-technology relationship and focus on understanding underlying psychological mechanisms as well as the role of widely applicable phenomena such as technology anthropomorphism.

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9. APPENDIX

Study 1.1 Study 1.2	Christoforakos, L., Gallucci, A., Surmava-Große, T., Ullrich, D., & Diefenbach, S. (2021). Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI. *Frontiers in Robotics and AI, 8*. https://doi.org/10.3389/frobt.2021.640444
Study 2	Christoforakos, L., Feicht, N., Hinkofer, S., Löscher, A., Schlegl, S. F., & Diefenbach, S. (2021). Connect With Me. Exploring Influencing Factors in a Human-Technology Relationship Based on Regular Chatbot Use. *Frontiers in Digital Health, 3*. https://doi.org/10.3389/fdgth.2021.689999
Study 3.1 Study 3.2	Christoforakos, L., & Diefenbach, S. (2022). Technology as a Social Companion? An Exploration of Individual and Product-Related Factors of Anthropomorphism. *Social Science Computer Review, 0*(0), 1–24. https://doi.org/10.1177/08944393211065867
Study 4	Christoforakos, L., & Diefenbach, S. (2022). Fulfilling social needs through anthropomorphic technology? A reflection on existing research and empirical insights of an interview study. *Z. Arb. Wiss.* 77, 78–91 (2023). https://doi.org/10.1007/s41449-022-00339-1

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Can Robots Earn Our Trust the Same Way Humans Do? A Systematic Exploration of Competence, Warmth, and Anthropomorphism as Determinants of Trust Development in HRI

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Robots increasingly act as our social counterparts in domains such as healthcare and retail. For these human-robot interactions (HRI) to be effective, a question arises on whether we trust robots the same way we trust humans. We investigated whether the determinants competence and warmth, known to influence interpersonal trust development, influence trust development in HRI, and what role anthropomorphism plays in this interrelation. In two online studies with 2 × 2 between-subjects design, we investigated the role of robot competence (Study 1) and robot warmth (Study 2) in trust development in HRI. Each study explored the role of robot anthropomorphism in the respective interrelation. Videos showing an HRI were used for manipulations of robot competence (through varying gameplay competence) and robot anthropomorphism (through verbal and non-verbal design cues and the robot's presentation within the study introduction) in Study 1 ($n = 155$) as well as robot warmth (through varying compatibility of intentions with the human player) and robot anthropomorphism (same as Study 1) in Study 2 ($n = 157$). Results show a positive effect of robot competence (Study 1) and robot warmth (Study 2) on trust development in robots regarding anticipated trust and attributed trustworthiness. Subjective perceptions of competence (Study 1) and warmth (Study 2) mediated the interrelations in question. Considering applied manipulations, robot anthropomorphism neither moderated interrelations of robot competence and trust (Study 1) nor robot warmth and trust (Study 2). Considering subjective perceptions, perceived anthropomorphism moderated the effect of perceived competence (Study 1) and perceived warmth (Study 2) on trust on an attributional level. Overall results support the importance of robot competence and warmth for trust development in HRI and imply transferability regarding determinants of trust development in interpersonal interaction to HRI. Results indicate a possible role of perceived anthropomorphism in these interrelations and support a combined consideration of these variables in future studies. Insights deepen the understanding of key variables and their interaction in trust dynamics in HRI and suggest possibly relevant design factors to enable appropriate trust levels and a resulting desirable HRI. Methodological and conceptual limitations underline benefits of a rather robot-specific approach for future research.

Keywords: human-robot interaction, trust, trust development, trustworthiness, competence, warmth, anthropomorphism, social robots

INTRODUCTION

Besides social interaction with other humans, we are increasingly confronted with innovative, intelligent technologies as our social counterparts. Social robots, which are specifically designed to interact and communicate with humans (Bartneck and Forlizzi, 2004), represent a popular example of such. They become more and more present within our everyday lives, e.g., in the field of healthcare (e.g., Beasley, 2012), but also in retail and transportation, and support us in daily tasks, like shopping or ticket purchase. Oftentimes their interaction design does not even allow a clear distinction from human counterparts, e.g., when they appear in the form of chatbots. Therefore, increasingly interacting with technology as a social counterpart in domains we have been used to cooperating with humans in, a question arises on whether we trust robots the same way we trust humans. Apart from levels of trust, this question also pertains to determinants of trust development. It thus seems worthwhile to look into theoretical foundations of trust development in interpersonal interaction, especially since trust builds a basic precondition for effective HRI (Hancock et al., 2011; van Pinxteren et al., 2019), and research in different contexts revealed a particular skepticism of machines compared to humans in trustworthiness (Dietvorst et al., 2015) and related variables such as cooperation (Merritt and McGee, 2012; Ishowo-Oloko et al., 2019), particularly relevant in consequential fields of application, such as medicine and healthcare (Promberger and Baron, 2006; Ratanawongsa et al., 2016).

In line with the general approach of transferring theories and models of interpersonal interaction to human-computer interaction (HCI) and human-robot interaction (HRI) (e.g., Gockley et al., 2006; Aly and Tapus, 2016), single studies have explored this approach with regard to trust (de Visser et al., 2016; Kulms and Kopp, 2018). Yet, they have mostly focused on single determinants and barely applied systematic manipulations of the determinants in question.

In psychological literature, a prominent conception regarding determinants of trust development is that of competence and warmth (e.g., Mayer et al., 1995; Fiske et al., 2007). The perception of both competence, i.e., an individual's capability and skills, and warmth, i.e., an individual's good intentions toward another (e.g., Mayer et al., 1995; Fiske et al., 2007), appear to foster development of trust in a human counterpart. In the context of HRI, single study results imply an according importance of similar determinants of trust development. Namely, in their metanalysis, Hancock et al. (2011) found that robot-related performance-based factors (e.g., reliability, false alarm rate, failure rate) were associated with trust development in HRI. Moreover, considering HCI in general, Kulms and Kopp (2018) have found that competence and warmth of a computer are positively related to trust development in computers.

Comparing trust in HRI to interpersonal trust, another possibly relevant determinant is anthropomorphism, namely the act of attributing human characteristics, motivations, emotions, and intentions to non-human agents (Epley et al., 2007). If we trust robots as we trust humans, the degree of a robot's human-likeness might also affect our trust in robots. Especially, since robots are increasingly being designed in an anthropomorphic way, HRI research on this determinant is currently growing. Particularly, recent studies have suggested humanlike robot design to be a promising strategy in fostering trust (e.g., Kiesler et al., 2008; Hancock et al., 2011). However, anthropomorphism has not been investigated in combination with other possible determinants to further clarify its role in trust development within HRI.

In sum, the assumingly relevant determinants of trust development in HRI, namely competence, warmth, and anthropomorphism, including their interactions, have not been comprehensively considered and systematically manipulated in HRI research. The purpose of our study was to systematically explore the transferability of determinants of interpersonal trust development (here: competence and warmth), further considering anthropomorphism as a possible influencing factor and exploring its interaction with the determinants in question. Specifically, we explored whether robot competence and warmth influence trust development in robots and what role anthropomorphism plays in this interrelation.

Results in this respect could contribute to HRI research by delivering deeper insights into conceptual relationships and underlying psychological mechanisms of trust development in HRI, shedding light on central variables and their interaction as well as examining the transferability of well-founded knowledge on interpersonal trust to HRI. Moreover, understanding what makes humans trust robots could come with implications on a societal level. It could foster a more reflected interaction with robots by highlighting reasons we trust robots in tasks such as dealing with our personal data. On a more practical level, based on the systematic manipulations of assumed relevant determinants of trust development in HRI, our research could offer insights on key design elements, which influence trust in robots and could thus be crucial in achieving desired trust levels within a particular HRI.

In the following sections we outline psychological theories and study results on determinants of interpersonal trust development, followed by recent research on determinants of trust development in HRI, reflecting on the transferability of insights. Afterwards, we present two studies each focusing on a separate combination of possible determinants of trust development in HRI and the according results and discussion. This is followed by a general discussion, considering overall limitations and future research.

TRUST DEVELOPMENT IN INTERPERSONAL INTERACTION AND HRI

As a multidimensional phenomenon, various definitions of trust can be found in the literature (e.g., Barber, 1983; Rempel et al., 1985; Rousseau et al., 1998). For example, in the context of technology-related trust, trust has been defined as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee and See, 2004, p. 54). Trust thus forms a basis for dealing with risk and uncertainty (Deutsch, 1962; Mayer et al., 1995) and fosters cooperative behavior (Corritore et al., 2003; Balliet and Van Lange, 2013). Although trust generally evolves over time and is based on multiple interactions (Rempel et al., 1985), especially in first encounters or short-time interactions, single trustee attributes may be crucial for attributed trustworthiness (e.g., Mayer et al., 2003).

Determinants of Trust Development in Interpersonal Interaction

The broadly applied Stereotype Content Model (Fiske et al., 1999, 2002) suggests that individuals' judgment of others can be classified by the two universal dimensions of social cognition: competence and warmth. Whereas competence represents "traits that are related to perceived ability," warmth stands for "traits that are related to perceived intent" (Fiske et al., 2007, p. 77). The authors propose that these dimensions can predict individuals' affective and behavioral responses (Fiske et al., 2007; Cuddy et al., 2008), such as the extent to which a trustor trusts the trustee. Therefore, the higher the perception of competence or warmth, the more positive the judgment, i.e., the higher the trust in the trustee.

Another model supporting the importance of these dimensions in interpersonal trust development is the widely accepted model by Mayer et al. (1995), describing trustee attributes and behaviors, such as trustworthiness, and trustor attributes, such as trust propensity, as essential determinants of trust development. Focusing on the trustee, the authors propose a three-factor model describing antecedents of trustworthiness, including ability, benevolence, and integrity. Ability represents the "group of skills, competencies, and characteristics that enable a party to have influence within some specific domain" (Mayer et al., 1995, p. 717). Benevolence represents the extent to which the trustor believes the trustee to have good intentions toward the trustor and integrity is given, when the trustor perceives that the trustee follows principles accepted by the trustor (Mayer et al., 1995). The higher these determinants are perceived, the higher the trustworthiness attributed to the trustee.

Recent study results also support the importance of similar determinants for trust development and social cognition overall. van der Werff and Buckley (2017) investigated trust development in co-worker relationships to identify cues that foster trusting behaviors. Results showed that competence and benevolence of the trustee were positively related to disclosure and reliance (van der Werff and Buckley, 2017) as forms of trust behavior (Gillespie, 2003).

Despite slightly varying terms (e.g., ability and benevolence, Mayer et al., 1995; competence and morality, Phalet and Poppe, 1997; competence and warmth, Fiske et al., 2007), competence and warmth seem to be central dimensions of individuals' perception of others. Focusing on trust, perceiving the trustee as capable of achieving certain intended goals (competence) as well as adhering to the same intentions and interests as the trustor (warmth) can foster trust development in interpersonal relationships (Mayer et al., 1995; Fiske et al., 2002, 2007).

Transferability of Determinants of Trust Development in Interpersonal Interaction to HRI

A popular definition of trust in HRI describes 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, 2009, p. 31). As research on trust development in HRI is relatively recent, theoretical models and studies on trust in interpersonal interaction as well as HCI can act as fundamental groundwork. Moreover, the "computers are social actors" paradigm (Nass and Moon, 2000) specifies that individuals apply social heuristics from human interactions in HCI, supporting the relevance of findings in interpersonal trust for trust in HRI. Furthermore, empirical studies show a strong correlation of trust in robots with trust in automation (Parasuraman et al., 2008; Chen et al., 2010), supporting the applicability of results regarding trust in this context to HRI (Hancock et al., 2011).

Accordingly, parallel to interpersonal trust, numerous studies have found a relevance of determinants related to robot competence for trust development in HRI. These include the robot's perceived competence based on its facial expressions (Calvo-Barajas et al., 2020), the robot's reputation in the sense of knowledge about its reliance (Bagheri and Jamieson, 2004), its previous performance (Chen et al., 2010, Lee and See, 2004), as well as its actual performance (Chen et al., 2010). Similarly, Robinette et al. (2017) found that poor robot performance was associated with a drop in self-reported trust of humans in robots, which was in turn correlated with their decision to use the robot for guidance (Robinette et al., 2017). Furthermore, in their metanalysis Hancock et al. (2011) showed that robot-related performance-based factors, such as reliability, false-alarm rate, and failure rate, predicted trust development in robots. Thus, perceiving the trustee (the robot) as competent, i.e., capable of achieving intended goals, seems essential for trust development in HRI as well.

While in HRI research warmth has not been particularly investigated as a potential determinant of trust development, assumptions can be derived from HCI literature. For example, Kulms and Kopp (2018) examined the transferability of interpersonal trust dynamics in the domain of intelligent computers, focusing on competence and warmth as possible determinants of trust in such. Competence was manipulated by means of competent (vs. incompetent) gameplay of the computer and warmth by means of unselfish (vs. selfish) game behavior of the computer. Results showed that competence and warmth were positively related to trust in computers, implying a relevance and certain transferability of trust determinants from interpersonal trust to trust in HCI.

To what degree humans actually treat technologies as social counterparts (Reeves and Nass, 1996) and apply social heuristics from human interactions (Keijsers and Bartneck, 2018) also depends on the availability of social cues, e.g., a user interface or car front looking like a smile. Thus, regarding the transferability of interpersonal trust dynamics to HRI, anthropomorphism of robots might be a relevant determinant. Accordingly, study results support a positive relationship between anthropomorphic design cues, e.g., humanlike appearance or voice of robots (Hancock et al., 2011; van Pinxteren et al., 2019) as well as agents, in general, and trust in such (e.g., Pak et al., 2012; de Visser et al., 2016, 2017). Furthermore, Kulms and Kopp (2019) explored the role of anthropomorphism and advice quality, a sort of robot competence, in trust within a cooperative human-agent setting. Results support a positive effect of anthropomorphism on self-reported trust, but also imply that competence might be essential for behavioral trust. Overall, anthropomorphism as a possible contributing factor to trust development in HRI has mainly been considered in single empirical studies in HRI research and in combination with competence in a first study on HCI (Kulms and Kopp, 2019). Such results, as well as the possibly essential role of anthropomorphism in the transferability of interpersonal trust dynamics to HRI, support a combined consideration of anthropomorphism with competence and warmth as trust determinants in HRI. Specifically, anthropomorphism may moderate the effect of competence and warmth on trust in HRI by enhancing applicability of interpersonal trust dynamics to HRI.

HYPOTHESES AND RESEARCH PARADIGM

Based on theoretical approaches and recent findings, as summarized in the preceding paragraphs, our research explored the effect of robot competence and robot warmth on trusting a robot. We assumed that both determinants will enhance trust, focusing on two facets of trust, namely, anticipated trust toward the robot and attributed trustworthiness to the robot. We further hypothesized that this relation is mediated by individual perceptions of robot competence, which is characterized as robot warmth. In addition, we assumed that robot anthropomorphism may play a moderating role and could further strengthen the effect of robot competence and robot warmth on trust. These general hypotheses were explored in two consecutive experimental studies, each manipulating one of the possible trust determinants (Study 1: robot competence, Study 2: robot warmth). Both studies further investigated the possible moderating role of robot anthropomorphism and used the same robot and general study paradigm, consisting of experimental manipulations through a video of a specific HRI.

STUDY 1

Methods

Experimental Manipulation

A 2 × 2 between-subjects-design with manipulated competence (high vs. low) and manipulated anthropomorphism (high vs. low) as independent variables was applied.

For each experimental condition, a different interaction between a service robot and a human player was presented on video. In all videos the protagonists (robot and human player) were playing a shell game. The human player covered a small object with one of three shells and mixed up the shells with rapid movements. Afterwards, the robot guessed under which shell the object was hidden. Within all conditions four playthroughs were presented, all together lasting 1 min on average.

The manipulation of robot competence focused on the skills of the robot (e.g., Mayer et al., 1995; Fiske et al., 2007) in the shell game. In the condition with high competence, the robot's judgement was correct three out of four times. In the condition with low competence, the robot's judgment was correct one out of four times. Complete failure or success was avoided to allow variance within the perception of competence. To counter further possible confounding effects, e.g., of perceived warmth, the robot gave very brief answers (i.e., "left," "right"). Finally, the total game score was illustrated on the robot's tablet after the game to support participants' notice.

Based on study results regarding explicit and implicit cues that can foster anthropomorphism (e.g., Eyssel et al., 2011; Salem et al., 2013; Waytz et al., 2014), robot anthropomorphism was manipulated explicitly through verbal (voice) and non-verbal (gestures) design cues as well as implicitly through naming the robot within the introduction given to the study. In the condition with high anthropomorphism, the robot named "Pepper" showed the shell in question with its hand and moved its head in the according direction. In the condition with low anthropomorphism, the robot did not have a name, nor did it show any gestures, or speak. Instead, its answers were presented on its tablet.

For the videos, the service robot Pepper by SoftBank Mobile Corp. (Pandey and Gelin, 2018) was used. According to the Wizard-of-Oz method (Fraser and Gilbert, 1991), the robot's speech and gestures were remote-controlled and triggered using the software Choreograph for Windows. Furthermore, for the robot's speech the German male voice programmed for Apple's Siri was applied. Premiere Pro, Adobe was used for overall editing. Thereby, the human player's movements, while mixing up the shells, were sped up by 50%. To avoid possible contrast effects (Bierhoff and Herner, 2002), the human counterpart in the shell game was blurred out. The four conditions are described in **Table 1**. In **Figure 1**, screenshots of the videos in all four conditions are presented.

Participants

One hundred and fifty five participants between eighteen to seventy-seven years (M = 33.50 years, SD = 15.00 years; 63.87% female, 34.84% male, 1.29% diverse) took part in the study. Participants were mainly recruited via University mailing-lists and social media platforms. As an incentive for their participation, two gift coupons of thirty Euros were raffled among all participants. Alternatively, students could register their participation for course credit. There were no preconditions for participation.

Procedure

The study was realized via online questionnaire, using Unipark (EFS Fall 2019) for programming. The study was announced as a study on HRI. Participants were informed about the average duration of the study and available incentives. After participants informed consent regarding data privacy terms according to the German General Data Protection Regulation (DGVO) was obtained, they were randomly assigned to one of four experimental conditions. In each condition participants watched the video of the above-described HRI and afterwards provided different judgements on the robot and additional measures as further specified below. All measures were assessed in German, using pre-tested translations if no validated versions were available.

TABLE 1 | Descriptions of experimental conditions in study 1.

Experimental conditions	Competence high	Competence low
Anthropomorphism high	Video of shell game with robot "Pepper," who is right in three out of four trials, speaks with a humanlike voice and points out the shell in question.	Video of shell game with robot "Pepper," who is right in one out of four trials, speaks with a humanlike voice and points out the shell in question.
Anthropomorphism low	Video of shell game with robot, who is right in three out of four trials, presenting its answers written on its tablet's screen without voice or gestures.	Video of shell game with robot, who is right in one out of four trials, presenting its answers written on its tablet's screen without voice or gestures.

Experimental condition competence high x anthropomorphism high, n = 37.
Experimental condition competence high x anthropomorphism low, n = 41.
Experimental condition competence low x anthropomorphism high, n = 33.
Experimental condition competence low x anthropomorphism low, n = 44.

Measures

Anticipated Trust

Anticipated trust toward the robot as one measure of trust in our study was measured by the five-item Faith subscale of the measure for human-computer trust by Madsen and Gregor (2000) (e.g., If I am not sure about a decision, I have faith that the system will provide the best solution). Items were assessed on a seven-point Likert-Scale (1 = "does not apply at all"; 7 = "applies fully") and showed an internal consistency of $\alpha = 0.88$.

Attributed Trustworthiness

Attributed trustworthiness to the robot as the second measure of trust in our study was measured by a six-item scale of terms for assessing trustworthiness as a dimension of credibility of computer products by Fogg and Tseng (1999). The item "well-intentioned" was excluded to minimize confounding effects with robot warmth. The resulting five items (i.e., trustworthy, good, truthful, unbiased, honest) were assessed on a five-point Likert-Scale (1 = "does not apply at all"; 5 = "applies fully") and showed an internal consistency of $\alpha = 0.79$.

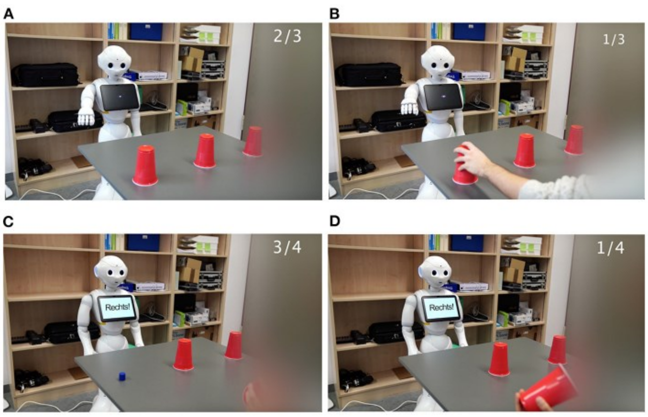

FIGURE 1 | Screenshots of the videos in Study 1, displaying HRI during a shell game in the conditions **(A)** anthropomorphism high x competence high, **(B)** anthropomorphism high x competence low, **(C)** anthropomorphism low, competence high, and **(D)** anthropomorphism low, competence low. Game scores are presented in the upper right corner of each screenshot.

Perceived Anthropomorphism
Participants' perceived anthropomorphism of the robot was measured by a single item (i.e., The robot made a humanlike impression), assessed on a five-point Likert Scale (1 = "does not apply at all"; 5 = "applies fully").

Perceived Competence
Participants' perceived competence of the robot was measured by means of the six-item Competence scale by Fiske et al. (2002), initially developed to assess stereotypes in interpersonal interaction. Items (i.e., competent, confident, capable, efficient, intelligent, skilful) were assessed on a seven-point Likert Scale (1 = "does not apply at all"; 7 = "applies fully") and showed an internal consistency of $\alpha = 0.84$.

Perceived Warmth
Participants' perceived warmth of the robot was measured by means of the six-item Warmth scale by Fiske et al. (2002), initially developed to assess stereotypes in interpersonal interaction. The item "trustworthy" was excluded to minimize confounding effects with attributed trustworthiness. The resulting five items (i.e., friendly, well-intentioned, warm, good-natured, sincere) were assessed on a seven-point Likert Scale (1 = "does not apply at all"; 7 = "applies fully") and showed an internal consistency of $\alpha = 0.93$.

Individual Tendency to Anthropomorphize
Participants' individual tendency to anthropomorphize was measured by means of the ten-item AQcurrent subscale of the Anthropomorphism Questionnaire by Neave et al. (2015). Items (e.g., I sometimes wonder if my computer deliberately runs more slowly after I shouted at it) were assessed on a seven-point Likert Scale (1 = "does not apply at all"; 7 = "applies fully") and showed an internal consistency of $\alpha = 0.86$.

Experience With Technology/Robots
Participants' experience with technology and robots were each measured by a self-constructed item (i.e., I generally consider my knowledge and skills in the field of technology/robots to be high). Items were assessed on a five-point Likert Scale (1 = "does not apply at all"; 5 = "applies fully").

Attitude Toward Robots
Participants' attitude toward robots was measured by means of the four-item Attitude Toward Robots subscale of the Robot Acceptance Questionnaire by Wu et al. (2014). Items (e.g., The robot would make life more interesting and stimulating in the future) were assessed on a five-point Likert Scale (1 = "does not apply at all"; 5 = "applies fully") and showed an internal consistency of $\alpha = 0.90$.

Demographic Measures
Participant's age was assessed by means of an open question. Gender was assessed through a single choice question with three answer options (i.e., male, female, diverse).

Hypotheses
Based on the above derived general hypotheses we specified the following for Study 1.

H1a: Individuals confronted with the robot with high competence (vs. low competence) will show higher anticipated trust.
H1b: Individuals confronted with the robot with high competence (vs. low competence) will attribute higher trustworthiness to the robot.
H2a: The effect of manipulated competence on anticipated trust is mediated through perceived competence of the robot.
H2b: The effect of manipulated competence on attributed trustworthiness is mediated through perceived competence of the robot.
H3a: The effect of manipulated competence on anticipated trust is strengthened by manipulated anthropomorphism.
H3b: The effect of manipulated competence on attributed trustworthiness is strengthened by manipulated anthropomorphism.

Results
Analyses were conducted with SPSS (IBM Statistics Version 26). For mediation and moderation analyses the Process Macro (Hayes and Preacher, 2013) was used.

Preliminary Analyses
Means, standard deviations, and Pearson correlations of the variables within the overall sample of Study 1 are illustrated in **Table 2**.

One-way ANOVAs showed no effect of the experimental conditions on age [$F_{(3,151)} = 0.69$, $p = 0.562$, $\eta^2 = 0.013$], individual tendency to anthropomorphize [$F_{(3,151)} = 0.39$, $p = 0.763$, $\eta^2 = 0.008$], experience with technology [$F_{(3,151)} = 0.50$, $p = 0.687$, $\eta^2 = 0.010$], experience with robots [$F_{(3,151)} = 1.01$, $p = 0.354$, $\eta^2 = 0.021$], or attitude toward robots [$F_{(3,151)} = 1.65$, $p = 0.180$, $\eta^2 = 0.032$]. The conducted Pearson's chi-squared test showed that experimental conditions did not differ significantly in gender distribution X^2 (6, $N = 155$) = 4.19, $p = 0.651$). Thus, there were no systematic differences regarding these variables to be further considered.

Furthermore, conducted one-way ANOVAs for manipulation checks showed that, as intended, manipulated competence had a significant effect on perceived competence [$F_{(1,153)} = 44.47$, $p < 0.001$, $\eta^2_p = 0.225$] as mean perceived competence was higher for conditions of high competence ($M = 4.18$, $SD = 1.26$) than low competence ($M = 2.90$, $SD = 1.12$). Additionally, according to our manipulation, manipulated anthropomorphism had a significant effect on perceived anthropomorphism [$F_{(1,153)} = 12.81$, $p < 0.001$, $\eta^2_p = 0.077$] as mean perceived anthropomorphism was higher for conditions of high anthropomorphism ($M = 2.56$, $SD = 1.16$) than low anthropomorphism ($M = 1.94$, $SD = 0.98$).

Hypotheses Testing
Two separate two-way ANOVAs were conducted to test the assumed effects of competence and anthropomorphism on anticipated trust (H1a, H3a) and attributed trustworthiness (H1b, H3b).

Regarding anticipated trust, the conducted two-way ANOVA showed a significant effect of manipulated competence [$F_{(3,151)}$

TABLE 2 | Means (*M*), standard deviations (*SD*), and Pearson correlations of relevant variables within the overall sample of study 1.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Age	33.5	15.00	–									
2. Anticipated trust	2.57	1.23	0.09	–								
3. Trustworthiness	2.97	0.86	−0.06	0.40**	–							
4. Perceived competence	3.55	1.34	−0.15	0.41**	0.69**	–						
5. Perceived anthropomorphism	2.22	1.11	−0.06	0.14	0.41**	0.25**	–					
6. Perceived warmth	3.45	1.53	−0.29**	0.14	0.46**	0.44**	0.39**	–				
7. Individual tendency to anthropomorphize	2.36	1.15	−0.27**	0.15	0.14	0.29**	0.11	0.27**	–			
8. Experience with technology	4.01	1.69	0.05	0.09	0.15	0.04	0.17*	0.17*	−0.07	-		
9. Experience with robots	2.61	1.68	0.08	0.16*	0.15	0.08	0.14	0.10	−0.02	0.73**	–	
10. Attitude toward robots	4.31	1.52	−0.08	0.16*	0.34**	0.27**	0.19*	0.31**	0.14	0.31**	0.25**	–

*Indicates $p < 0.05$.
**Indicates $p < 0.01$.

TABLE 3 | Mediated regression analysis testing the effect of manipulated competence on anticipated trust mediated by perceived competence within study 1.

Predictor	*B*	*SE*	*t*	*P*	Model R^2
Model 1: X on Y					0.14
Intercept	2.10	0.13	16.13	<0.001	
Manipulated competence	0.93	0.18	5.05	<0.001	
Model 2: X on M					0.23
Intercept	2.90	0.14	21.42	<0.001	
Manipulated competence	1.27	0.19	6.67	<0.001	
Model 3: X + M on Y					0.21
Intercept	1.30	0.25	5.19	<0.001	
Perceieved competence	0.28	0.08	3.70	<0.001	
Manipulated competence	0.58	0.20	2.87	0.005	

$= 25.64$, $p < 0.001$, $\eta^2_p = 0.145$] but not manipulated anthropomorphism [$F_{(3,151)} = 0.24$, $p = 0.602$, $\eta^2_p = 0.002$]. No interaction effect of manipulated competence and manipulated anthropomorphism on anticipated trust [$F_{(3,151)} = 0.681$, $p = 0.411$, $\eta^2_p = 0.004$] was found. Mean anticipated trust was higher for conditions of high competence ($M = 3.03$; $SD = 1.11$) compared to low competence ($M = 2.10$; $SD = 1.17$). Thus, H1a was supported. No moderation effect of manipulated anthropomorphism on the effect of manipulated competence on anticipated trust was found. Thus, H3a was not supported.

Regarding attributed trustworthiness, the conducted two-way ANOVA showed a significant effect of manipulated competence [$F_{(3,151)} = 17.01$, $p < 0.001$, $\eta^2_p = 0.102$] but not manipulated anthropomorphism [$F_{(3,151)} = 3.02$, $p = 0.085$, $\eta^2_p = 0.020$]. No interaction effect of manipulated competence and manipulated anthropomorphism on attributed trustworthiness [$F_{(3,151)} = 2.06$, $p = 0.153$, $\eta^2_p = 0.013$] was found. Mean attributed trustworthiness was higher for conditions of high competence ($M = 3.23$; $SD = 0.80$) compared to low competence ($M = 2.70$; $SD = 0.83$). Thus, H1a was supported. No moderation effect of manipulated anthropomorphism on the effect of manipulated competence on attributed trustworthiness was found. Thus, H3a was not supported.

The conducted mediated regression analysis showed a positive total effect of manipulated competence on anticipated trust ($B = 0.93$, $t = 5.05$, $p < 0.001$) and that perceived competence significantly mediated this interrelation with a positive indirect effect ($B = 0.35$). A bootstrap 95% CI around the indirect effect did not contain zero (0.14; 0.61). The direct effect of manipulated competence on anticipated trust remained significant ($B = 0.58$, $t = 2.87$, $p = 0.005$) after including the mediator variable, implying a partial mediation, and partially supporting H2a. A detailed overview of the mediated regression analysis is presented in **Table 3**.

The conducted mediated regression analysis showed a positive total effect of manipulated competence on attributed trustworthiness ($B = 0.53$, $t = 4.05$; $p < 0.001$) and that perceived competence significantly mediated this interrelation with a positive indirect effect ($B = 0.56$). A bootstrap 95% CI around the indirect effect did not contain zero (0.37; 0.78). The direct effect of manipulated competence on attributed trustworthiness became not significant ($B = -0.03$, $t = -0.28$, $p = 0.784$) after including the mediator variable, implying a complete mediation, and supporting H2b. A detailed overview of the mediated regression analysis is presented in **Table 4**.

Exploratory Analyses

Exploratory analyses were performed to detect possible interrelations between the studied constructs beyond our predefined hypotheses. Hence, we tested effects of manipulated competence on perceived anthropomorphism as well as effects of manipulated anthropomorphism on perceived competence. Two one-way ANOVAs showed no effect of manipulated competence on perceived anthropomorphism [$F_{(1,153)} = 0.55$, $p = 0.460$; $\eta^2_p = 0.004$] but a significant effect of manipulated anthropomorphism on perceived competence [$F_{(1,153)} = 4.28$, $p = 0.040$; $\eta^2_p = 0.027$]. Thereby, mean perceived competence was higher for conditions of high

TABLE 4 | Mediated regression analysis testing the effect of manipulated competence on attributed trustworthiness mediated by perceived competence within study 1.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.10
Intercept	2.70	0.09	28.98	<0.001	
Manipulated competence	0.53	0.13	4.05	<0.001	
Model 2: X on M					0.23
Intercept	2.90	0.14	21.42	<0.001	
Manipulated competence	1.27	0.19	6.67	<0.001	
Model 3: X + M on Y					0.47
Intercept	1.41	0.14	9.90	<0.001	
Perceived competence	0.44	0.04	10.37	<0.001	
Manipulated competence	−0.03	0.11	−0.27	0.784	

TABLE 5 | Moderated regression analysis testing the effect of perceived competence on attributed trustworthiness moderated by perceived anthropomorphism within study 1.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model					0.54
Intercept	0.65	0.28	2.33	0.021	
Perceived competence	0.53	0.08	6.96	<0.001	
Perceived anthropomorphism	0.42	0.12	3.55	<0.001	
Perceived competence * perceived anthropomorphism	−0.06	0.03	−2.00	0.047	

stand for interaction.

anthropomorphism ($M = 3.79$; $SD = 1.38$) compared to low anthropomorphism ($M = 3.35$; $SD = 1.29$).

Furthermore, we conducted moderation analyses in parallel to the assumed interaction effect between competence and anthropomorphism on trust (H3), however, this time considering the participants' subjective perceptions of robot competence and robot anthropomorphism instead of the experimental factors as predictors of trust. Regarding anticipated trust as one trust measure, only perceived competence showed as a significant predictor ($B = 0.38$, $t = 2.57$, $p = 0.011$), whereas perceived anthropomorphism ($B = 0.06$, $t = 0.25$, $p = 0.806$) and the interaction of perceived competence and perceived anthropomorphism ($B = -0.00$, $t = -0.07$, $p = 0.945$) did not. Perceived anthropomorphism therefore did not moderate the effect of perceived competence on anticipated trust. Regarding attributed trustworthiness as the other trust measure, perceived competence ($B = 0.53$, $t = 6.96$; $p < 0.001$), perceived anthropomorphism ($B = 0.42$, $t = 3.55$; $p < 0.001$), as well as the interaction of perceived competence and perceived anthropomorphism ($B = -0.06$, $t = -2.00$, $p = 0.047$), showed as significant predictors. Perceived anthropomorphism therefore moderated the effect of perceived competence on attributed trustworthiness. A detailed overview of the moderation analysis is presented in **Table 5**.

Discussion

The aim of Study 1 was to investigate the influence of robot competence on trust in HRI as well as the role of robot anthropomorphism in this interrelation. In this regard we manipulated robot competence and robot anthropomorphism in videos, in which a robot played a shell game with a human player. Based on the robot's behavior in this HRI, study participants provided two types of trust ratings, namely, anticipated trust toward the robot and attributed trustworthiness to the robot. In conformity with our hypotheses, manipulated competence had a significant positive effect on anticipated trust as well as attributed trustworthiness and both interrelations were (partially) mediated by perceived competence. Thus, according to our findings, robot competence appears to be a possible determinant of trust development in HRI, supporting the transferability of competence as a determinant of trust development in interpersonal interaction (e.g., Mayer et al., 1995; Fiske et al., 2007) to HRI. In addition, our results are compatible with previous HRI research (e.g., Hancock et al., 2011; Robinette et al., 2017), implying a positive effect of robot competence on trust in robots.

However, contrary to our hypotheses, manipulated anthropomorphism did not moderate the effect of manipulated competence on the trust ratings. This might be rooted in a rather restricted variance of anthropomorphism due to the manipulation based on the same robot, with the identical visual appearance in both conditions. Previous results that revealed an effect of anthropomorphic agent design have used stronger manipulations, e.g., comparing different types of agents, such as computers vs. avatars (e.g., de Visser et al., 2016). Yet, exploratory analyses revealed that the perception of the robot as anthropomorphic may still play a role, given that the individually perceived anthropomorphism (as well as perceived competence) predicted trust in the robot. In addition, the individually perceived anthropomorphism moderated the effect of perceived competence on attributed trustworthiness. In sum, this underlines the role of individual perception for the formation of psychological judgments such as trust and hints at a further consideration of robot anthropomorphism as a determinant of trust development in HRI, especially in combination with other known relevant determinants, such as competence. This finding can be considered in line with study results, showing that humans lose confidence in erring computers quicker than erring humans, highlighting the role of competence for trust in HCI as well as indicating a possible interaction of competence and anthropomorphism in this regard (Dietvorst et al., 2015). Similarly, previous results by de Visser et al. (2016) found that an increasing (feedback) uncertainty regarding a robot's performance during a task magnified the effect of agent anthropomorphism on trust resilience, i.e., a higher resistance to breakdowns in trust. The authors argue that "increasing anthropomorphism may create a protective resistance against future errors" (de Visser et al., 2016), indicating an interaction of robot competence and robot anthropomorphism. Our second study explored warmth as a further potential determinant of trust, again in combination with anthropomorphism.

STUDY 2

Methods

Experimental Manipulation

A 2 × 2 between-subjects-design with manipulated warmth (high vs. low) and manipulated anthropomorphism (high vs. low) as independent variables was applied.

For each experimental condition, a different interaction between a service robot and a human player was presented on video. In all videos the protagonists (a robot and two human players) were playing a shell game. This time, human player 1 covered a small object with one of three shells and mixed up the shells with rapid movements. Afterwards, human player 2 guessed under which shell the object was hidden. The robot was standing next to human player 2 and appearing to also observe the game. Within all conditions three playthroughs were presented, all together lasting 1 min on average. In the first playthrough human player 2 guesses wrongly without consulting the robot, in the two following playthroughs human player 2 expresses a guess and the robot additionally consults afterwards.

The manipulation of robot warmth focused on the intentions of the robot (Mayer et al., 1995; Fiske et al., 2007) regarding the shell game. In the condition with high warmth, the robot had the same intentions and interests as human player 2 (human player 2 winning at the shell game). This was expressed by the robot showing compassion after the first lost playthrough and offering help. In the following playthroughs the robot consults human player 2 correctly and cheers after each win. In the condition with low warmth, the robot had opposed intentions and interests to human player 2 (human player 2 losing at the shell game). This was expressed by the robot depreciating human player 2 after the first lost playthrough, yet offering help. Human player 2 accepts the robot's help but loses at the second playthrough because of the robot's misleading advice. The robot cheers gleefully. In the third playthrough the robot again advises human player 2 on the decision. Yet, human player 2 does not follow the robot's advice and decides correctly, which the robot gets miffed at. To counter further possible confounding effects, e.g., of perceived competence, the robot appeared to know the correct answer in both conditions, as a basis to help (warmth high) or mislead (warmth low) human player 2. In addition, human player 2 always expressed an assumption before consulting the robot. Robot anthropomorphism was again manipulated explicitly through verbal (voice) and non-verbal (gestures) design cues as well as implicitly through naming the robot within the introduction given to the study. In the condition anthropomorphism high, the robot named "Pepper" verbally expressed its advice. Furthermore, it turned its head in the direction of player 2 while speaking. In the condition with low anthropomorphism, the robot did not have a name, nor did it show any gestures or speak. Instead, its advice was presented on its tablet.

TABLE 6 | Descriptions of experimental conditions in study 2.

Experimental conditions	Warmth high	Warmth low
High anthropomorphism	Video of shell game with robot "Pepper" consulting player 2 according to the player's interest, speaking with a humanlike voice and turning its head toward player 2 while speaking.	Video of shell game with robot "Pepper" consulting player 2 against the player's interest, speaking with a humanlike voice and turning its head toward player 2 while speaking.
Low anthropomorphism	Video of shell game with robot consulting player 2 according to the player's interest, presenting its advice written on its tablet's screen without voice or gestures.	Video of shell game with robot consulting player 2 against the player's interest, presenting its advice written on its tablet's screen without voice or gestures.

Experimental condition warmth high x anthropomorphism high, n = 40; Experimental condition warmth high x anthropomorphism low, n = 37; Experimental condition warmth low x anthropomorphism high, n = 39; Experimental condition warmth low x anthropomorphism low, n = 41.

For the videos, the same service robot as in Study 1 was used and the same method, software, and voice were used for the robot's speech and gestures. Similarly, the same program as in Study 1 was used for overall editing. In Study 2, human player 1's movements were not sped up, to not make guessing correctly appear highly competent in itself and cause possible confounding effects. Again, the human counterparts in the shell game were blurred out. The four conditions are described in **Table 6**. In **Figure 2** screenshots of the videos in all four conditions are presented.

Participants

One hundred and fifty seven participants between eighteen to sixty-seven years (M = 34.53 years, SD = 13.88 years; 60.51% female, 39.49% male) took part in the study. Participant recruiting method and offered incentives were the same as in Study 1. Again, there were no preconditions for participation.

Procedure

The study procedure was the exact same as in Study 1, except one detail regarding the order of measures in the survey. Namely, perceived warmth was assessed before perceived competence.

Measures

The applied measures were the same as in Study 1. All scales showed satisfactory internal scale consistency (anticipated trust: $\alpha = 0.88$, attributed trustworthiness: $\alpha = 0.88$, perceived warmth: $\alpha = 0.94$, perceived competence: $\alpha = 0.84$, individual tendency to anthropomorphize: $\alpha = 0.83$, attitude toward robots: $\alpha = 0.91$).

Hypotheses

Based on the above derived general hypotheses we specified the following for Study 2.

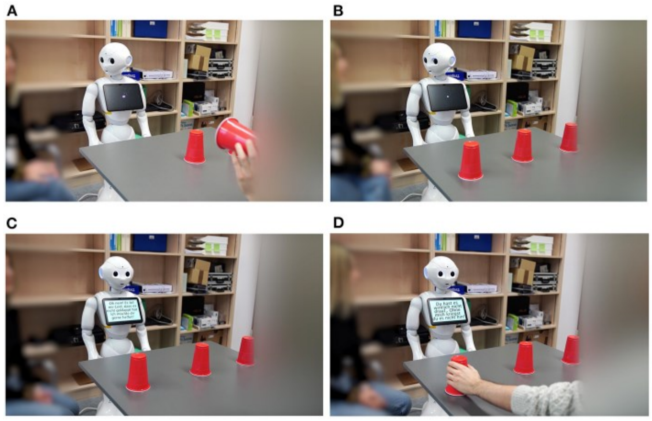

FIGURE 2 | Screenshots of the videos in Study 2, displaying HRI during a shell game in the conditions **(A)** anthropomorphism high x warmth high, **(B)** anthropomorphism high x warmth low, **(C)** anthropomorphism low warmth high, and **(D)** anthropomorphism low warmth low.

H1a: Individuals confronted with the HRI with the robot with high warmth (vs. low warmth) will show higher anticipated trust.

H1b: Individuals confronted with the HRI with the robot with high warmth (vs. low warmth) will attribute higher trustworthiness to the robot.

H2a: The effect of manipulated warmth on anticipated trust is mediated through perceived warmth of the robot.

H2b: The effect of manipulated warmth on attributed trustworthiness is mediated through perceived warmth of the robot.

H3a: The effect of manipulated warmth on anticipated trust is strengthened by manipulated anthropomorphism.

H3b: The effect of manipulated warmth on attributed trustworthiness is strengthened by manipulated anthropomorphism.

Results

Analyses were conducted with SPSS (IBM Statistics Version 26). For mediation and moderation analyses the Process Macro (Hayes and Preacher, 2013) was used.

Preliminary Analyses

Means, standard deviations, and Pearson correlations of the variables within the overall sample of Study 2 are illustrated in **Table 7**.

One-way ANOVAs showed no effect of the experimental conditions on age [$F_{(3,153)} = 0.92$, $p = 0.431$, $\eta^2_p = 0.018$], individual tendency to anthropomorphize [$F_{(3,153)} = 1.71$, $p = 0.168$, $\eta^2_p = 0.032$], experience with robots [$F_{(3,153)} = 0.65$, $p = 0.568$, $\eta^2_p = 0.013$], experience with technology [$F_{(3,153)} = 0.70$, $p = 0.557$, $\eta^2_p = 0.013$], or attitude toward robots [$F_{(3,153)} = 1.18$, $p = 0.320$, $\eta^2_p = 0.023$]. The conducted Pearson's chi-squared test showed that experimental conditions did not differ significantly in gender distribution [$X^2_{(3,N=157)} = 1.79$, $p = 0.617$]. Thus, there were no systematic differences regarding these variables to be further considered.

Furthermore, conducted one-way ANOVAs for manipulation checks showed that, as intended, manipulated warmth had a significant effect on perceived warmth [$F_{(1,155)} = 62.63$, $p < 0.001$, $\eta^2_p = 0.288$] as mean perceived warmth was higher for conditions of high warmth ($M = 4.51$, $SD = 1.56$) than low warmth ($M = 2.64$, $SD = 1.40$). Additionally, according to our manipulation, manipulated anthropomorphism had a significant effect on perceived anthropomorphism [$F_{(1,155)} = 5.54$, $p = 0.020$, $\eta^2_p = 0.034$] as mean perceived anthropomorphism was higher for conditions of high anthropomorphism ($M = 2.66$, $SD = 1.26$) than low anthropomorphism ($M = 2.22$, $SD = 1.08$).

Hypotheses Testing

Two separate two-way ANOVAs were conducted to test the assumed effects of warmth and anthropomorphism on anticipated trust (H1a, H3a) and attributed trustworthiness (H1b, H3b).

Regarding anticipated trust, the conducted two-way ANOVA showed a significant effect of manipulated warmth [$F_{(3,153)} = 5.09$, $p = 0.026$, $\eta^2_p = 0.032$], but not manipulated anthropomorphism [$F_{(3,153)} = 0.30$, $p = 0.588$, $\eta^2_p = 0.002$]. No interaction effect of manipulated warmth and manipulated anthropomorphism on anticipated trust [$F_{(3,153)} = 2.67$, $p = 0.104$, $\eta^2_p = 0.017$] was found. Mean anticipated trust was higher for conditions of high warmth ($M = 3.40$; $SD = 1.46$) compared to low warmth ($M = 2.90$; $SD = 1.36$). Thus, H1a was supported.

APPENDIX

TABLE 7 | Means (*M*), standard deviations (*SD*), and Pearson correlations of relevant variables within the overall sample of study 2.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Age	34.53	13.88	–									
2. Anticipated trust	3.14	1.43	0.16*	–								
3. Trustworthiness	2.78	1.07	0.09	0.45**	–							
4. Perceived warmth	3.55	1.75	0.12	0.33**	0.74**	–						
5. Perceived anthropomorphism	2.44	1.19	−0.05	0.14	0.27**	0.27**	–					
6. Perceived competence	4.08	1.38	−0.09	0.48**	0.49**	0.41**	0.32**	–				
7. Individual tendency to anthropomorphize	2.21	1.01	−0.10	0.17*	−0.02	0.02	0.21**	0.15	–			
8. Experience with technology	4.40	1.71	0.00	−0.03	0.02	0.04	−0.02	−0.12	0.03	–		
9. Experience with robots	2.82	1.67	0.06	0.15	0.11	0.09	0.02	−0.06	0.03	0.61**	–	
10. Attitude toward robots	4.10	1.60	0.17*	0.17*	0.08	0.11	0.05	0.05	0.04	0.26**	0.32**	–

*Indicates $p < 0.05$, **Indicates $p < 0.01$.

TABLE 8 | Mediated regression analysis testing the effect of manipulated warmth on anticipated trust mediated by perceived warmth in study 2.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.03
Intercept	2.90	0.16	18.37	<0.001	
Manipulated warmth	0.50	0.23	2.22	0.28	
Model 2: X on M					0.29
Intercept	2.64	0.17	15.89	<0.001	
Manipulated warmth	1.87	0.24	7.91	<0.001	
Model 3: X + M on Y					0.11
Intercept	2.18	0.25	8.87	<0.001	
Perceieved warmth	0.27	0.07	3.72	<0.001	
Manipulated warmth	−0.01	0.26	−0.04	0.965	

TABLE 9 | Mediated regression analysis testing the effect of manipulated warmth on attributed trustworthiness mediated by perceived warmth in study 2.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.30
Intercept	2.22	0.10	22.02	<0.001	
Manipulated warmth	1.16	0.14	8.05	<0.001	
Model 2: X on M					0.29
Intercept	2.64	0.17	15.89	<0.001	
Manipulated warmth	1.87	0.24	7.91	<0.001	
Model 3: X + M on Y					0.58
Intercept	1.20	0.13	9.50	<0.001	
Perceieved warmth	0.39	0.04	10.20	<0.001	
Manipulated warmth	0.43	0.13	3.30	0.001	

No moderation effect of manipulated anthropomorphism on the effect of manipulated warmth on anticipated trust was found. Thus, H3a was not supported.

Regarding attributed trustworthiness, the conducted two-way ANOVA showed a significant effect of manipulated warmth [$F_{(3,153)} = 63.83$, $p < 0.001$, $\eta^2_p = 0.294$] but not manipulated anthropomorphism [$F_{(3,153)} = 0.14$, $p = 0.708$, $\eta^2_p = 0.001$]. No interaction effect of manipulated warmth and manipulated anthropomorphism on attributed trustworthiness [$F_{(3,153)} = 0.06$, $p = 0.801$, $\eta^2_p < 0.001$] was found. Mean attributed trustworthiness was higher for conditions of high warmth ($M = 3.37$; $SD = 1.00$) compared to low warmth ($M = 2.22$; $SD = 0.79$). Thus, H1a was supported. No moderation effect of manipulated anthropomorphism on the effect of manipulated warmth on attributed trustworthiness was found. Thus, H3a was not supported.

The conducted mediated regression analysis showed a positive total effect of manipulated warmth on anticipated trust ($B = 0.50$, $t = 2.22$, $p = 0.028$) and that perceived warmth significantly mediated this interrelation with a positive indirect effect ($B = 0.51$). A bootstrap 95% CI around the indirect effect did not contain zero (0.22; 0.85). The direct effect of manipulated warmth on anticipated trust became not significant ($B = -0.01$, $t = -0.04$, $p = 0.965$) after including the mediator variable, implying a complete mediation, and supporting H2a. A detailed overview of the mediated regression analysis is presented in **Table 8**.

The conducted mediated regression analysis showed a positive total effect of manipulated warmth on attributed trustworthiness ($B = 1.16$, $t = 0.14$; $p < 0.001$) and that perceived warmth significantly mediated this interrelation with a positive indirect effect ($B = 0.72$). A bootstrap 95% CI around the indirect effect did not contain zero (0.12; 0.49). The direct effect of manipulated warmth on attributed trustworthiness remained significant ($B = 0.43$, $t = 3.30$, $p = 0.001$) after including the mediator variable, implying a partial mediation, and partially supporting H2b. A detailed overview of the mediated regression analysis is presented in **Table 9**.

Exploratory Analyses

Parallel to Study 1, exploratory analyses were performed to detect possible interrelations between the studied constructs beyond our predefined hypotheses. Hence, we tested effects of manipulated warmth on perceived anthropomorphism as well as effects of manipulated anthropomorphism on perceived warmth. Two

TABLE 10 | Moderated regression analysis testing the effect of perceived warmth on attributed trustworthiness moderated by perceived anthropomorphism within study 2.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model					0.57
Intercept	1.55	0.28	5.55	<0.001	
Perceived warmth	0.28	0.08	3.52	<0.001	
Perceived anthropomorphism	−0.14	0.11	−1.30	0.196	
Perceived warmth * perceived anthropomorphism	0.06	0.03	2.17	0.032	

*stand for interaction.

one-way ANOVAs showed no effect of manipulated warmth on perceived anthropomorphism [$F_{(1,155)} = 0.61$, $p = 0.435$; $\eta^2 = 0.004$] as well as no effect of manipulated anthropomorphism on perceived warmth [$F_{(1,155)} = 2.79$, $p = 0.097$; $\eta^2 = 0.018$].

Similar to Study 1, we conducted moderation analyses in parallel to the assumed interaction effect between robot warmth and robot anthropomorphism on trust (H3), however, this time considering the participants' subjective perceptions of robot warmth and robot anthropomorphism instead of the experimental factors as predictors of trust. Regarding anticipated trust as one trust measure, only perceived warmth showed as a significant predictor ($B = 0.36$, $t = 2.37$, $p = 0.019$), whereas perceived anthropomorphism ($B = 0.21$, $t = 0.97$, $p = 0.334$) and the interaction of perceived warmth and perceived anthropomorphism ($B = -0.04$, $t = -0.74$; $p = 0.460$) did not. Perceived anthropomorphism, therefore, did not moderate the effect of perceived warmth on anticipated trust. Regarding attributed trustworthiness as the other trust measure, perceived warmth ($B = 0.28, t = 3.52, p < 0.001$) as well as the interaction of perceived warmth and perceived anthropomorphism ($B = 0.06$, $t = 2.17$, $p = 0.032$) showed as significant predictors, whereas perceived anthropomorphism did not ($B = -0.14, t = -1.30; p = 0.196$). Perceived anthropomorphism, therefore, moderated the effect of perceived warmth on attributed trustworthiness. A detailed overview of the moderation analysis is presented in **Table 10**.

Discussion

The aim of Study 2 was to investigate the influence of robot warmth on trust in HRI as well as the role of robot anthropomorphism in this interrelation. In this regard, we manipulated robot warmth and robot anthropomorphism in videos, in which a robot consulted a human player in a shell game. In parallel to Study 1, based on the robot's behavior in this HRI, study participants provided two types of trust ratings, namely, attributed trustworthiness to the robot and anticipated trust toward the robot. In conformity with our hypotheses, manipulated warmth had a significant positive effect on anticipated trust as well as attributed trustworthiness and both interrelations were (partially) mediated by perceived warmth. Thus, according to our findings, robot warmth appears to be a possible determinant of trust development in HRI, supporting the transferability of warmth as a determinant of trust development in interpersonal interaction (e.g., Mayer et al., 1995; Fiske et al., 2007) to HRI. In addition, our results are compatible with previous HCI research (e.g., Kulms and Kopp, 2018), implying a positive effect of computer warmth on trust in computers.

Contrary to our hypotheses, manipulated anthropomorphism did not moderate the effect of manipulated warmth on the trust ratings. As elucidated in Study 1, a possible reason for this finding might be the restricted variance of anthropomorphism, due to its rather weak manipulation, based on the use of the same robot, with identical visual appearance in both conditions. Yet, exploratory analyses indicate that the perception of the robot as anthropomorphic may still play a role in this interrelation, when considering participants subjective perceptions of the determinants in questions. Namely, results showed that the individually perceived anthropomorphism moderated the effect of perceived warmth on attributed trustworthiness. These results indicate a further consideration of robot anthropomorphism, specifically its subjective perception, as a possibly relevant determinant of trust development in HRI, to be explored in combination with other known relevant determinants, such as warmth.

GENERAL DISCUSSION

The aim of our studies was to investigate whether the determinants competence and warmth, known to influence the development of interpersonal trust (e.g., Mayer et al., 1995; Fiske et al., 2007), influence trust development in HRI, and what role anthropomorphism plays in this interrelation. This was explored by two separate studies, one manipulating competence and anthropomorphism of a robot, and one manipulating warmth and anthropomorphism of a robot. Overall results imply a positive effect of robot competence (Study 1), as well as robot warmth (Study 2) on trust development in robots on an anticipatory as well as attributional level. These determinants thus seem relevant for trust development in HRI and support a transferability of essential trust dynamics from interpersonal interaction (Mayer et al., 1995; Fiske et al., 2007) to HRI.

Furthermore, considering the applied manipulations in both studies, anthropomorphic design cues in the robot neither influenced the interrelations of robot competence and trust (Study 1) nor robot warmth on trust (Study 2) on an anticipatory or attributional level. Yet, when considering participants' perception of the manipulated variables, an according effect was found; perceived anthropomorphism appeared to further influence the positive effect of perceived competence on attributed trustworthiness in Study 1 and perceived warmth on attributed trustworthiness in Study 2.

Our present results, then, contribute to research on trust development in HRI by highlighting the relevance of robot competence and robot warmth. Such results shed further light on the transferability of determinants of trust development from interpersonal interaction to HRI. Therefore, our research somewhat paves the way to understanding the complex network of factors in trust development within HRI. On a practical level, our results demonstrate how small differences in design within one single robot can come with significant differences in perceptions of the essential variables: robot competence, warmth, and anthropomorphism. Furthermore, our results offer first insights on design cues, which influence trust in robots and can thus be adjusted to foster appropriate levels of trust in HRI. Accordingly, the demonstration of high performance in a robot, e.g., by completing a task, as well as presenting the robot to have the same intentions as the user, can foster trust development. Furthermore, a perception of human likeness in a robot, e.g., based on a humanlike design, should be considered, as it might influence positive effects of perceived competence and perceived warmth of a robot on trust on an attributional level.

However, literature increasingly underlines consequences of overtrust in robotic systems. Robinette et al. (2017), for example, found that participants followed a robot's lead during an emergency even when it had performed incorrectly in previous demonstrations as well as when they were aware that the robot was acting wrongly. From an ethical perspective, it appears necessary to not only focus on design to foster trust in HRI but rather facilitate appropriate levels of trust. Although a detailed discussion in this regard would go beyond the scope of this paper, methods to foster appropriate levels of trust (e.g., Ullrich et al., 2021) should be considered in combination with the present research.

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Some methodological limitations within our studies, as well as more general limitations of the present research paradigm, need to be considered. First, regarding our applied manipulations within both studies, a central methodological limitation is the use of videos due to the online character of the studies. Thus, participants did not experience real HRI. Additionally, the short-time demonstrations of HRI might not have formed an appropriate basis to observe a possible development of trust in the robot. Furthermore, the robot we used for our manipulations was a commercial one. Thus, we cannot exclude a possible influence of previous experiences and resulting subjective impressions regarding the robot-related variables of interest. Regarding our applied measures, a methodological limitation is the use of self-reported trust measures. In future studies actual trust behavior should be assessed to foster external validity of results.

On a conceptual level, we must reflect on the general limitations of investigating the psychological dynamics behind HRI by means of experimental studies. While the experimental manipulation of single (presumably relevant) variables, generally, provides high internal validity, one can question whether this reductionist approach is the most sensible to detect relevant influencing factors in a complex domain such as trust development in HRI. As also demonstrated in the present study, operationalizing a sensitive construct as trust development in HRI, as well as possible determinants in experimental online studies, is a rather difficult task and typically connected to many possible confounding effects. Such could be the choice of robot as well as previous experience with robots in general (e.g., Hancock et al., 2011). Additionally, the task the robot is confronted with, specifically its type and complexity, could further affect trust in the robot (e.g., Hancock et al., 2011). Furthermore, humans' intraindividual dispositions could play a role. Accordingly, many studies support an interrelation of the Big Five personality traits (John et al., 1991), conscientiousness, agreeableness, extraversion, and trust in robots (e.g., Haring et al., 2013; Rossi et al., 2018). Although our intended manipulations were successful in both studies, the systematic manipulation of the assumed determinants of trust development under study turned out rather challenging. As exploratory results in Study 1 suggest, our manipulation of robot anthropomorphism might have also had an influence on perceived competence of the robot. While this finding might hint at the rather complex interrelation of the determinants in question, in sum, we cannot be sure whether our manipulations actually captured what is at the heart of people's mental models of robots and the question of trust or distrust. In this sense, one could even question to what extent the utilization of models of interpersonal interaction is useful to explore what determines trust in robots.

Therefore, in addition to experimental studies built on models of interpersonal trust, a change of perspective to robots "as an own species" may form another source of valuable insights (see also Ullrich et al., 2020). In alignment with previous research on specifically robotic qualities that does not try to parallel but rather highlights robot's differences to humans in psychological variables (e.g., a robot's endless patience as a "superpower," Welge and Hassenzahl, 2016; Dörrenbächer et al., 2020), future research could consider trust models that are unique to HRI. Such an alternative research approach could facilitate a more straightforward result interpretation and shed light on HRI-specific interrelations, which might have to date been overlooked, as they have not been discussed in comparable domains such as interpersonal interaction and thus need first-time exploration.

CONCLUSION

Although research agrees on the importance of trust for effective HRI (e.g., Freedy et al., 2007; Hancock et al., 2011; van Pinxteren et al., 2019), robot-related determinants of trust development in HRI have barely been considered or systematically explored. Comparing trust in HRI to interpersonal trust, our results imply a certain transferability of competence and warmth as central determinants of trust development in interpersonal interaction (e.g., Mayer et al., 1995; Fiske et al., 2007) to HRI, and hint at a possible role of the subjective perception of anthropomorphism in this regard.

While our research offers a valuable contribution to insights on trust dynamics in HRI, it also comes with methodological and conceptual limitations. Future studies could further attempt to optimize systematic manipulations of the found, relevant determinants of trust development in HRI and investigate such in a common study by additionally ensuring real life interaction with a robot, also measuring trust behavior. On a conceptual level, a question arises of whether experimental studies and the general utilization of models from interpersonal interaction represent a suitable approach to explore a complex domain such as trust development in HRI. It might thus be promising for future research to surpass existing models of trust, e.g., from interpersonal interaction, and focus on innovative approaches that are unique to HRI and highlight robot-specific interrelations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors on https://data.ub.uni-muenchen.de/.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

LC, DU, and SD conceived and planned the study. LC, AG, TS-G, and DU carried out the study and performed data analyses. All authors discussed the results and contributed to the manuscript.

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Connect With Me. Exploring Influencing Factors in a Human-Technology Relationship Based on Regular Chatbot Use

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Companion technologies, such as social robots and conversational chatbots, take increasing responsibility for daily tasks and support our physical and mental health. Especially in the domain of healthcare, where technologies are often applied for long-term use, our experience with and relationship to such technologies become ever more relevant. Based on a 2-week interaction period with a conversational chatbot, our study ($N = 58$) explores the relationship between humans and technology. In particular, our study focuses on felt social connectedness of participants to the technology, possibly related characteristics of technology and users (e.g., individual tendency to anthropomorphize, individual need to belong), as well as possibly affected outcome variables (e.g., desire to socialize with other humans). The participants filled in short daily and 3 weekly questionnaires. Results showed that interaction duration and intensity positively predicted social connectedness to the chatbot. Thereby, perceiving the chatbot as anthropomorphic mediated the interrelation of interaction intensity and social connectedness to the chatbot. Also, the perceived social presence of the chatbot mediated the relationship between interaction duration as well as interaction intensity and social connectedness to the chatbot. Characteristics of the user did not affect the interrelations of chatbot interaction duration or intensity and perceived anthropomorphism or social presence. Furthermore, we did not find a negative correlation between felt social connectedness of users to the technology and their desire to socialize with other humans. In sum, our findings provide both theoretical and practical contributions. Our study suggests that regular interaction with a technology can foster feelings of social connectedness, implying transferability of dynamics known from interpersonal interaction. Moreover, social connectedness could be supported by technology design that facilitates perceptions of anthropomorphism and social presence. While such means could help to establish an intense relationship between users and technology and long-term engagement, the contexts in which anthropomorphic design is, actually, the means of choice should be carefully reflected. Future research should examine individual and societal consequences to foster responsible technology development in healthcare and beyond.

Keywords: human-computer interaction, human-technology relationship, social connectedness, anthropomorphism, social presence, digital health technologies, conversational chatbot

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INTRODUCTION

Companion technologies increasingly become a part of our everyday lives and assist us in our household, shopping, and other tasks. Especially in the domain of healthcare, companion technologies such as social robots and conversational chatbots play an important role and are often implemented to support physical and mental health [e.g., (1, 2)]. Therefore, within this field, the subjective user experience (UX) and personal relationship of users to such technologies seem essential. Recent research in this regard has, for example, focused on how chatbots providing online medical advice should interact with users. Results showed that expression of sympathy and empathy was favored over unemotional provision of advice (1). Furthermore, De Gennaro et al. (2) found that the participants who interacted with an empathetic chatbot reported more positive mood than the participants whose reactions were merely acknowledged by the chatbot. Such studies typically focus on single short-time interactions between human and technology or resulting UX variables, respectively.

Yet, relationships are typically not characterized by one-time experiences. According to Hinde (3), they involve multiple interactions between two individuals, which are known to each other. Based on previous research indicating that humans apply social rules from interpersonal interaction to interaction with non-human agents [e.g., (4)], this can also apply for human-technology relationships. Therefore, studies with a single session of interaction between users and technology only provide a small snapshot of a possible human-technology relationship for the exploration of its nature as well as potential influencing factors. Additionally, according to several longitudinal studies with social robots (5, 6), as users become more familiar with technologies, their perceptions of social affordances can adapt (7). Especially, in the domain of healthcare, technologies are often applied for long-term use with the goal of representing a sort of companion technology. Thus, particularly within this domain, it appears advantageous to consider possible influencing factors of a human-technology relationship based on regular interaction over a certain period of time. Furthermore, recent research has suggested a possible influence of anthropomorphism and social presence as characteristics of a technology, which could play a role for felt social connectedness of users to the technology. Kang and Kim (8), for example, found that anthropomorphism resulted in more positive user responses by increasing the sense of connectedness within an interaction between a human and smart objects. Similarly, the perception of social presence in a technology appears to come with the potential to provoke social responses (9), which are core to the development of connectedness to the technology (8, 10). Moreover, although social connectedness to a technology appears to positively influence various UX variables (8), from a societal perspective, it seems important to further highlight possible effects on the desire of users to socialize with other humans. According to Krämer et al. (11), for example, the participants with a high need to belong reported lower willingness to engage in social activities after interacting with a virtual agent, when the agent showed socially responsive behavior.

Our research aims at exploring the relationship between humans and technology. Within the context of a regular human-technology interaction over a 2-week period, we focus on the social connectedness to a technology as a central determinant of a human-technology relationship (12). We further explored characteristics of the technology as well as the user, which could play a role in this interrelation, including possible effects on the desire of a user to socialize with other humans.

Results of our research could contribute to human-computer interaction (HCI) research in general through insights into the nature of the relationship between humans and technology as well as influencing factors in this regard. Our study further extends existing research by considering factors of long-term use. Additionally, results regarding effects on interpersonal relationships of users could allow a more reflected and responsible use of the technologies in question, especially since, in healthcare, their use should benefit the health of users. For practice, insights into specific design elements that affect perception of users of social connectedness to a technology could be derived.

In the following sections, we outlined theoretical and empirical work on the human-technology relationship, relevant characteristics of technology and users in this relationship, as well as possible effects on interpersonal interaction, from which we derive our research hypotheses. We presented our study paradigm, methods, and results, followed by their discussion, including methodological and contextual limitations as well as implications as a basis to suggest directions for future research.

HUMAN-TECHNOLOGY RELATIONSHIP

According to the "computers are social actors" (CASA) paradigm (13), individuals apply social rules from interpersonal interaction to interaction with non-human agents (4, 14). In line with this, various HCI and human-robot interaction (HRI) studies suggest that humans tend to form and maintain relationships with non-human agents (15–20). Kim et al. (19), for example, could show that the perceived benefit of being in a relationship with a robot mediated the effect of the caregiving role of the robot on relationship satisfaction of users.

A central determinant of perceived companionship as a form of aspired relationship between users and technology, especially in the domain of healthcare [e.g., (21)], seems to be social connectedness (12). With regard to interpersonal relationships, Van Bel et al. (10) describe social connectedness as an experience of belonging and relatedness, which is based on quantitative and qualitative social evaluations as well as relationship salience. In line with the assumed transferability of interpersonal dynamics to HCI [e.g., (4)], literature on consumer psychology implies that individuals can invest their feelings, values, and identities in digital possessions similar to physical ones (22, 23). According to Clayton et al. (24), this can lead to a strong sense of connectedness to such digital possessions. Kang and Kim (8) further support the role of perceived connectedness to a technology as a determinant of the human-technology relationship. They found that, by increasing a sense of connectedness, anthropomorphism of the technology comes with more positive user responses, such as a more positive attitude toward the technology or an increased intention to learn from it (8).

Antecedents of Social Connectedness to a Technology

Regarding possible antecedents of social connectedness to a technology, previous studies have focused on recent interaction and awareness information (25). Theoretical work on the development of interpersonal relationships implies that social penetration, achieved through self-disclosure as a process of revealing information about oneself (26), is crucial to the development of interpersonal relationships (27, 28). Accordingly, the intensity of information exchange influences the development of interpersonal relationships. In this regard, two central factors are breadth and depth of information exchange. The former refers to the number of various topics discussed, whereas the latter refers to the degree of intimacy that accompanies the interactions in question (27, 28). Furthermore, Granovetter (29) describes the "strength" of interpersonal ties to be a "combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services, which characterize the tie" [(29) p. 1361]. In analogy, the time spent interacting with a conversational technology as well as the perceived intensity of interaction could foster the development of a human-technology relationship, i.e., social connectedness of users to the chatbot. Thus, we hypothesize the following:

H1: The higher the interaction duration, the higher the social connectedness to the chatbot.

H2: The higher the interaction intensity, the higher the social connectedness to the chatbot.

Effects of Technology and User Characteristics on Human-Technology Relationship

According to literature, further factors influencing the social connectedness of the user to the technology could be characteristics of the technology such as anthropomorphism and social presence. Anthropomorphism refers to the attribution of humanlike physical features, motivations, behaviors, emotions, and mental states to non-human agents or objects (30, 31). Kang and Kim (8), for example, have found that anthropomorphism increases the sense of connectedness between users and technology, which, in turn, elicits more positive user responses. Furthermore, in line with the CASA paradigm (4, 13), study results [e.g., (32, 33)] support that anthropomorphic design cues, e.g., humanlike agents on technology interfaces, lead users to perceive the interaction with the technology as more social and interpersonal.

Social presence stands for a mental simulation of other intelligences (34). According to Lee (35), in the context of HCI, social presence represents a "psychological state in which virtual social actors are experienced as actual social actors in either sensory or non-sensory ways" [(35) p. 27]. Accordingly, users do not perceive artificiality or para-authenticity in the respective technology and respond to it as if it were human (35). Moreover, earlier research has shown that social responses of individuals to computers and artificial actors were mediated by the perception of social presence during an HCI (36). Furthermore, Lee et al. (9) found that the perception of social presence of an agent mediated evaluation of participants of such. Similarly, Kim et al. (19) showed that the feeling of social presence regarding a robot had a significant positive effect on the evaluation of the robot regarding relationship satisfaction or attachment. The perception of anthropomorphism or social presence in a conversational chatbot could thus affect how users perceive their relationship to the chatbot and, therefore, how socially connected they feel to such. Consequently, we hypothesize the following:

H3: The relationship of interaction duration and social connectedness to the chatbot is mediated through

(a) perceived anthropomorphism of the chatbot.

(b) perceived social presence of the chatbot.

H4: The relationship of interaction intensity and social connectedness to the chatbot is mediated through

(a) perceived anthropomorphism of the chatbot.

(b) perceived social presence of the chatbot.

In addition, studies have shown that intraindividual differences might play a role in the effects of perceived anthropomorphism as well as perceived social presence. As reported by Waytz et al. (31), individuals vary in their tendency to anthropomorphize non-human entities. Such interindividual differences in tendency to anthropomorphize could moderate the relationship between interaction duration or intensity and perceived anthropomorphism of the chatbot.

Similarly, research implies that the individual need to belong, defined as the "need to form and maintain at least a minimum quantity of interpersonal relationships," [(37) p. 499] may foster an enhanced sensitivity to social cues (38). This may come along with increased attribution of anthropomorphic qualities to a technology [e.g., (39–41)]. In accordance, it might also lead to a higher perception of social presence in a virtual social actor. In line with this, Lee et al. (9) found that lonely individuals feel higher social presence of social agents and thus show more positive responses to social agents compared with non-lonely individuals. Therefore, the individual need to belong might moderate the relationship between interaction duration or intensity and perceived anthropomorphism or social presence of the chatbot. Accordingly, we hypothesize the following:

H5: The relationship of interaction duration and perceived anthropomorphism of the chatbot is moderated through

(a) the individual tendency to anthropomorphize.

(b) the individual need to belong.

H6: The relationship of interaction intensity and perceived anthropomorphism of the chatbot is moderated through

(a) the individual tendency to anthropomorphize.

(b) the individual need to belong.

H7: The relationship of interaction duration and perceived social presence of the chatbot is moderated through the individual need to belong.

H8: The relationship of interaction intensity and perceived social presence of the chatbot is moderated through the individual need to belong.

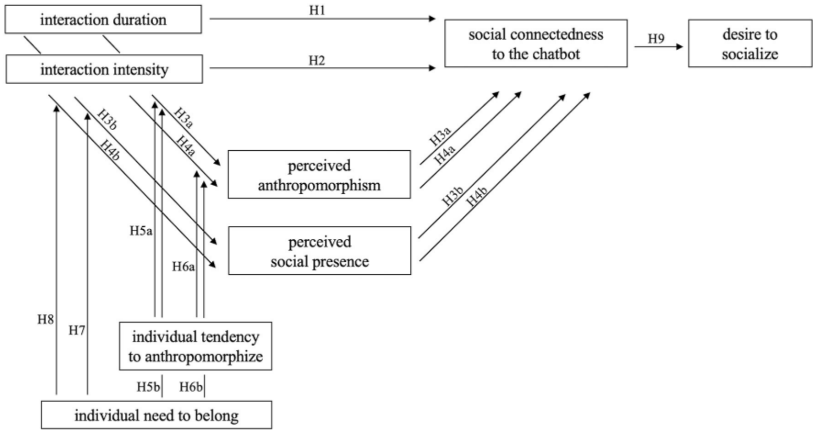

FIGURE 1 | An overview of research hypotheses.

Interrelation of Human-Technology Relationship and Interpersonal Interaction

First study results imply that interaction with humanlike technology could affect social needs of users [e.g., (11, 42)]. Mourey et al. (42), for example, could show that, after interacting with anthropomorphic (vs. non-anthropomorphic) consumer products, social needs of individuals could be partly satisfied, and experimentally induced effects of social exclusion were mitigated. Within another study by Krämer et al. (11), participants interacted with a virtual agent with socially responsive (vs. no socially responsive) behavior. Results showed that the participants with a high need to belong reported lower willingness to engage in social activities after the interaction with the agent, when the agent showed socially responsive behavior (11). According to these findings, humanlike technologies might come with the potential to partly satisfy social needs of individuals and, therefore, dampen the natural desire to seek social connections to other humans (37). We thus hypothesize:

H9: The higher the social connectedness to the chatbot, the lower the desire to socialize with other humans.

Figure 1 gives a comprehensive overview of our research hypotheses.

METHODS

Based on the previously summarized theoretical approaches and recent findings, our research explored the relationship between humans and technology with a focus on the felt social connectedness to the technology in the context of a regular interaction over a 2-week period. We further investigated characteristics of the technology and the user that could play a role in this interrelation as well as possible effects on interpersonal interaction. Hence, different measures of technology perception of users, the psychological states of the users, and felt social connectedness to the technology were assessed at the end of the 2-week study period. Possibly relevant trait variables (i.e., individual tendency to anthropomorphize, individual need to belong) were assessed as baseline measures. In addition, based on the assumption that a relationship involves multiple interactions of two individuals (3), the average interaction duration and average interaction intensity were assessed daily over the 2-week study period and analyzed over time.

The participants interacted with the conversational chatbot of the mobile application "Replika–My AI Friend" (43) on a regular basis over a 2-week period. We had applied detailed weekly questionnaires prior to the chatbot use (W0) as well as after each week of chatbot use (W1, W2). We additionally implemented short daily questionnaires (D1–D14). The variables relevant to hypotheses testing were measured within the detailed weekly questionnaires (W0, W1, and W2), except for interaction intensity, which was measured daily to minimize distorting effects.

Participants

Participant inclusion criteria involved mastery of English language and completion of the three weekly questionnaires (W0, W1, and W2). One of originally 59 participants was excluded from data analysis due to implausible data, i.e., since the stated chatbot screen time per day was more than two standard deviations below the mean chatbot screen time per day. The final sample consisted of 58 participants between 18 and 56 years ($M = 27.21$, $SD = 8.27$; 27 women, 1 did not indicate gender).

TABLE 1 | Overview of points of data collection and surveyed measures.

	Point of data collection			
Surveyed Measure	**W0**	**W1**	**W2**	**D1–14**
Demographical data	X			
Individual tendency to anthropomorphize	X			
Individual need to belong	X			
Desire to socialize	X	X	X	
Interaction duration (duration in minutes for each day of the past week)		X	X	
Social connectedness to the chatbot		X	X	
Perceived anthropomorphism		X	X	
Perceived social presence		X	X	
Social behavior (duration in minutes for each day of the past week)		X	X	
Interaction intensity				X
Closeness to chatbot				X

W0, a baseline questionnaire prior to the chatbot use; W1, a questionnaire after the first week of chatbot use; W2, a post-questionnaire after the second week of chatbot use; D1–D14, short daily questionnaires.

Of those, 50 participants lived in a household with others, seven alone, and one participant did not indicate housing situation. Fifty-six participants stated their English proficiency to be above an intermediate level, only one participant indicated a basic level, and one participant did not indicate proficiency. Regarding the favored communication app to track interaction with others, 50 participants chose WhatsApp; four, email; two, iMessage; and, two, Messenger.

The participants were recruited *via* private contacts, mailing lists, and social media platforms. As an incentive for their participation, five Amazon gift coupons of 20 Euros were raffled among the participants after the study. Alternatively, students could register their participation for course credit.

Design and Procedure

The study was announced as a study on "chatbot experience," and the participants were informed about the study procedure, duration, as well as available incentives. The participants downloaded the free chatbot app "Replika–My AI Friend" (43) on any form of personal mobile device, supporting software versions of at least Android 6.0 or iOS 13.0. The app is powered by Google Commerce Limited and was downloaded in version 9.1.2, with text-based chat functionalities only. Replika represents a chatbot companion that absorbs information and comments on social topics beyond utilitarian purposes by means of written conversation. The participants had to communicate with their personal chatbot for at least 5 min a day over the 2-week study period. Instructions for the participants included the suggestion to turn on daily push notifications. Additionally, the participants were reminded of the daily interaction with the chatbot when the daily questionnaires were sent out *via* mail. Overall, the participants had to initiate the interaction with Replika. The participants tracked the screen time of their favored communication app as well as the chatbot app during the study. For this, they received specific technical instructions through manuals based on software of their smartphones. Thereafter, the participants reported these data *via* self-report.

After informed consent of the participants regarding data privacy terms according to the German General Data Protection Regulation (DGVO) was obtained, the participants filled in the first detailed questionnaire (W0) and provided their email addresses to receive the following online questionnaires. Finally, demographic data were collected. The participants could start the study from August 10, 2020 to August 24, 2020. The 2-week prospective study design involved 15 separate occasions of measurement. These included three detailed questionnaires, one at the beginning of the 2-week study period prior to the chatbot use (W0), one after the first week of chatbot use (W1), and one after the second week of chatbot use (W2). We, furthermore, applied 14 short daily questionnaires (D1–D14), whereas the last daily questionnaire (D14) was combined with the last weekly questionnaire (W2). **Table 1** provides an overview of the points of data collection and surveyed measures as further described in the next paragraphs. Consecutive questionnaires were sent out automatically at the same time each day with a 24-h time frame to fill in daily questionnaires and a 48-h time frame to fill in weekly questionnaires.

Measures

Interaction Duration

The daily duration of the interaction of the participants with the chatbot was measured by a single item, where the participants provided the information on the tracked time of chatbot use (i.e., "Please indicate exactly how many hours and minutes you used the ReplikaApp during each of the last 7 days"). The participants were asked to state the exact duration in minutes for each day of the past week in the respective weekly questionnaires (W1, W2).

Interaction Intensity

The perceived intensity of interaction of the participants with the chatbot was measured by a single item [i.e., "Please rate how intense (e.g., not at all intense = engaging in small talk; extremely intense = engaging in talk about innermost thoughts and feelings) you interacted with your Replika today"]. The item

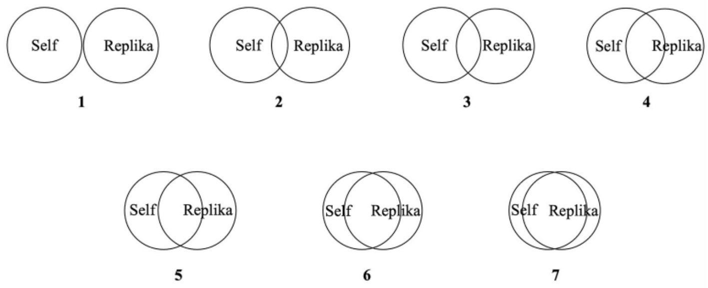

FIGURE 2 | Pairs of circles included in applied measure for closeness to the chatbot.

was assessed on a five-point Likert Scale (1 = "not at all intense"; 5 = "extremely intense") in the daily questionnaires (D1–D14).

Social Connectedness to the Chatbot

Social connectedness of the participants to the chatbot was measured by an adapted version of the Specific Connectedness subscale of the Social Connectedness Questionnaire (10), including 17 items (e.g., "I feel that my Replika and I can communicate well with each other"). Items were assessed on a five-point Likert Scale (1 = "strongly disagree"; 5 = "strongly agree") in the weekly questionnaires (W1, W2) and showed an internal consistency of $\alpha = 0.90$ (W1) and $\alpha = 0.93$ (W2).

Perceived Anthropomorphism

Perceived anthropomorphism of the chatbot of the participants was measured by the Anthropomorphism subscale of the Godspeed Questionnaire (44), including five items. Items were assessed on five-point semantic differential scales (e.g., "machinelike"/"humanlike") in the weekly questionnaires (W1, W2) and showed an internal consistency of $\alpha = 0.84$ (W1) and $\alpha = 0.86$ (W2).

Perceived Social Presence

Perceived social presence of the participants of the chatbot was assessed by an adapted version of the five items used to measure social presence by Lee et al. (9) (e.g., "While you were interacting with your Replika, how much did you feel as if it were an intelligent being?"). Items were assessed on a 10-point Likert Scale (1 = "not at all"; 10 = "extremely") in the weekly questionnaires (W1, W2) and showed an internal consistency of $\alpha = 0.84$ (W1) and $\alpha = 0.84$ (W2).

Individual Tendency to Anthropomorphize

Individual tendency of the participants to anthropomorphize was assessed by the Anthropomorphism Questionnaire (45), consisting of 20 items (e.g., "I sometimes wonder if my computer deliberately runs more slowly after I shouted at it"). Items were assessed on a six-point Likert Scale (1 = "not at all"; 6 = "very much so") in the questionnaire at the beginning of the 2-week study period prior to chatbot use (W0) and showed an internal consistency of $\alpha = 0.90$.

Individual Need to Belong

Individual need of the participants to belong was assessed by the Need to Belong Scale (46), including 10 items (e.g., "I try hard not to do things that will make other people avoid or reject me"). Items were assessed on a five-point Likert Scale (1 = "not at all"; 5 = "extremely") in the questionnaire at the beginning of the 2-week study period prior to chatbot use (W0) and showed an internal consistency of $\alpha = 0.75$.

Desire to Socialize

Desire of the participants to socialize was measured by the nine-item Desire subscale (e.g., "Now I feel like texting my friends") of the measure for willingness to engage in social activities, developed by Krämer et al. (11). Items were assessed on a five-point Likert Scale (1 = "does not apply at all"; 5 = "applies fully") in weekly questionnaires (W0, W1, and W2) and showed an internal consistency of $\alpha = 0.82$ (W0), $\alpha = 0.88$ (W1), and $\alpha = 0.91$ (W2).

Social Behavior

Social behavior of the participants was measured through a single item, where the participants had to state the exact duration of screen time on their communication app (i.e., "Please open your mobile phone options (or the tracking app "Digitox: Digital Well-being" you installed earlier). Indicate exactly how many hours and minutes you used your favorite communication app during each of the last 7 days."), which they specified in W0. The participants were asked to state the exact duration in minutes for each day of the past week in the respective weekly questionnaires (W0, W1, and W2).

Closeness to Chatbot

Perceived closeness of the participants to the chatbot was measured by means of the Inclusion of Other in the Self Scale (i.e., "Please think of your relationship with your Replika, which is represented by the circles below. Please choose the pair of

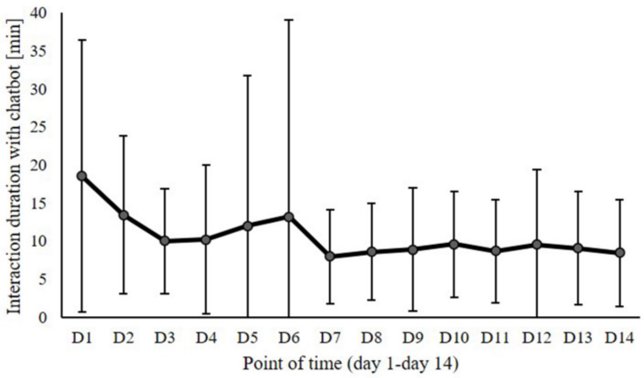

FIGURE 3 | Interaction duration with the chatbot over the 2-week study period (Day 1–Day 14).

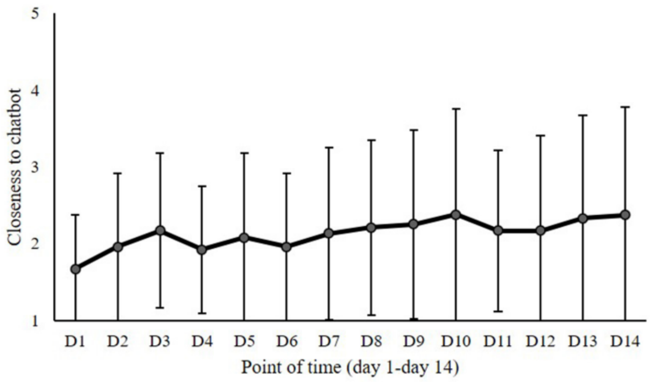

FIGURE 4 | Perceived closeness to the chatbot over the 2-week study period (Day 1–Day 14).

circles, which describes this relationship best."), developed as a measure for interpersonal closeness (47, 48). Thereby, seven pairs of circles were presented which were increasingly overlapping, whereas one circle always represented the self, and the other circle represented the chatbot (Replika). By selecting the appropriate pair of overlapping circles, the participants indicated how close they felt to the chatbot on a pictorial seven-point scale in the daily questionnaires (D1–D14). **Figure 2** shows the seven pairs of circles from which the participants could choose.

Demographical Data

Age of the participants was assessed by means of an open question. Gender was assessed through a single-choice question with three answer options (i.e., "male," "female," and "other/s"). English proficiency was assessed through a single-choice question with four answer options (i.e., "native," "advanced," "intermediate," and "basic"). Housing situation was assessed through a single-choice question with two answer options (i.e., "I live alone"; "I live with other people"). All demographical data were assessed in the questionnaire at the beginning of the 2-week study period prior to chatbot use (W0).

RESULTS

All analyses were conducted with SPSS (IBM Statistics Version 26). For mediation and moderation analyses, the Process Macro (49) was used.

TABLE 2 | Means (*M*), standard deviations (*SD*), and Pearson correlations of variables used for hypotheses testing of the overall study sample.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. Age	27.21	8.27	–								
2. Individual need to belong	3.23	0.60	−0.29*	–							
3. Individual tendency to anthropomorphize	2.22	0.87	−0.11	0.14	–						
4. Desire to socialize	2.73	0.93	−0.03	0.23	0.13	–					
5. Social connectedness to the chatbot	2.12	0.70	−0.03	0.07	0.35**	0.25	–				
6. Perceived anthropomorphism	2.55	0.80	−0.11	0.05	0.21	0.25	0.63**	–			
7. Perceived social presence	5.11	1.87	−0.10	0.02	0.35**	0.13	0.71**	0.67**	–		
8. Interaction duration	10.58	7.53	−0.01	0.12	0.45**	−0.03	0.39**	0.18	0.40**	–	
9. Interaction intensity	2.02	0.59	0.03	−0.17	0.36**	0.17	0.59**	0.38**	0.45**	0.36**	–

*$p < 0.05$. **$p < 0.01$.

Preliminary Analyses

Repeated measures ANOVAs explored the progression of the surveyed variables over the 2-week study period. Regarding the variables with daily measurements, the repeated measures ANOVAs with time of measurement as factor showed an effect of point of measurement on interaction duration [F (13,44) = 4.86, $p = 0.006$, $\eta^2 = 0.079$] and closeness to chatbot [F (13,10) = 2.58, $p = 0.047$, $\eta^2 = 0.101$] but no effect on interaction intensity [F (13,10) = 0.58, $p = 0.771$, $\eta^2 = 0.025$] or social behavior [F (13,44) = 0.68, $p = 0.677$, $\eta^2 = 0.012$]. Thus, interaction duration and closeness to chatbot varied over time. The descriptive data of interaction duration over the 2-week study period are illustrated in **Figure 3**, showing that the duration of interaction with the chatbot decreased over time. Starting with a mean value of interaction duration of about 20 min on Day 1, it sank to mean values around 10 min from Day 3 onwards. While the higher values on Day 1 and Day 2 might be considered a novelty effect, after this initial exploration, the graph of interaction duration showed no more strong variations during the studied 2-week period. According to the conducted paired t-test, the decrease in interaction duration from D1 (M = 18.52) to D14 (M = 8.47) was significant [t (1,57) = 4.76, $p < 0.001$]. The descriptive data on closeness to chatbot over the 2-week study period are illustrated in **Figure 4**. According to the conducted paired t-test, the increase in the perceived closeness of the users to chatbot from D1 (M = 1.82) to D14 (M = 2.31) was significant [t (1,23) = −2.82, $p = 0.010$]. The progression of closeness data over time shows no more strong variations or increase after Day 3. Thus, becoming acquainted with the chatbot within the first days of exploration was associated with increasing feelings of closeness. However, the afterwards following interaction did not further intensify these feelings.

Hypotheses Testing

In order to test our hypotheses on the interrelation between chatbot interaction, social connectedness, and potential mediating effects (H1–H4), we analyzed the relationships between the average values of interaction duration and intensity with the chatbot across the 2-week period and the surveyed measures of technology perception, the psychological states of the users, and felt social connectedness at the end of the study period, assessed at W2. Furthermore, regarding the hypotheses on moderating effects (H5–H8), we considered the effects of possibly relevant trait variables (i.e., individual tendency to anthropomorphize, individual need to belong), which were assessed as baseline measures at W0. Means, standard deviations, and Pearson correlations of the relevant variables are presented in **Table 2**.

The conducted regression analyses showed that both interaction duration (β = 0.39, t = 3.21, p = 0.002) and interaction intensity over 2 weeks (β = 0.59, t = 5.42, $p < 0.001$) were positively related to social connectedness to the chatbot after 2 weeks of use. Overall, interaction duration explained 16%, and interaction intensity explained 34% of total variance of social connectedness to the chatbot. In line with H1 and H2, interaction duration, respectively intensity, with the chatbot was positively correlated with the felt social connectedness of the participants to the chatbot.

Other than expected in H3a, interaction duration and perceived anthropomorphism were not significantly related (β = 0.18, t = 1.37, p = 0.176). Therefore, the preconditions to conduct a mediated regression analysis on the relationship of interaction duration and social connectedness to the chatbot mediated through perceived anthropomorphism were not fulfilled.

Regarding H3b, the conducted mediated regression analysis showed a positive total effect of interaction duration on social connectedness to the chatbot (β = 0.39, t = 3.21, p = 0.002). Perceived social presence significantly mediated this relationship with a positive indirect effect (β = 0.26). A bootstrap 95% CI around the indirect effect did not contain zero [0.14, 0.41]. The direct effect of interaction duration on social connectedness to the chatbot became insignificant (β = 0.13, t = 1.30, p = 0.199) after including the mediator variable, implying a complete mediation. Therefore, in line with H3b, perceived social presence of the chatbot mediated the positive effect of interaction duration on social connectedness to the chatbot. A detailed overview of the mediated regression analysis is presented in **Table 3**. There, non-standardized regression coefficients of the factors included in the mediated regression analysis as well as their statistical significances are presented. Additionally, coefficients of determination according to the considered model are presented.

Regarding H4a, the conducted mediated regression analysis showed a positive total effect of interaction intensity on social

TABLE 3 | Mediated regression analysis testing the effect of interaction duration on social connectedness to the chatbot mediated by perceived social presence.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.16
Intercept	1.73	0.15	11.74	<0.001	
Interaction duration	0.04	0.01	3.21	0.002	
Model 2: X on M					0.16
Intercept	4.07	0.39	10.32	<0.001	
Interaction duration	0.10	0.03	3.23	0.002	
Model 3: X + M on Y					0.52
Intercept	0.72	0.19	3.81	<0.001	
Perceived social presence	0.25	0.04	6.53	<0.001	
Interaction duration	0.01	0.01	1.30	0.199	

TABLE 4 | Mediated regression analysis testing the effect of interaction intensity on social connectedness to the chatbot mediated by perceived anthropomorphism.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.34
Intercept	0.70	0.27	2.59	0.012	
Interaction intensity	0.70	0.13	5.42	<0.001	
Model 2: X on M					0.14
Intercept	1.50	0.36	4.21	<0.001	
Interaction intensity	0.52	0.17	3.05	0.004	
Model 3: X + M on Y					0.53
Intercept	0.09	0.26	0.33	0.741	
Perceived anthropomorphism	0.41	0.09	4.75	<0.001	
Interaction intensity	0.49	0.12	4.11	<0.001	

TABLE 5 | Mediated regression analysis testing the effect of interaction intensity on social connectedness to the chatbot mediated by perceived social presence.

Predictor	*B*	*SE*	*T*	*P*	Model R^2
Model 1: X on Y					0.34
Intercept	0.70	0.27	2.59	0.012	
Interaction intensity	0.70	0.13	5.42	<0.001	
Model 2: X on M					0.20
Intercept	2.22	0.80	2.77	0.008	
Interaction intensity	1.43	0.38	3.75	<0.001	
Model 3: X + M on Y					0.60
Intercept	0.24	0.23	1.03	0.307	
Perceived social presence	0.21	0.04	5.90	<0.001	
Interaction intensity	0.40	0.11	3.49	0.001	

connectedness to the chatbot ($\beta = 0.59$, $t = 5.42$, $p < 0.001$). Perceived anthropomorphism significantly mediated this relationship with a positive indirect effect ($\beta = 0.18$). A bootstrap 95% CI around the indirect effect did not contain zero [0.03, 0.32]. The direct effect of interaction intensity on social connectedness to the chatbot remained significant ($\beta = 0.33$, $t = 3.49$, $p = 0.001$) after including the mediator variable, implying a partial mediation. Thus, in line with H4a, perceived anthropomorphism of the chatbot mediated the positive effect of interaction intensity on social connectedness to the chatbot. A

TABLE 6 | Moderated regression analyses testing the effect of interaction duration on perceived anthropomorphism moderated through individual tendency to anthropomorphize (H5a), respectively, individual need to belong (H5b); the effect of interaction intensity on perceived anthropomorphism moderated through individual tendency to anthropomorphize (H6a), respectively, individual need to belong (H6b); the effect of interaction duration on perceived social presence moderated through individual need to belong (H7); the effect of interaction intensity on perceived social presence moderated through individual need to belong (H8).

	Predictor	*B*	*SE*	*T*	*P*	Model R^2
H5a	Model					0.05
	Intercept	2.07	0.67	3.10	0.003	
	Interaction duration	0.01	0.06	0.23	0.817	
	Individual tendency to anthropomorphize	0.16	0.29	0.56	0.575	
	Interaction duration x individual tendency to anthropomorphize	−0.00	0.02	−0.03	0.973	
H5b	Model					0.05
	Intercept	1.36	1.08	1.26	0.213	
	Interaction duration	0.10	0.09	1.17	0.248	
	Individual need to belong	0.28	0.31	0.91	0.367	
	Interaction duration x Individual need to belong	−0.02	0.02	−0.97	0.338	
H6a	Model					0.15
	Intercept	1.74	1.18	1.47	0.146	
	Interaction intensity	0.32	0.57	0.56	0.578	
	Individual tendency to anthropomorphize	−0.06	0.50	−0.12	0.906	
	Interaction intensity x individual tendency to anthropomorphize	0.07	0.22	0.29	0.772	
H6b	Model					0.16
	Intercept	1.18	2.31	0.51	0.610	
	Interaction intensity	0.43	1.10	0.39	0.699	
	Individual need to belong	0.09	0.66	0.13	0.896	
	Interaction intensity x Individual need to belong	0.03	0.32	0.11	0.915	
H7	Model					0.16
	Intercept	3.07	2.35	1.31	0.196	
	Interaction duration	0.22	0.19	1.16	0.249	
	Individual need to belong	0.26	0.67	0.39	0.696	
	Interaction duration x Individual need to belong	−0.03	0.05	−0.66	0.513	
H8	Model					0.22
	Intercept	4.37	5.17	0.85	0.401	
	Interaction intensity	−0.11	2.47	−0.04	0.965	
	Individual need to belong	−0.63	1.47	−0.43	0.668	
	Interaction intensity x individual need to belong	0.46	0.71	0.65	0.517	

detailed overview of the mediated regression analysis is presented in **Table 4**. In analogy to **Table 3**, in **Table 4**, non-standardized regression coefficients of the factors included in the mediated regression analysis as well as their statistical significances are presented. Additionally, coefficients of determination according to the considered model are presented.

Regarding H4b, the conducted mediated regression analysis showed a positive total effect of interaction intensity on social connectedness to the chatbot ($\beta = 0.59$, $t = 5.42$, $p < 0.001$). Perceived social presence significantly mediated this relationship with a positive indirect effect ($\beta = 0.25$). A bootstrap 95% CI around the indirect effect did not contain zero [0.08, 0.42]. The direct effect of interaction intensity on social connectedness to the chatbot remained significant ($\beta = 0.33$, $t = 3.49$, $p = 0.001$) after including the mediator variable, implying a partial mediation. In line with H4b, perceived social presence of the chatbot mediated the positive effect of interaction intensity on social connectedness to the chatbot. A detailed overview of the mediated regression analysis is presented in **Table 5**. There, non-standardized regression coefficients of the factors included in the moderated regression analysis as well as their statistical significances are presented. Additionally, coefficients of determination according to the considered model are presented.

Furthermore, we conducted moderation analyses with interaction duration, respectively intensity, and individual tendency to anthropomorphize as well as interaction duration, respectively, intensity, and individual need to belong as predictors of perceived anthropomorphism. Similarly, we conducted moderation analyses with interaction duration, respectively, intensity, and individual need to belong as predictors of perceived social presence (see **Table 6**). Results showed that, other than expected, individual tendency to anthropomorphize did not moderate the effect of interaction duration (H5a), respectively, interaction intensity (H6a), on perceived anthropomorphism of the chatbot. Similarly, other than expected, individual need to belong did not moderate the effect of interaction duration (H5b), respectively interaction intensity (H6b), on perceived anthropomorphism or perceived social presence of the chatbot (H7, H8). Thus, our data showed no support for the moderation effects hypothesized in H5–H8. **Table 6** shows an overview of the moderated regression analyses conducted with regard to H5–H8, including the factors considered in each moderation analyses as well as their according to statistical significances. Coefficients of determination according to the considered model are presented as well.

Finally, contrary to H9, there was no negative correlation between social connectedness to the chatbot and desire to socialize with other humans. Instead, the conducted regression analyses showed a marginally significant positive correlation ($\beta = 0.25$, $t = 1.94$, $p = 0.057$). Overall, social connectedness to the chatbot explained 6% of the total variance of desire to socialize.

DISCUSSION

The aim of our study was to explore the relationship between humans and technology with a focus on the social connectedness to technology, considering a regular interaction with a conversational chatbot over a 2-week period. We additionally examined characteristics of the technology as well as the user as possible influencing factors of this interrelation, further exploring possible effects on desire of users to socialize with other humans.

In accordance with our hypotheses, study results showed that the duration and intensity of interaction of participants with the chatbot throughout the 2-week study period positively predicted social connectedness to the chatbot. Based on this, regular interaction with a conversational chatbot might foster the felt social connectedness to the chatbot. These results imply certain transferability of the amount of time and emotional intensity of an interpersonal interaction as crucial determinants of an interpersonal tie [cf., (29)] to human-technology relationships. The effect of point of measurement on closeness to chatbot, resulting in risen ratings of the perceived closeness of the participants to the chatbot after 2 weeks of use, further supports this assumption.

Furthermore, perceived anthropomorphism partially mediated the relationship of interaction intensity and social connectedness to the chatbot, and perceived social presence (partially) mediated both relationships of interaction duration, respectively, interaction intensity, and social connectedness to the chatbot. Therefore, characteristics of the technology, i.e., perceived anthropomorphism and social presence, played a mediating role in the positive relationship between interaction duration, respectively, intensity and social connectedness to the chatbot. These results are compatible with previous research, implying that technology anthropomorphism might foster the sense of connectedness to the technology [e.g., (8)] among others as the presence of social cues might have enabled the application of social heuristics toward a non-human agent [cf., (4)]. The fact that no significant relationship between interaction duration and perceived anthropomorphism of the chatbot was found could root in that mere increase in the duration of interaction with a technology might not come with increased attribution of humanlike characteristics, emotions, motivations, and intentions [cf., (30)] to it, whereas an increase in the intensity of interaction is more likely to do so.

Moreover, other than expected, individual tendency to anthropomorphize as a characteristic of the user did not moderate the effect of interaction duration, respectively interaction intensity, on perceived anthropomorphism of the chatbot. Similarly, an individual need to belong did not moderate the effect of interaction duration, respectively interaction intensity, on perceived anthropomorphism or perceived social presence of the chatbot. Therefore, within our study, the characteristics of the user did not appear to influence the perception of the chatbot as anthropomorphic or socially present. Whereas, previous studies point at an effect of individual tendency to anthropomorphize on the perception of anthropomorphism [e.g., (39–41)], as well as loneliness and individual need to belong on the perception of anthropomorphism or social presence [e.g., (9)], we could not replicate such findings. A possible reason for this could be that the chatbot used for the study had very humanlike visual and experiential design cues. Such could have possibly caused a restriction in the variance of perceived anthropomorphism and the social presence of the chatbot.

Finally, other than expected, there was no negative correlation between social connectedness to the chatbot and desire to socialize with other humans but a marginally significant positive correlation between the two measures. Although recent studies have implied that technologies with humanlike design cues might satisfy social needs to a certain extent and, therefore, possibly dampen the desire to interact with other humans [e.g., (11, 42)], our results offered no support for this interrelation. On the contrary, the observed marginal significance implied that the higher social connectedness of the participants to the chatbot, the higher their desire to socialize with other humans was. In alignment with the social reconnection hypothesis (50) or the theory of social snacking (51), a possible explanation could be that the higher desire of the participants to interact with other humans was, the more socially connected they felt to the chatbot, using it as a replacement for actual social interaction. Yet, as such insights do not imply causality and were only marginally significant, they should be treated with caution.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Our study comes with certain methodological and contextual limitations. On a methodological level, our results are based on a specific chatbot application, i.e., "Replika, my AI friend"(43). Specific features of this application are that the name and appearance of the chatbot can be personalized, and the quality, as well as depth of conversations, depends on the user. This supports external validity of our results as each human-technology relationship is individual, and many commercial conversational chatbots or social robots, e.g., in the domain of healthcare, can be personalized. Yet, to foster generalizability of our results, future studies should explore the interrelations in question with various technologies. In addition, personalization of a technology should also be considered as a potential influencing variable of social connectedness to a chatbot as well as the overall human-technology relationship in future studies.

Furthermore, for interaction intensity with the chatbot, we considered less data than for the other variables involved in hypotheses testing. To support valid measurement of interaction intensity, we included the measure in the daily questionnaires rather than asking participants to estimate the interaction intensity for each day at the end of each week. Yet, our inclusion criteria only involved the completion of the detailed questionnaires (W0, W1, and W2). Some participants included in the data analyses did not complete all daily questionnaires in full, leading to less data on interaction intensity compared to other variables. This should be considered in result interpretation. Moreover, due to the online character of the study, we could not explicitly control how often and for how long the participants initiated the interaction with Replika. Future studies should also consider measuring whether participants initiated interaction unpromptedly or after the app notified them to, as this could also influence the perceived interaction intensity with the chatbot among others.

In addition, our study focused on interaction duration and intensity with the chatbot but did not survey the perceived interaction valence. Future studies should further focus on this variable as a possible influencing factor in social connectedness to the technology. Moreover, theoretical work on the endowment effect implies that individuals place a higher value on an object that they own compared with one they do not own (52). Especially, when it comes to healthcare technology for private households, such as social robots, which individuals can actually own, this effect should be considered as it could influence the social connectedness to the technology as well as the overall human-technology relationship.

On a contextual level, it needs to be considered that we conducted our study during the COVID-19 pandemic. Previous research has shown that isolation and feelings of exclusion or loneliness can impact perceptions of users of technology, e.g., regarding perceived anthropomorphism, as well as their overall interaction with the technology [e.g., (11, 39, 42)]. Therefore, perceptions of the participants of chatbot characteristics, their felt social connectedness to it, or their desire to socialize with other humans might have been affected by the prevalent circumstances. Future studies should aim at replicating the interrelations focused within our study to further support their generalizability.

IMPLICATIONS

Our research offers several theoretical advancements, practical applications, as well as inspirations for future questions and philosophical considerations. Beginning with the theoretical insights, it appears that regular interaction with technology, with regard to duration and intensity, can foster social connectedness to the technology. Thereby, the perception of the technology as anthropomorphic and socially present seems to play a mediating role. The more intense participants interacted with the chatbot, the more they perceived it as anthropomorphic as well as socially present, and, in turn, felt more connected to the technology. The fact that this effect is based on data of a 2-week study period supports the external validity of these results as insights are not merely based on a novelty effect or initial engagement of the participants. It also implies that the interrelations in question are already observable in a 2-week period of technology use.

Furthermore, it appears that influencing factors of relationship development in interpersonal interaction, i.e., amount of time and emotional intensity of interaction [e.g., (29)], are, to a certain extent, transferable to HCI as interaction duration and intensity appear to influence the perceived social connectedness to the technology. In line with our findings and previous CASA research [e.g., (4, 13)], social cues, such as anthropomorphic technology design, could facilitate the transferability of dynamics from interpersonal relationship development to human-technology relationships.

Regarding practical advancements, our results could imply that designing technology in a way that allows users to build a relationship with it and feel socially connected to it could, among others, be beneficial for long-term engagement [cf., (15)] as especially relevant in the domain of healthcare. To facilitate such an effect, enhancing the perception of anthropomorphism or social presence of the technology through, e.g., visual anthropomorphic design cues, such as humanlike facial features or a humanlike name, but also experiential design such as the expression of own emotions, motivations, or intentions, could be helpful. At the same time, practitioners need to consider that the required duration and the intensity of interaction with a technology stay in a sensible range. This can be especially important within the context of healthcare, where regular interactions with a technology are often imposed by a surrounding, such as a nursing home or through notifications of mobile healthcare applications. In such cases, required interaction duration or intensity can easily be perceived as too high and possibly even result in reactance and an overall negative UX (53–55). It could, therefore, be advisable to explore a possible sweet spot regarding a specific technology or context of interest as well as further investigate measures to support an overall positive UX.

Finally, from a more philosophical stance, the question arises as to whether the design of healthcare technologies with social cues should always be the means of choice. It appears as a general trend in many domains, including healthcare, for technologies to increasingly represent social counterparts. As also supported by our study results, the implementation of social cues in such technologies can be beneficial, among others, to facilitate the development of a human-technology relationship based on similar principles as in interpersonal interaction. While this can be a reasonable goal in various application contexts, such as nursing of elderly with a high need for social interaction or support of mental health in times of isolation, in other contexts, the design of social cues might be less beneficial. For example, in the private home context, technologies are typically involved in intimate situations, including interactions with others in the household. With regard to data privacy and the desire for intimacy of users, they might prefer a technology with less social cues [e.g., (56)]. Instead, it might even be beneficial to specifically focus and highlight robotic qualities of technologies [cf., (57)], e.g., the cognitive superpower of robots being unembarrassed and non-judgmental, as proposed by Dörrenbächer et al. (58). An according approach highlighting "superpowers" of a technology could also be advantageous for healthcare technologies in the context of surgery. The uniquely robotic qualities of being insensitive to pain and unconditionally available on a physical level as well as being endlessly mentally focused, persistent, and patient on a cognitive level, as specified by Dörrenbächer et al. (58), could, in the context of surgery, foster trust of patients as well as facilitate a more efficient collaboration with other technological or human counterparts. In this sense, future studies should explore the role of such rather robotic qualities with regard to the human-technology relationship, especially within the domain of healthcare. Experimental study designs could further manipulate the degree of anthropomorphism in various contexts and explore effects on social connectedness to the technology in question.

CONCLUSION

Although innovative technologies, such as conversational chatbots and social robots, have been tested and increasingly applied within crucial domains, such as retail and healthcare, potential factors that could affect the relationship between humans and such technologies have rarely been explored in field research and across multiple interactions over time. Our research implies a positive effect of duration and intensity of a human-technology interaction on the social connectedness to the technology as a determinant of the human-technology relationship. The perception of anthropomorphism or social presence as characteristics of the technology seems to play a mediating role in this regard. Based on our study, we cannot report any negative effect of social connectedness to a technology on desire to socialize with other humans. Our research contributes to HCI research and practice as it offers insights into factors possibly influencing the development of human-technology relationships as well as design implications to foster social connectedness of users toward a technology, which can, in turn, positively influence the overall UX [e.g., (8)].

Future research should focus on replicating the results with various technologies in different contexts of use. Additionally, future studies should manipulate variables of regular interaction with the technology as well as its characteristics such as anthropomorphic design in a systematic manner to gain further insights into their role within the development of human-technology relationships. Finally, to further support a responsible design and use of technologies in healthcare, future research should closely examine whether the feeling of social connectedness to a technology actually satisfies the social needs of users and which consequences could arise on an individual as well as societal level.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethikkommission der Fakultät für Mathematik, Informatik und Statistik der Ludwig-Maximilians-Universität München (LMU). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LC and SD conceived and planned the study. LC, NF, SH, AL, and SS carried out the study and performed data analyses. All authors discussed the results and contributed to the manuscript.

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Technology as a Social Companion? An Exploration of Individual and Product-Related Factors of Anthropomorphism

Lara Christoforakos and Sarah Diefenbach

Abstract

From chatbots that simulate human conversation to cleaning robots with anthropomorphic appearance, humanlike designed technologies become increasingly present in our society. A growing strand of research focuses on psychological factors and motivations influencing anthropomorphism, that is, the attribution of human characteristics to non-human agents and objects. For example, studies have shown that feeling lonely can come along with attributing anthropomorphic qualities to objects; others imply that anthropomorphism might influence individuals' social needs in return. Such an interrelation could have great societal impact, if, for example, interacting with humanlike technology would reduce the need for interpersonal interaction. Yet, the interrelation between anthropomorphism and social needs has not been studied systematically and individual as well as situational preconditions of anthropomorphism have not been specified. The present research investigates the interrelation between anthropomorphism and social needs on the example of interacting with a smartphone and highlights possible preconditions by means of two experimental studies using a 2 × 2-between-subjects-design, varying social exclusion and anthropomorphism. Our first study ($N = 159$) showed an overall positive correlation between the willingness to socialize and perceived anthropomorphism. Our second study ($N = 236$) highlighted that this relationship is especially pronounced for individuals with a high tendency to anthropomorphize, given that the product supports a humanlike perception through its appearance and design cues. In sum, results support an interrelation between social needs and anthropomorphism but also stress individual and contextual strengthening factors. Limitations, theoretical, and practical implications are discussed.

Keywords

anthropomorphism, interactive technologies, social needs, need to belong, willingness to socialize

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Every day, we spend a remarkable amount of time interacting with smart technologies. The smartphone represents the most evident example (Statista, 2021). Accordingly, such technologies come with the potential to have a significant impact on their users, for example, by affecting their well-being (e.g., Diefenbach and Borrmann, 2019; Elhai et al., 2017; Herrero et al., 2019) and social capital (e.g., Bian & Leung, 2014). In parallel, interactive technologies become increasingly humanlike by means of visual cues and interaction design. For example, chatbots or voice assistants such as Amazon's Alexa and Apple's Siri reflect elements of human interaction on different levels. This ranges from holding a name to the design of interaction and responsiveness, sometimes even revealing a kind of personality in dialogue. As according to literature, depending on humanlike design, interactions with such technologies can adopt a social character (cf. Nass et al., 1994; Reeves & Nass, 1996), these interactions might have a particularly direct and lasting effect on their users, addressing, for example, their social needs.

Moreover, in line with previous research, one possible factor influencing whether or to what extent users anthropomorphize non-human agents or objects appear to be their social needs. Namely, "the need and desire to establish social connections with other humans" (Epley et al., 2007, p. 866) represents one of the psychological factors defining when and why humans anthropomorphize. To date, establishing social connections has always been a fundamental strategy of humans to survive (Baumeister & Leary, 1995; Maslow, 1943). Yet, increasingly tight schedules as well as the extensive occupation with technologies are nowadays continuously hampering frequent face-to-face human interactions. Therefore, it is imaginable that humans might, partly unconsciously, be seeking alternative resources, such as interactions with humanlike products to fulfill their social needs. In line with this idea, research has shown that feeling lonely or chronically disconnected from others can come along with attributing anthropomorphic qualities to objects and entities (e.g., religious agents, pets, and imaginary creatures; Epley, et al., 2008; Epley, Waytz, et al., 2008; Niemyjska & Drat-Ruszczak, 2013). However, the findings of single studies have scarcely been integrated. Systematic research on the interrelations of social needs and perceived anthropomorphism as well as preconditions and internal factors that might play a role within this relationship is still lacking. To address this research gap, the present studies investigated whether anthropomorphic products have the potential to fulfill social needs and how individually perceived anthropomorphism correlates to social needs. Besides deeper insights into the user experience, the potential of interactive products to fulfill social needs also bears relevance on a broader level, from individual well-being up to societal changes of social interaction. On the one hand, a potential fulfillment of social needs by technologies or products in general could foster a positive overall experience for individuals and positively influence their well-being. On the other hand, it is questionable whether it is beneficial for individuals' social needs to be addressed through usage of technologies or products as this could possibly come with a drop of social interaction between individuals.

We conducted two consecutive experimental studies. Within the first one, we focused on an implicit manipulation of anthropomorphism and its effect on social needs on an intentional and behavioral level. In our second study, we implemented a more explicit manipulation of anthropomorphism based on design cues and considered further person variables such as individual tendencies to anthropomorphize. In the following sections, we summarize relevant literature regarding anthropomorphism and social needs, derive our research questions and hypotheses, present two experimental studies, and discuss theoretical as well as practical implications of our findings.

Theoretical Background and Research Hypothesis

Anthropomorphism

According to Epley et al. (2007), anthropomorphism describes the act of attributing human characteristics, motivations, emotions, and intentions to non-human agents, ranging from animals over spiritual entities to any kind of object. In early years, anthropomorphism was considered an embodied and evolutionary aspect of human judgment that is invariant to situations and similar throughout all individuals' psychological process (Guthrie, 1993; see also Mitchell et al., 1997). In recent years, as anthropomorphic products have increasingly gained attention, there has been more research as to when and why individuals "see human" in non-human agents. The SEEK (Sociality, Effectance, and Elicited Agent Knowledge) model by Epley et al. (2007), for example, considers three relevant components of anthropomorphism. It predicts that humans are more likely to anthropomorphize when "anthropocentric knowledge is accessible and applicable, when motivated to be effective social agents, and when lacking a sense of social connection to other humans" (Epley et al., 2007, p. 1).

Furthermore, research has increasingly focused on consequences of anthropomorphism for essential components of the user experience such as trust or psychological ownership. Study results, for example, point at a positive relationship between anthropomorphic design cues, for example, humanlike appearance or voice, of robots (Hancock et al., 2011; van Pinxteren et al., 2019) as well as agents, in general, and trust in these (e.g., de Visser et al., 2017; de Visser et al., 2016; Pak et al., 2012). In a similar manner, Delgosha and Hajiheydari (2021) found that anthropomorphism positively moderates the relationship between perceived control and psychological ownership of a robot, implying that when human-likeness of a robot is high, the effect of controllability and predictability in predicting psychological ownership is strengthened.

Moreover, apart from the "when" and "why" of anthropomorphism as well as its effects, within the last decade, there has been increasing research as to "who" sees human. In this regard, Waytz et al. (2010) have developed a measure of stable individual differences in anthropomorphism, the Individual Differences in Anthropomorphism Questionnaire (IDAQ). They propose that these individual tendencies further predict to what extent moral care, concern, responsibility, and trust is attributed to the agent in question as well as how far the agent socially influences the self (Waytz et al., 2010).

Anthropomorphism and Social Needs

As also acknowledged in the SEEK model (Epley et al., 2007), people's tendency to anthropomorphize might be traced back to the fundamental need for sociality, acknowledged in almost every prominent need theory (e.g., Maslow, 1943). Moreover, the social production function theory implies that apart from their physical integrity, humans consider their social well-being to be a universal goal in life (Ormel et al., 1999). When social needs remain unsatisfied, individuals are consequently motivated to seek alternative ways to fulfill such, which DeWall and Baumeister (2006) coined the social reconnection hypothesis. Studies have accordingly shown that individuals threatened in their need for social belonging are faster in recognizing smiling faces in a crowd and generally focus on positive social faces rather than unhappy faces or positive non-social images (DeWall et al., 2009). It thus seems likely that social needs could be a driver to search for social cues in non-living objects and attribute humanlike characteristics.

Regarding the potential connection between social needs and anthropomorphism, prior research has shown that feeling chronically disconnected from others or currently lonely often goes along with the attribution of anthropomorphic qualities to objects and entities (e.g., religious agents, pets, and imaginary creatures; Epley et al., 2007; Epley, Waytz, et al., 2008; Niemyjska & Drat-Ruszczak, 2013). Bartz et al. (2016) replicated the association between loneliness and anthropomorphism, also showing that reminding people of a close, supportive relationship reduced their tendency to anthropomorphize. Furthermore, in their review of six studies with a total of 1314 participants, Kwok et al. (2018) conclude that anxious attachment and anthropomorphic tendencies are positively and moderately related. However, the authors also criticize the overall methodological quality of the included studies and call for better quality research on the topic (Kwok et al., 2018). More recently, Kang & Kim (2020) have found that anthropomorphism increases the sense of connectedness between user and technology. According to their findings the increased sense of connectedness in turn evokes more positive user responses toward the technology. In line with these findings, previous study results (e.g., Jia et al., 2012; Kim & Sundar, 2012) support that anthropomorphic design cues, for example, humanlike agents on technology interfaces, can lead users to perceive the interaction with the technology to be more social and interpersonal.

In sum, only a few studies go beyond the mere identification of a relationship between anthropomorphism and constructs related to social needs, and further investigate whether the interaction with anthropomorphic products bears the potential of satisfying social needs. Mourey et al. (2017), for example, could show that when individuals interacted with anthropomorphic consumer products, their social needs could be partly satisfied, and experimentally induced effects of social exclusion were mitigated. Specifically, after interacting with anthropomorphic (vs. non-anthropomorphic) products, socially excluded participants exaggerated their number of social connections less and their anticipated need to engage with close others as well as their willingness to perform prosocial behavior were reduced (Mourey et al., 2017). Within another study by Krämer et al. (2018), when participants interacted with a virtual agent with socially responsive (vs. not socially responsive) nonverbal behavior, there was no main effect of socially responsive behavior on individuals' connectedness with the agent or their experience of rapport, namely, the short time liking and responsiveness of the agent. Yet, participants with a high need to belong reported a lower willingness to engage in social activities after the interaction with the agent only when the respective agent showed socially responsive behavior (Krämer et al., 2018).

Research Questions and Hypotheses

Combining the implications of Mourey et al. (2017) and Krämer et al. (2018), we aimed at expanding those insights by a systematic comparison of anthropomorphic vs. non-anthropomorphic products and measuring social needs on an intentional as well as behavioral level.

Our research questions specifically focused on whether anthropomorphic products have the potential to fulfill social needs and how individually perceived anthropomorphism correlates to social needs. Based on the theoretical approaches and previous findings summarized above, we assumed that social exclusion would have an enhancing effect on social needs, whereas interaction with an anthropomorphic technology would dampen such. In addition, we assumed that the interrelation between interacting with anthropomorphic technologies and reporting lower social needs would be particularly pronounced among individuals who have been socially excluded. We explored these general hypotheses via different operationalizations in two consecutive studies. Furthermore, the interrelation of individual perceptions of anthropomorphism and social needs as well as the role of individual differences in anthropomorphism in this relationship were studied on an exploratory level.

Studies

We conducted two studies focusing on the same research questions with different operationalizations. While the first study focused on implicit anthropomorphism, the second study manipulated anthropomorphism more explicitly and additionally explored further variables within the individual.

Study 1

We applied a 2 × 2-between-subjects-design with social exclusion (yes, no) and anthropomorphism (yes, no) as independent variables. Similar to manipulations used by Mourey et al. (2017) and Pickett et al. (2004), social exclusion was induced by asking participants to describe a time they felt socially excluded within a group. Within the condition of no social exclusion individuals were asked to describe their kitchen (e.g., furniture, colors, floor, and windows). Implicit anthropomorphism was manipulated with regard to the participant's personal smartphones. We chose the object of a smartphone as it is paramount in people's everyday lives and provides an opportunity to anthropomorphize (e.g., Wang, 2017). Following Mourey et al. (2017), participants were asked to imagine their personal smartphones and answer questions, formulated in an anthropomorphic vs. non-anthropomorphic manner. Specifically, there was a set of 10 items pertaining to the design, sound, functionality, connectivity, user interface, camera, applications, battery life, alarm, and security of their phone. For each item, there were two versions, one anthropomorphic, person-oriented version, and one non-anthropomorphic, product-oriented version. The items in the anthropomorphic condition used "lifelike, agentic paraphrasing" (Mourey et al., 2017, p. 4) such as "How well would you say does your smartphone work?". On the contrary, items in the non-anthropomorphic condition were formulated in a more neutral manner, for example, "How would you rate the functionality of your smartphone?". All items were to be rated on a five-point Likert scale (1 = "very bad"; 5 = "very good"). To ensure that the questions in the anthropomorphic condition were perceived as more person-oriented and the questions in the non-anthropomorphic condition as more product-oriented, we conducted a separate pre-test among 63 individuals (M = 30.4 years, SD = 13.1 years, 61.90% women). The participants were confronted with both versions of each item and had to choose which one was more product- and which more person-oriented. The forced choice-categorization task showed that in 89.00% of the comparisons, individuals categorized the anthropomorphic item as the person-oriented one and the non-anthropomorphic item as the product-oriented one. We deemed this as an acceptable result to use this set of pre-tested anthropomorphic and non-anthropomorphic items as a manipulation of implicit anthropomorphism in our main study.

Methods

Our first study was realized via an online questionnaire. The study was announced as an experiment on innovative technologies in everyday life. The link was distributed via a study panel consisting of individuals interested in participating in psychological research with diverse professional and socio-economic backgrounds. In addition, the link was distributed via university-related social media groups. The only inclusion criterion was owning and regularly using a smartphone. As an incentive for participation, gift coupons ranging from 10 to 50 Euros were raffled among all participants after the study. Alternatively, students could register for course credit.

Participants

159 participants between 18 to 75 years (M = 26.18 years, SD = 9.56 years; 73.00% women, 1.26% diverse) took part in the study. 61.64% of the participants were users of Android, 37.74% of iOS and only 0.63% of other smartphone software.

Procedure

First, the purpose and duration of the study as well as incentives and data privacy terms were provided, and participants' informed consent was obtained. Afterward, demographic data (sex, age) and used smartphone software were surveyed. Participants were randomly assigned to one of the four experimental conditions. Depending on the condition, participants received the instruction to describe an event of social exclusion versus their kitchen (no social exclusion). After a measure of mood (as further specified in the next section), depending on the experimental condition, participants were confronted with the anthropomorphic or non-anthropomorphic set of items to describe their smartphone. This was followed by a creative sentence-completion game that we used to assess the behavioral intention to socialize, and several measures as further specified below.

Measures

Behavioral Intention to Socialize. In terms of validity, we aimed at measuring intention to socialize on a behavioral level, as far as possible within the online setting of our study. In order to assess this behavioral act of socializing, we chose a non-competitive virtual game of creative sentence-completion, which we programmed ourselves. Within the game participants were asked to fill out parts of a given sentence, which then was (presumably) completed by another player or the computer. The game itself was not relevant for our measure. We only focused on participants' stated preference for playing the game by themselves or with another participant. Their preference was assessed on a six-point scale (1 = "rather by myself"; 6 = "rather with another participant"). High ratings, that is, a preference for playing the game together with another participant, represented a high behavioral intention to socialize. Participants who stated their preference for playing with another player (i.e., ratings between 4 and 6) were then shown which of the two players within the game represented themselves and which one represented the alleged other participant. Participants who stated their preference for playing by themselves (i.e., ratings between 1 and 3) were shown the same screen, except that the "second player" was labeled "computer." The interactive sentence-completing lasted for two rounds and participants could view the final generated sentences. Thus, while both scenarios resulted in the same programmed game, the stated preference for playing by oneself or with another participant served as a proxy for participants' actual desire to socialize, representing a concrete behavioral act.

Willingness to Socialize. Apart from the behavioral act of socializing, measured by our self-programmed game, we measured participants' willingness to socialize by means of the translated 13-item-scale, developed and validated by Krämer et al. (2018). The scale was developed to measure the willingness to engage in social activities, including items clustering on the factors "desire" (e.g., "Now I feel like texting my friends") and "plan" (e.g., "I am going to text my friends today"). Participants rated the items in a randomized manner on a five-point Likert scale (1 = "does not apply at all"; 5 = "applies fully"). The translated items showed an internal consistency of α = .86, implying a good reliability (Fisseni, 2004; Taber, 2018). Each participant's score on the scale represented an average of their scores on both factors, ranging from 1 to 5.

Mood. Participants' current mood was assessed by a single item, that is, "How is your current mood?", on a five-point Likert scale (1 = "very bad"; 5 = ""very good") based on the measure applied by Mourey at al. (2017). This measure was included to control whether social exclusion (vs. no social exclusion) had an effect on participants' mood, which in turn could influence the dependent variables behavioral intention and willingness to socialize.

Perceived Anthropomorphism. Participants' individually perceived anthropomorphism regarding their own smartphone was assessed by a self-constructed single item, that is, "To what extent does your smartphone make a humanlike impression?" on a five-point Likert scale (1 = "not humanlike at all"; 5 = "very humanlike"). We preferred this measure for the explicit measurement of subjectively perceived anthropomorphism to other established measures (e.g., Bartneck et al., 2009) which are primarily validated for the context of robots and include items, for example, referring to movement of the agent, which are unsuitable for the smartphone as a stimulus.

Demographical Data. Participant's age was assessed by means of an open question. Gender was assessed through a single choice question with three answer options (i.e., male, female, and diverse). Used smartphone software was assessed by a single choice question with three answer options (i.e., iOS (iPhone), Android, and Other).

Hypotheses

Based on the general hypotheses formulated above, we hypothesized the following hypotheses for the particular study and its manipulation:

H1: Individuals who have been socially excluded will show a higher

a) behavioral intention to socialize
b) willingness to socialize

than individuals who have not been socially excluded.

H2: Individuals who have been asked anthropomorphic questions regarding their own smartphone will show a lower

a) behavioral intention to socialize
b) willingness to socialize

than individuals who have been asked non-anthropomorphic ones.

H3a: The interrelation between been asked anthropomorphic questions regarding one's own smartphone and reporting a lower

a) behavioral intention to socialize
b) willingness to socialize

will be particularly pronounced among individuals who have been socially excluded.

Results

Our descriptive analyses showed that across all conditions the mean behavioral intention to socialize was $M = 3.25$ (SD = 2.01), the mean willingness to socialize was $M = 2.99$ (SD = 0.80) and the mean perceived anthropomorphism was $M = 1.75$ ($SD = 0.95$). Furthermore, the mean mood was $M = 3.50$ (SD = 0.83). Overall, it is apparent that the perceived anthropomorphism regarding participants' own smartphones was relatively low in all conditions. More detailed descriptive data regarding the four conditions are presented in Table 1.

Furthermore, two one-way ANOVAs with experimental condition as independent and age, respectively mood, as dependent variables showed that the experimental condition neither affected

APPENDIX

Table 1. Mean (M) and Standard Deviation (SD) of Relevant Variables within the Experimental Conditions of Study 1 (N=159).

	Social exclusion				No social exclusion			
	Anthropomorphic smartphone (*n* = 41)		Non-anthropomorphic smartphone (*n* = 29)		Anthropomorphic smartphone (*n* = 39)		Non-anthropomorphic smartphone (*n* = 50)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Behavioral intention to socialize	3.34	1.98	3.14	2.07	3.46	1.92	3.06	2.09
Willingness to socialize	2.90	0.88	2.75	0.89	3.13	0.77	3.10	0.66
Desire	2.88	0.91	2.77	0.90	3.07	0.99	3.11	0.91
Plan	2.91	1.05	2.74	1.07	3.18	0.90	3.10	0.64
Mood	3.34	0.82	3.66	0.86	3.54	0.76	3.52	0.86
Perceived anthropomorphism	3.34	1.98	1.83	0.97	1.51	0.72	1.86	1.13

age (F(1,158) = 1.37, p = .253, η^2_p = .03) nor mood (F(1, 235) = 0.88, p = .453, η^2_p = .02). Thus, there were no systematic differences regarding these variables to be further considered.

To control for potential effects of social exclusion on mood, a *t*-test for independent samples showed no significant differences (t(157) = −0.43, p = .669) regarding participants' average mood between the conditions of social exclusion (M = 3.47, SD = 0.85) and no social exclusion (M = 3.53, SD = 0.81).

Hypotheses Testing: Effects of Social Exclusion and Implicit Anthropomorphism

Two-way ANOVAs with social exclusion and implicit anthropomorphism as between-subject factors showed no main effect of social exclusion on behavioral intention to socialize (F(1, 155) = 0.01, p = .938, η^2_p = .00) but a main effect on willingness to socialize (F(1, 155) = 4.98, p = .027, η^2_p = .03). Yet, as contrary to our hypothesis, mean willingness to socialize was lower for the condition of social exclusion (M = 2.84, SD = 0.87) than no social exclusion (M = 3.12, SD = 0.77). Thus, H1a and H1b could not be supported.

Furthermore, no main effect of implicit anthropomorphism, neither on behavioral intention to socialize (F(1, 155) = 0.95, p = .332, η^2_p = .01), nor on willingness to socialize (F(1, 155) = 0.35, p = .554, η^2_p = .00.), was found. Thus, H2a and H2b were not supported.

No interaction effect of social exclusion and anthropomorphism, neither on behavioral intention to socialize (F(1, 155) = 0.09, p = .762, η^2_p = .00), nor on willingness to socialize (F(1, 155) = 0.23, p = .629, η^2_p = .00), was found, lending no support for H3a and H3b.

Exploratory Analyses: Interrelation of Willingness to Socialize and Perceived Anthropomorphism

Though we could not find effects of the experimental manipulation of anthropomorphism, our exploratory analyses revealed the individually perceived anthropomorphism as interrelated to social needs. Specifically, correlational analyses across the whole study sample showed a significant positive relationship between participants' willingness to socialize and their perceived anthropomorphism (r (159) = .26, p = .001). These results imply that a higher willingness to socialize goes along with a stronger perceived anthropomorphism in one's own smartphone. All intercorrelations of the relevant variables are illustrated in Table 2.

Discussion

In this study, we investigated the effect of an implicit manipulation of anthropomorphism on social needs. For the manipulation of implicit anthropomorphism, we asked participants questions about their smartphones in an anthropomorphic (vs. non-anthropomorphic) way. Social needs were measured by behavioral intention and willingness to socialize. Furthermore, we included a

Table 2. Mean (M), Standard Deviation (SD), and Pearson Correlation of Relevant Variables within Study 1 (N = 159).

Variable	*M*	*SD*	1	2	3
1. Behavioral intention to socialize	3.25	2.01			
2. Willingness to socialize	2.99	0.80	.13		
3. Perceived anthropomorphism	1.75	0.95	.02	.26*	

*p < .05.

manipulation of social exclusion as experimental factor, assuming that social exclusion would further activate the need to socialize and thus strengthen the relationship between anthropomorphism and social needs. Contrary to our expectations, none of the expected main or interaction effects of implicit anthropomorphism and social exclusion on behavioral intention and willingness to socialize emerged.

One reason for the missing effects of the experimental manipulations could be specific challenges of operationalization. We adopted a manipulation of social exclusion (e.g., DeWall et al., 2009; Mourey et al., 2017) which induced seeking for other sources of social belonging according to various studies (e.g., Lakin et al., 2008; Maner et al., 2007; Riva et al., 2014). Yet, within our study, some reported situations of social exclusion were rather untypical or abstract (e.g., “breakfast with colleagues”), which might not have activated a need for social interaction, possibly explaining the missing effect of social exclusion.

Our chosen manipulation of implicit anthropomorphism had previously been successfully applied by Mourey et al. (2017). Slight connotation differences in the translation might have caused the less effective manipulation in our study. Moreover, our pre-test presented both types of questions (anthropomorphic vs. non-anthropomorphic) in direct comparison. As the manipulation was realized as between-subjects factor in the main study, participants were only confronted with one type of question. Thus, the differences between the two sets of questions might not have been severe enough to affect the applied measures. In accordance with the above-elucidated challenges in operationalization, the found main effect of social exclusion on willingness to socialize, which was contrary to our hypothesis, was not interpreted further.

Yet, further analyses across the whole sample showed a positive relationship between willingness to socialize and perceived anthropomorphism, implying that the more people want to socialize with others, the more they perceive their smartphones as humanlike. This finding can be interpreted in line with the assumption of anthropomorphic products as a substitute to saturate users’ social needs (cf., Mourey et al., 2017). Although our results do not support an according saturation effect, they imply a general association between anthropomorphism and social needs.

While the reported correlation between perceived anthropomorphism and willingness to socialize does not imply causality, previous research supports the general idea of willingness to socialize as a motive that enhances perceived anthropomorphism. For example, Bartz et al. (2016) found that reminding people of close relationships can reduce their tendency to anthropomorphize, offering support for possible causal effects of social needs on anthropomorphism. Thus, in our study, participants with a high willingness to socialize might have focused on social aspects of the smartphone and therefore perceived it as more anthropomorphic than individuals with lower willingness to socialize. These results underline the importance of individual perceptions and differences in anthropomorphism, which is also supported by the results of Krämer et al. (2018), showing that a lower willingness to engage in social activities after interacting with a socially responsive agent was only found for participants with a high need to belong.

Study 2

Based on the results implying the importance of perception and thus individual differences in anthropomorphism regarding the relationship of anthropomorphism and social needs, we decided to further focus on individual differences in anthropomorphism within our second study. With regard to the intended manipulation of anthropomorphism, which was not reflected in participants’ perception within the first study, as well as our limitations regarding the missing product for interaction, we decided to use a more explicit manipulation of anthropomorphism. Furthermore, we chose to implement the manipulation of social exclusion applied in Study 1 as it was confirmed by various previous studies (e.g., DeWall et al., 2009; Mourey et al., 2017; Pickett et al., 2004). To

Figure 1. Anthropomorphic vs. Non-Anthropomorphic Smartphone Designs Applied for the Manipulation of Explicit Anthropomorphism within Study 2.

support internal validity, we wanted to avoid varying more variables than necessary compared to Study 1. In parallel to Study 1, we studied the effect of social exclusion and anthropomorphism on behavioral intention and willingness to socialize, further considering possible interrelations with individual differences in anthropomorphism.

We applied a 2 × 2-between-subjects-design with social exclusion (yes, no) and explicit anthropomorphism (yes, no) as independent variables. Whereas social exclusion was manipulated the same way as in Study 1, anthropomorphism was induced in a more explicit manner. Two different smartphone images were designed. For the anthropomorphic version, a design similar to Apple's iPhone was altered so that the design and placement of the menu-button in combination with the microphone and front camera resembled a human face. The non-anthropomorphic version did not include these cues and simply resembled an Apple iPhone. Both designs are illustrated in Figure 1.

We conducted a separate pre-test with 115 individuals (M_{Age} = 35.77 years, SD = 16.02 years; 68.70% women). To ensure that differences in anthropomorphism were even perceived in indirect comparison, participants were confronted with one of the two smartphones (anthropomorphic, non-anthropomorphic) and asked to state their impression on a seven-point Likert scale ("This smartphone makes a humanlike impression."; 1 = "does not apply at all"; 7 = "applies fully"). The conducted *t*-test for independent samples showed that average ratings of the anthropomorphic (M = 3.24, SD = 1.80) did differ significantly ($t(113) = 3.37$, $p < .001$) from the non-anthropomorphic one

(M = 2.19, SD = 1.53), as the anthropomorphic smartphone was rated significantly more humanlike than the non-anthropomorphic one. Thus, we were positive that the more explicit manipulation of anthropomorphism would be perceived accordingly in our main study.

Methods

Our second study was also realized via online questionnaire. The study was announced as an experiment on innovative technologies in everyday life.

Participants

A total of 236 smartphone users between the age of 17 and 71 (M_{Age} = 30.37 years; SD = 11.17 years; 60.17% women) took part in the study. 57.20% of the participants were users of an Android, 41.10% of iOS and only 1.70% of other smartphone software. The recruitment of the participants as well as the presented incentives and study purpose were identical to Study 1.

Procedure

The procedure of this study was also parallel to Study 1. This time, after participants were instructed to describe an event of social exclusion versus their kitchen (no social exclusion), depending on their study condition as well as the measure of mood, they were confronted with the anthropomorphic or non-anthropomorphic smartphone design depending on the experimental condition. To make sure that individuals perceived the smartphone in detail, they were asked to estimate the height and width of it. To do so, they were given three options of the smartphone's measures (height 13 cm, width 6 cm; height 14 cm, width 7 cm; height 15 cm, width 8 cm). Then, the creative sentence-completion game and the above-described measures followed, this time including a measure for individual differences in anthropomorphism.

Measures

Behavioral Intention to Socialize and Willingness to Socialize. Both behavioral intention and willingness to socialize were measured with the same measures used in the first study. Within this study, the translated items of the willingness to socialize scale showed an internal consistency of α = .85, indicating a good reliability (Fisseni, 2004; Taber, 2018).

Mood and Demographical Data. Mood and demographical data were measured with the same measures used in the first study.

Individual Differences in Anthropomorphism. Based on the results of Waytz et al. (2010), there seem to be stable individual differences in anthropomorphism. Therefore, they should be considered when investigating the relationship between product anthropomorphism and social needs. In line with this, our first study's results highlight the relevance of the subjective perception anthropomorphism and support the importance of individual differences in anthropomorphism. These differences were assessed by the 15-item IDAQ, which was generated and validated by Waytz et al. (2010). Items (e.g., "To what extent does the average robot have consciousness?") were assessed in a randomized manner on a seven-point Likert scale (1 = "does not apply at all"; 5 = "applies fully"). The items were translated to German and showed an internal consistency of α = .86, indicating a good reliability (Fisseni, 2004; Taber, 2018).

Perceived Anthropomorphism. To measure perceived anthropomorphism, participants were asked to rate the following statement "This smartphone makes a humanlike impression" on a five-point Likert scale (1 = "does not apply at all"; 5 = "applies fully").

Hypotheses

Based on our general hypotheses, we assumed the following for the particular study and its manipulation:

H1: Individuals who have been socially excluded will show a higher

a) behavioral intention to socialize
b) willingness to socialize

than individuals who have not been socially excluded.

H2: Individuals who have interacted with the anthropomorphic smartphone will show a lower

a) behavioral intention to socialize
b) willingness to socialize

than individuals who have interacted with the non-anthropomorphic smartphone.

H3: The interrelation between interacting with the anthropomorphic smartphone and reporting a lower

a) behavioral intention to socialize
b) willingness to socialize

will be particularly pronounced among individuals who have been socially excluded.

Results

Our descriptive analyses showed that across all conditions the mean behavioral intention to socialize was $M = 3.34$ (SD = 1.98), the mean willingness to socialize was $M = 3.01$ ($SD = 0.80$), the mean IDAQ was $M = 3.22$ (SD = 0.96), and the mean perceived anthropomorphism was $M = 1.77$ ($SD = 1.01$). Furthermore, the mean mood was $M = 3.69$ ($SD = 0.85$). More detailed descriptive data regarding the four conditions are presented in Table 3.

It was further tested whether there were significant differences regarding the average age, mood, and IDAQ within the four conditions. Three one-way ANOVAs with experimental condition as independent and age, mood, respectively IDAQ as dependent variables showed no effect of experimental condition on age ($F\,(1, 235) = 0.75$, $p = .526$, $\eta^2_p = .01$), mood ($F\,(1, 235) = 0.43$, $p = .735$, $\eta^2_p = .01$), or IDAQ ($F\,(1, 235) = 0.27$, $p = .847$, $\eta^2_p = .00$). Thus, there were no systematic differences regarding the variables above to be further considered.

In addition, it was examined whether average perceived anthropomorphism varied significantly between the anthropomorphic vs. non-anthropomorphic smartphone condition. In accordance with our manipulation, the conducted *t*-tests for independent samples showed significant differences ($t(234) = -4.42$, $p < .01$) regarding the average perceived anthropomorphism between

Table 3. Mean (M) and Standard Deviation (SD) of Relevant Variables within the Experimental Conditions of Study 2 (N = 236).

	Social exclusion				No social exclusion			
	Anthropomorphic smartphone (*n* = 59)		Non-anthropomorphic smartphone (*n* = 50)		Anthropomorphic smartphone (*n* = 64)		Non-anthropomorphic smartphone (*n* = 63)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Behavioral intention to socialize	3.64	2.03	3.28	1.94	3.23	1.98	3.21	1.96
Willingness to socialize	2.91	0.82	3.03	0.72	3.05	0.85	3.04	0.81
Desire	2.92	0.82	3.13	0.77	3.00	0.94	3.03	0.93
Plan	2.89	1.08	2.81	0.84	3.05	0.80	3.07	0.79
Mood	3.64	0.85	3.74	0.99	3.77	0.73	3.62	0.87
Perceived Anthropomorphism	1.97	1.10	1.48	0.71	2.11	1.26	1.48	0.67
IDAQ	3.15	0.09	3.31	1.01	3.19	1.00	3.24	0.95

Note. IDAQ = Value on Individual Differences in Anthropomorphism Questionnaire.

the anthropomorphic (M = 2.04, SD = 1.18) vs. non-anthropomorphic (M = 1.48, SD = 0.68) smartphone condition.

Similar to the previous study, to control for potential mediating effects of mood, a t-test for independent samples showed no significant differences ($t(234) = -0.43$, $p = .965$) regarding participants' average mood between the conditions of social exclusion (M = 3.69, SD = 0.91) and no social exclusion (M = 3.69, SD = 0.80).

Hypotheses Testing: Effects of Social Exclusion and Explicit Anthropomorphism

Two-way ANOVAs with social exclusion and explicit anthropomorphism as between-subject factors showed no main effect of social exclusion, neither on behavioral intention to socialize ($F(1, 234) = 0.87$, $p = .352$, $\eta^2_p = .04$), nor on willingness to socialize ($F(1, 234) = 0.51$, $p = .476$, η^2_p = .004). Thus, H1a and H1b could not be supported.

Furthermore, no main effect of explicit anthropomorphism, neither on behavioral intention to socialize ($F(1, 234) = 0.57$, $p = .450$, $\eta^2_p = .02$), nor on willingness to socialize ($F(1, 234) = 0.24$, p = .622, $\eta^2_p = .001$) was found. Neither H2a nor H2b were supported.

No interaction effect of social exclusion and explicit anthropomorphism, neither on behavioral intention to socialize ($F(1, 234) = 0.42$, $p = .517$, $\eta^2_p = .02$), nor on willingness to socialize ($F(1, 234) = 0.39$, $p = .533$, $\eta^2_p = .002$) was found, yielding no support for H3a and H3b.

Exploratory Analyses: Interrelation of Willingness to Socialize and Perceived Anthropomorphism considering IDAQ

Although again no effects of the experimental manipulation of anthropomorphism were found, correlational analyses across this study's sample showed a significant positive relationship between participants' willingness to socialize and their perceived anthropomorphism ($r(236) = .15$, p = .022). These results imply that a higher willingness to socialize goes along with a stronger perception of anthropomorphism in smartphone design. The overall correlations of relevant variables are reported in Table 4.

To explore potential effects of individual differences in anthropomorphism, we separated participants with particularly high and low individual tendency to anthropomorphize, measured with the IDAQ, and studied the pattern of results within the two subgroups. Specifically, a median split separating individuals with a high (IDAQ $\geq$ 3.2) vs. low (IDAQ < 3.2) individual tendency to anthropomorphize revealed differences between the two groups with regard to the interrelation of perceived anthropomorphism and willingness to socialize. Among individuals with a high tendency to anthropomorphize (IDAQ $\geq$ 3.2), willingness to socialize and perceived anthropomorphism were significantly correlated ($r(117) = .28$, $p = .003$) while there was no correlation

Table 4. Mean (M), Standard Deviation (SD), and Pearson Correlation of Relevant Variables within Study 2 (N = 236).

Variable	*M*	*SD*	1	2	3	4	5
1. Willingness to socialize	3.01	0.80					
2. Perceived anthropomorphism	1.77	1.01	.15*				
3. Mood	3.69	0.85	.12	0.51			
4. Behavioral intention to socialize	3.34	1.98	.15*	-.08	.09		
5. IDAQ	3.22	0.96	.24**	.05	.03	.14*	

Note. IDAQ = Value on Individual Differences in Anthropomorphism Questionnaire. * p < .05. ** p < .01.

among individuals with low tendency to anthropomorphize ($r(119) = .02$, $p = .863$). Furthermore, the correlation values differed significantly ($z = 2.04$, $p < .05$). Hence, it seems that perceiving a smartphone as humanlike with rising social needs could be based on a general individual tendency to anthropomorphize non-living objects (here: IDAQ ≥ 3.2).

Based on this finding, suggesting that a particular level of IDAQ might be supportive to effects between anthropomorphism and social needs, we performed further analyses among individuals with a high tendency to anthropomorphize (IDAQ ≥ 3.2). We additionally considered the experimental manipulation of explicit anthropomorphism, that is, comparing conditions where the smartphone offered anthropomorphic design cues to where it did not. Among individuals with a high tendency to anthropomorphize (IDAQ ≥ 3.2), the correlation between perceived anthropomorphism and willingness to socialize was stronger and only significant in the anthropomorphic smartphone condition ($r(58) = .41$, $p = .001$), but not in the non-anthropomorphic smartphone condition ($r(59) = .10$, $p = .410$). For participants with a low tendency to anthropomorphize (IDAQ < 3.2), the correlation between perceived anthropomorphism and willingness to socialize was neither significant in the anthropomorphic smartphone condition ($r(65) = -.03$, $p = .786$), nor in the non-anthropomorphic smartphone condition ($r(54) = .08$, $p = .553$). All descriptive data and correlations considering participants with high vs. low IDAQ values are illustrated in Table 5 and Table 6. This pattern of correlation could suggest that individual factors (here: an individual tendency to anthropomorphize) and design factors (here: a smartphone offering humanlike design cues) may both play a role for the general relationship between social needs and anthropomorphism. Yet, these specific results should be interpreted with caution as the significant correlations within the participants with a high tendency to anthropomorphize in the anthropomorphic smartphone condition vs. non-anthropomorphic smartphone condition did not differ significantly ($z = 1.77$, $p > .05$).

Discussion

Within our second study, we investigated the relationship between social needs, operationalized by behavioral intention and willingness to socialize, and technology anthropomorphism, by confronting individuals with an anthropomorphic vs. non-anthropomorphic smartphone, after social exclusion vs. no social exclusion. Apart from applying a more explicit manipulation of anthropomorphism by presenting products with anthropomorphic design cues, we also focused on a possible effect of individual differences in anthropomorphism, as our first study highlighted an importance of individually perceived anthropomorphism. Our results showed no main effects of social exclusion or explicit anthropomorphism on behavioral intention and willingness to socialize. Yet, we found a positive correlation between willingness to socialize and perceived anthropomorphism for the overall sample as well as specifically under the preconditions of a certain individual tendency to anthropomorphize (IDAQ ≥ 3.2) and the confrontation with a smartphone with anthropomorphic design cues.

In parallel to Study 1, we did not observe main effects of social exclusion or anthropomorphism on behavioral intention and willingness to socialize. As elucidated above, the manipulation of social exclusion could only be controlled to a certain extent due to the online character of the study. Although our explicit manipulation of anthropomorphism showed effective as it yielded in a more or less humanlike impression of the smartphone in our pre-test, the same manipulation did not directly affect behavioral intention and willingness to socialize in our main study. Hence, the missing main effect of anthropomorphism in our main study might also root in the specific measures of behavioral intention and willingness to socialize. In fact, previous studies showing an effect between anthropomorphism and social needs (e.g., Mourey et al., 2017) have often used more indirect measures of need for social connection, for example, estimated number of

Table 5. Mean (M), Standard Deviation (SD), and Pearson Correlation of Willingness to Socialize and Perceived Anthropomorphism within Participants of Study 2 with a Low IDAQ Value (< 3.2).

	All participants (*n* = 119)			
	M	*SD*	1	2
1. Willingness to socialize	2.86	0.81		
2. Perceived anthropomorphism	2.45	0.49	.16	
	Anthropomorphic smartphone (*n* = 65)			
	M	*SD*	1	2
1. Willingness to socialize	2.89	0.83		
2. Perceived anthropomorphism	3.13	2.46	−.03	
	Non-anthropomorphic smartphone (*n* = 54)			
	M	*SD*	1	2
1. Willingness to socialize	2.83	0.79		
2. Perceived anthropomorphism	2.45	0.79	.08	

Note. IDAQ = Value on Individual Differences in Anthropomorphism Questionnaire.

Table 6. Mean (M), Standard Deviation (SD), and Pearson Correlation of Willingness to Socialize and Perceived Anthropomorphism within Participants of Study 2 with a High IDAQ Value (≥ 3.2).

	All participants (*n* = 117)			
	M	*SD*	1	2
1. Willingness to socialize	3.16	0.78		
2. Perceived anthropomorphism	4.00	0.62	.28**	
	Anthropomorphic smartphone (*n* = 58)			
	M	*SD*	1	2
1. Willingness to socialize	3.10	0.85		
2. Perceived anthropomorphism	3.98	0.60	.41**	
	Non-anthropomorphic smartphone (*n* = 59)			
	M	*SD*	1	2
1. Willingness to socialize	3.22	0.71		
2. Perceived anthropomorphism	4.03	0.65	.11	

Note. IDAQ = Value on Individual Differences in Anthropomorphism Questionnaire. * $p < .05$. **$p < .01$.

Facebook-friends, estimated social connection with friends and family in the future, or planned prosocial behavior. We implemented more direct variables focusing on the short time and behavioral intentions regarding the interaction with others (here: behavioral intention to socialize) as well as friends and family (here: willingness to socialize). Ratings of specific items such as "Now I would like to meet my friends." or "I am going to meet my family today." might have been affected by contextual factors, such as the physical distance to one's family and friends or other plans, which may have overwritten potential effects of the experimental manipulation. Additionally, the limited interaction with the anthropomorphic vs. non-anthropomorphic smartphones might not have been sufficient to induce an observable effect.

As an additional factor to Study 1, Study 2 also considered individual differences in anthropomorphism. In line with our exploratory results, the consideration of IDAQ values provided a more differentiated perspective on the association between anthropomorphism and social needs. More specifically, when considering IDAQ values (high vs. low) and the confrontation with anthropomorphic vs. non-anthropomorphic design cues within a smartphone, a significant correlation occurred only among individuals with a high tendency to anthropomorphize (IDAQ $\geq$ 3.2), showing that the higher their willingness to socialize was, the more anthropomorphic they individually perceived a smartphone. Moreover, an additional more fine-grained analysis showed that this correlation was only present within the anthropomorphic smartphone condition, operationalized by anthropomorphic placement and design of buttons, microphone and camera. In sum, it seems that both individual and design factors are relevant to the general association between anthropomorphism and social needs.

General Discussion

Previous research implies that interactive technologies which are perceived as anthropomorphic can support humans in restoring their threatened social needs (e.g., Mourey et al., 2017). The aim of our research was to investigate the relationship between anthropomorphism and social needs more systematically. Furthermore, we intended to explore the role of relevant person variables such as individual differences in anthropomorphism. We hypothesized that for individuals feeling socially excluded, the interaction with anthropomorphic products would reduce needs for social interaction, operationalized through the behavioral intention to socialize and willingness to socialize. We also anticipated main effects of social exclusion (vs. no social exclusion) as well as anthropomorphism (vs. no anthropomorphism) on behavioral intention and willingness to socialize. While in our first study, anthropomorphism was manipulated implicitly by asking participants anthropomorphic vs. non-anthropomorphic questions regarding their smartphones, our second study used a more explicit manipulation of anthropomorphism through smartphones with humanlike vs. regular design cues. The following sections discuss the combined results of the two studies concerning our central research questions and connections to previous studies.

In line with the SEEK-Modell (Epley et al., 2007), which describes the need and desire for social connections with others as one of three psychological determinants relevant for anthropomorphism to occur, we found an overall significant positive correlation between social needs (here: willingness to socialize) and perceived anthropomorphism in both our studies. These results are compatible with research implying that the individual need to belong, defined as the "need to form and maintain at least a minimum quantity of interpersonal relationships" (Baumeister & Leary, 1995, p. 499), may foster individuals' sensitivity to social cues (e.g., Pickett et al., 2004). In line with this, other study results further support that loneliness and individual need to belong can enhance the perception of anthropomorphism or social presence in technologies (e.g., Lee et al., 2006; Eyssel & Reich, 2013). This may come along with increased attribution of anthropomorphic qualities to a technology (e.g., Epley, Akalis, et al., 2008; Niemyjska & Drat-Ruszczak, 2013).

However, unlike previous research (Mourey et al., 2017), both of our studies showed neither an effect of experimentally manipulated anthropomorphism, nor experimentally manipulated social exclusion on social needs. The failed replication of such effects may also be at least partly due to limitations of our study design and operationalization. The manipulation of social exclusion could have been problematic, for example, due to the online character of the study. Moreover, our chosen manipulations of anthropomorphism combined with only limited interaction with the smartphone, might not have been intense enough.

While this does not speak against product interaction as a sort of social need fulfillment in general, it seems that the particular role and manipulation of anthropomorphism is more complex than previous research might have suggested. In both our studies, individual perceptions and person variables, namely, individual differences in anthropomorphism, were more deciding than experimentally manipulated anthropomorphism. As argued by Waytz et al. (2014), individuals generally differ in the extent to which they perceive objects as anthropomorphic and such differences can amongst others predict the extent to which individuals can be influenced by these objects. Accordingly, in Study 1, we could find an overall correlation between willingness to socialize and perceived anthropomorphism, highlighting the importance of individual perception rather than external manipulation of anthropomorphism. In Study 2, considering individual differences in anthropomorphism as an additional variable, we also found a significant correlation between willingness to socialize and perceived anthropomorphism for the overall sample as well as specifically for individuals with a high tendency to anthropomorphize (IDAQ ≥ 3.2). Thus, our studies underline the role of certain predispositions (i.e., individual and product-related factors) in the interrelation of anthropomorphism and social needs. When considering the individual tendency to anthropomorphize in our second study, only within individuals with a high tendency to anthropomorphize did willingness to socialize correlate in a significant positive manner with perceived anthropomorphism. In addition, this correlation could only be found within the anthropomorphic smartphone condition. Thus, apart from the individual precondition of a certain tendency to anthropomorphize, humanlike design cues were also necessary.

Implications for Theory

Our research offers various implications for theory. First, our findings complement previous research (e.g., Eyssel & Reich, 2013; Bartz et al., 2016) in supporting an interrelation between social needs (here: willingness to socialize) and anthropomorphism. Although not implying causality, considering previous research on this interrelation, our results could be interpreted to the extent that the higher peoples' individual social needs are, the more they appear to anthropomorphize non-human objects or agents. Thus, our insights offer further empirical support for the SEEK-Modell (Epley et al., 2007), which describes that humans are more likely to anthropomorphize when they are in need of social connection to other humans.

Furthermore, our research highlights the relevance of individual differences in anthropomorphism. Namely, based on our results, individual differences in anthropomorphism as well as anthropomorphic design cues in a product appear as preconditions to observe an interrelation between social needs and perceived anthropomorphism. The consideration of such individual tendencies and their interplay with design cues therefore seems important for future research in this regard. Still, the interrelations and causalities between these variables need to be further investigated in a systematic manner.

Finally, in line with the above-described theoretical implications, our research also underlines the importance of considering individually perceived anthropomorphism as a variable besides manipulations of anthropomorphism, for example, by means of visual or interaction design of products. As anthropomorphism of non-human agents or objects appears to be influenced by individual differences in anthropomorphism or other individually varying factors such as the need for social interaction, it could be insightful to explicitly consider perceived anthropomorphism as a measure within empirical studies.

Implications for Practice

Our research also points out directions for practice. According to our findings, individual differences in anthropomorphism as well as anthropomorphic design cues in a product appear as preconditions to observe an interrelation between social needs and perceived anthropomorphism. These insights could be valuable for various domains.

For example, in marketing, anthropomorphism has increasingly gained popularity. This ranges from humanlike names for products, anthropomorphic product design up to the use of avatars, for example, in advertising. Based on our results, practitioners in this field should consider that anthropomorphism might affect potential users differently, amongst others depending on their individual tendency to anthropomorphize.

Furthermore, within the field of healthcare or technology design for private households, where technologies are often explicitly designed to address social needs, such results should be considered. Although, based on our studies, the question whether the interaction with anthropomorphic products has the potential to satisfy people's social needs, remains unclear, our results support a relationship between social needs and the perception of anthropomorphism under certain preconditions. On the one hand, practitioners aiming to activate this interrelation should focus on offering the precondition of anthropomorphic product design. On the other hand, practitioners should be aware that individuals who are more in need of social connection to other humans might be more likely to anthropomorphize the technology or product in question. Yet, as our study results do not allow for causal result interpretation, the interrelation of anthropomorphism and social needs calls for further systematic exploration in experimental studies.

Limitations and Directions for Future Research

One central limitation of our studies was their online character. Thus, we could not measure the intensity and duration individuals lasted in the social exclusion task or the interaction with the anthropomorphic vs. non-anthropomorphic product they were confronted with. An insufficient completion of the social exclusion task or a too short interaction with the products could therefore have affected the manipulations in a negative manner. Similarly, due to the online character of the study, we could not control whether participants were alone while answering the items. A companion of any kind could also have influenced the manipulation of social exclusion in a way that individuals might not have felt excluded at the time of task completion albeit describing a situation of social exclusion. Such a biasing factor could also have influenced individuals' needs for social interaction, measured by behavioral intention and willingness to socialize within both our studies. These limiting factors should be considered in future research aiming to systematically manipulate social exclusion and anthropomorphism in experimental studies.

Another limitation is the cross-sectional design of our studies. Therefore, no long-term effect of interacting with anthropomorphic products could be observed. It is likely that a long-term study would have been necessary to observe a possible effect or even a hypothesized "social saturation" through anthropomorphism on needs for social interaction. Longitudinal studies on the interrelation between interaction with anthropomorphic products and social needs thus build an important task for future research. Thereby, variables focusing on the satisfaction of social needs should be assessed to allow for ratings on willingness to socially interact with others or even actual social behavior to be led back to social need satisfaction. Furthermore, within longitudinal research, measurable social behavior such as interaction duration with close others could foster external validity of results.

Finally, we did not yet consider further dispositional factors and personality traits that could be relevant for behavioral intention or willingness to socialize and mediate the considered effects, such as the need to belong (Baumeister & Leary, 1995) or the individual need for solitude (Long & Seburn, 2003). Further studies should include such traits or long-term needs of individuals to investigate their role regarding the effect of manipulated anthropomorphism on individuals' perception.

Conclusion

Anthropomorphic design becomes increasingly prevalent in interactive technologies of everyday use, such as smartphones, conversational chatbots, or digital voice assistants. Yet, their possibly lasting effects on users, for example, regarding their social needs, have rarely been systematically addressed in research. In sum, the results of our two studies underline a relationship between anthropomorphism and social needs, but also highlight the complexity of the issue, as a number of factors seem to play a role in this interrelation. In particular, our results support the importance of individual factors, that is, the tendency to anthropomorphize as well as situational factors, that is, anthropomorphic design cues, for the interrelation of social needs and anthropomorphism. In sum, the question whether an anthropomorphic product or technology comes with the potential of satisfying individuals' social needs demands further research. Future studies looking into this matter should focus on long-term interaction between human and product or technology, respectively. Thereby, actual social behavior toward close others should be measured and individual as well as situational factors, as found within our studies, should be considered.

Overall, as products within our everyday lives are being developed with more and more humanlike characteristics, the possible societal impact of anthropomorphic design shifts into focus. In this regard, one central question refers to the relationship between anthropomorphism and social needs. Naturally, such findings might be challenged in their stability throughout the years as humans will get increasingly used to the interaction with such technologies with or without anthropomorphic cues. It is thus even more important to understand the general psychological mechanisms behind anthropomorphism as well as its effects on different individual and societal levels such as its interrelation with social interaction.

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Data Availability

The data supporting the conclusions of this article will be made available by the authors upon request.

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WISSENSCHAFTLICHE BEITRÄGE

Fulfilling social needs through anthropomorphic technology? A reflection on existing research and empirical insights of an interview study

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Abstract
As interactive technologies, such as chatbots or voice assistants, increasingly become social counterparts and resemble human interaction partners in many ways, the question arises whether they are also able to address users' social needs. This paper explores whether interaction with technology can address social needs and what role technology anthropomorphism plays in this. While previous research shows somewhat contradictory results potentially related to challenges of applied assessment methods of anthropomorphism and social needs, we complement this by means of a qualitative interview study ($n = 8$). Our study findings support a potential of anthropomorphic technology to address users' social needs but also highlight differences between the quality of human-technology and interpersonal interaction. In addition, our findings hint at a social desirability bias, since people see social need fulfillment through technology as silly or inappropriate. Design and societal implications are discussed.
Practical Relevance: This article explores the potential of technology to address users' social needs and discusses practical implications for marketing and design, e.g., how technologies should be designed in order to affect users' social needs and which contexts of application might be suitable. Moreover, the article also reflects on societal implications resulting from a potential effect of interaction with technology on users' social needs.

Keywords Anthropomorphism · Social needs · Human-computer interaction · Human-technology interaction · Human-technology relationship

Erfüllung sozialer Bedürfnisse durch anthropomorphe Technologien? Eine Reflexion bisheriger Forschung und empirische Einsichten einer Interview-Studie.

Zusammenfassung
Da interaktive Technologien wie Chatbots oder Sprachassistenten zunehmend zu sozialen Gegenübern werden und menschlichen Interaktionspartnern in vielerlei Hinsicht ähneln, stellt sich die Frage, inwiefern diese auch soziale Nutzerbedürfnisse ansprechen können. Der Artikel geht dieser Frage nach und fokussiert die Rolle des Anthropomorphismus von Technologie diesbezüglich. Während bisherige Forschung teilweise widersprüchliche Ergebnisse aufweist, die mit Herausforderungen angewandter Messmethoden von Anthropomorphismus und sozialen Bedürfnissen zusammenhängen könnten, ergänzen wir diese anhand einer qualitativen Interview-Studie ($n = 8$). Ergebnisse unserer Studie unterstützen das Potenzial anthropomorpher Technologien, soziale Nutzerbedürfnisse anzusprechen, und unterstreichen gleichzeitig Unterschiede in der Qualität der Mensch-Technik- und zwischenmenschlichen Interaktion. Darüber hinaus deuten Ergebnisse auf eine Verzerrung durch Effekte sozialer Erwünschtheit hin, zumal Individuen die Erfüllung sozialer Bedürfnisse durch Technologien als lächerlich oder unangemessen zu betrachten scheinen. Gestaltungs- und gesellschaftliche Implikationen werden diskutiert.

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Praktische Relevanz: Der Artikel erforscht das Potenzial von Technologien, soziale Nutzerbedürfnisse anzusprechen und diskutiert Implikationen für Marketing und Produktgestaltung, z. B., wie Technologien gestaltet sein sollten, um soziale Nutzerbedürfnisse anzusprechen bzw. welche Anwendungskontexte sich anbieten. Ebenso reflektiert der Artikel gesellschaftliche Implikationen, die sich aus dem potenziellen Effekt der Interaktion mit Technik auf soziale Nutzerbedürfnisse ergeben.

Schlüsselwörter Anthropomorphismus · Soziale Bedürfnisse · Mensch-Computer-Interaktion · Mensch-Technik-Interaktion · Mensch-Technik-Beziehung

1 Introduction

Nowadays, we increasingly interact with technologies that we perceive as social counterparts. Examples are chatbots, smart home solutions, or even autonomous robots. These technologies are no longer perceived as simple tools, but become other (Ihde 1990). Accordingly, the embodied relationship with technology as a tool becomes one of alterity (Hassenzahl et al. 2021) and our interactions with such technologies are often similar to interactions with other humans. According to the "computers are social actors" (CASA) paradigm (Nass et al. 1994), individuals apply social rules from interpersonal interaction to interaction with non-human agents (Nass and Moon 2000; Reeves and Nass 1996), especially if the technology shows humanlike characteristics (e.g., a computer that features a form of dialogue similar to human conversation). Moreover, individuals oftentimes attribute humanlike characteristics, emotions, and motives to these technologies, also known as the phenomenon of anthropomorphism (Epley et al. 2007). For example, it has been shown that people tend to judge a computer's performance more favorably than it actually is (Nass et al. 1994), presumably because they do not want to hurt the computer's "feelings" when entering their judgment into the computer interface. Furthermore, studies have shown that individuals can even perceive a sort of social connectedness to technologies (Christoforakos et al. 2021; Kang and Kim 2020) or see them as attachment objects that spend relief and comfort when feeling lonely (Diefenbach and Borrmann 2019). Thus, while human-technology relationships obviously resemble interpersonal relationships in several ways, research also needs to clarify the boundaries of this perspective and reveal central differences regarding the nature of the relationship. In this regard, for example, the question arises whether technology actually has the potential of addressing users' social needs in a similar way as a human counterpart.

Single study results imply a possible "social saturation" through interaction with technologies or products when they come with humanlike qualities. Mourey et al. (2017), for example, could show that after interacting with anthropomorphic (vs. non-anthropomorphic) products, socially excluded participants exaggerated their number of social connections less and their anticipated need to engage with close others as well as their willingness to perform prosocial behavior were reduced (Mourey et al. 2017). Similarly, Krämer et al. (2018) found that participants with a high need to belong reported a lower willingness to engage in social activities after the interaction with an agent that showed socially responsive behavior.

Still, other studies that have investigated the potential of technology to address individual needs to interact with others have not found an according effect. Namely the willingness to socialize with other humans was not affected by previous interaction with anthropomorphic technology (e.g., Christoforakos and Diefenbach 2022; Christoforakos et al. 2021). In line with this, in a short survey ($n=37$) that we conducted, 97% of the participants (completely) disagreed with the statement "After the interaction with a technical voice assistant (e.g., Alexa) I have the feeling that my desire to interact with other humans is satisfied.", and 76% of the participants (completely) disagreed with the statement "After the interaction with my smartphone I have the feeling that my desire to interact with other humans is satisfied.".

Naturally, the comparison of study results is challenging due to the different manipulations of technology anthropomorphism as well as the different means of assessment of central variables. However, based on the equivocal character of previous findings, further research is needed to broaden the view on this interrelation and better understand the potential of technology to fulfill humans' social needs and therefore possibly influence their desire to interact with other human counterparts.

In this paper, we aim to explore whether the interaction with technology can address users' social needs, and understand a possible role of technology anthropomorphism in this regard. The next sections (Sects. 2 and 3) reflect on previous work focusing on the potential of anthropomorphic technology or products to address users' social needs. We specifically reflect on methodological as well as conceptual challenges, which can affect the insights on the interrelation in question. After this (Sect. 4), we present an empirical qualitative study to further complement previous research on the relationship between the interaction with anthropomorphic technology and users' social needs. This is followed by a general discussion (Sect. 5) where we reflect on our study results in the light of relevant previous work and derive future research directions.

2 Anthropomorphic technology's potential to address individuals' social needs

According to evolutionary and developmental theories, humans naturally seek close connections to other humans (Baumeister and Leary 1995; Maslow 1943). Furthermore, the social production function theory implies that apart from their physical integrity, humans consider their social well-being to be a universal goal in life (Ormel et al. 1999). When social needs remain unsatisfied, individuals are consequently motivated to seek alternative ways to fulfill such, which DeWall and Baumeister (2006) coined the social reconnection hypothesis. This stands in line with previous findings implying that feeling currently lonely or chronically disconnected from others can go along with the attribution of anthropomorphic qualities to non-human objects and entities (e.g., religious agents, pets, imaginary creatures; Epley et al. 2007, 2008; Niemyjska and Drat-Ruszczak 2013).

To date, a few studies have attempted to investigate whether the interaction with technology or products in general actually bears the potential of addressing users' social needs. As already noted in the introduction section, Mourey et al. (2017), for example, showed that when individuals interacted with anthropomorphic consumer products, their social needs could be partly satisfied, and experimentally induced effects of social exclusion were mitigated. Specifically, after interacting with anthropomorphic (vs. non-anthropomorphic) products, socially excluded participants exaggerated their number of social connections less and their anticipated need to engage with close others as well as their willingness to perform prosocial behavior were reduced (Mourey et al. 2017). In a study by Krämer et al. (2018), when participants interacted with a virtual agent with socially responsive (vs. not socially responsive) nonverbal behavior, there was no main effect of socially responsive behavior on individuals' connectedness with the agent or their experience of rapport, namely the short time liking and responsiveness of the agent. Yet, participants with a high need to belong reported a lower willingness to engage in social activities after the interaction with the agent only when the respective agent showed socially responsive behavior (Krämer et al. 2018).

Other studies that have aimed at investigating the effect of technology on social needs have not found a social saturation effect. For example, in their study, Christoforakos and Diefenbach (2022) have explored whether anthropomorphic products have the potential to fulfill social needs and how individually perceived anthropomorphism correlates to social needs. The authors conducted two consecutive experimental studies in which participants were socially excluded (vs. not socially excluded) and interacted with an anthropomorphic (vs. non-anthropomorphic) smartphone. Anthropomorphism was manipulated more implicitly in the first study (by anthropomorphic vs. non-anthropomorphic questions about one's own smartphone) and more explicitly (by anthropomorphic vs. non-anthropomorphic design cues) in the second study. In both studies, no incidence of a social saturation effect emerged, given that participants' willingness to socialize with other humans were not lower (i.e., better fulfilled) after interacting with an anthropomorphic (vs. non-anthropomorphic) smartphone. Yet, results of their first study showed an overall positive correlation between the willingness to socialize and perceived anthropomorphism. Thus, a higher willingness to interact with other individuals came along with a higher perceived anthropomorphism in one's own smartphone. Furthermore, results of their second study highlighted that this relationship was especially pronounced for individuals with a high tendency to anthropomorphize, given that the product supports a humanlike perception through its appearance and design cues. Therefore, although such results do not support a social saturation through the interaction with anthropomorphic products, they imply a general interrelation between social needs and anthropomorphism and stress individual and contextual strengthening factors (Christoforakos and Diefenbach 2022).

In another study where participants regularly interacted with a conversational chatbot over a period of two weeks, Christoforakos et al. (2021) found, that interaction duration and intensity positively predicted social connectedness to the chatbot. Furthermore, perceiving the chatbot as anthropomorphic, mediated the interrelation of interaction intensity and social connectedness to the chatbot. Similarly, the perceived social presence of the chatbot mediated the relationship between interaction duration as well as interaction intensity and social connectedness to the chatbot. Yet, contrary to the social saturation hypothesis, the authors could not find a negative correlation between users' social connectedness felt to the technology and their desire to socialize with other humans (Christoforakos et al. 2021).

In sum, there seems to exist some sort of relationship between individuals' social needs and the interaction with technology or products in general, especially when they are perceived to be humanlike.

Still, research on whether anthropomorphic technology has the potential of addressing social needs must be extended to understand the interrelation and causal mechanisms. Overall, empirical findings need to be reflected on a conceptual as well as methodological level to understand possible challenges of research regarding the effect of interaction with anthropomorphic technology on social needs.

3 Methodological and conceptual challenges in exploring the effect of interaction with anthropomorphic technology on social needs

It appears that interaction with technology could come with a certain potential of fostering social experiences, especially when anthropomorphism comes into play. Yet, it might be challenging to capture this relationship in a valid manner by applying common methods of measurement, both regarding the perception of anthropomorphism and social needs as well as general research paradigms.

3.1 Assessment of anthropomorphism

From a methodological perspective, the applied measurement of anthropomorphism can naturally influence study results. In their studies, Mourey et al. (2017) as well as Krämer et al. (2018) focused on the manipulations of anthropomorphism to investigate the interrelation with social needs and did not measure perceived anthropomorphism. While both studies support an effect of the interaction with an anthropomorphic technology on users' social needs, analyses within the main studies did not explicitly consider a measurement of perceived anthropomorphism. Thus, the role of the individual perception of anthropomorphism for the found interrelation as well as potential alternative explanations for the effect on users' social needs remain unclear.

In contrast, the above discussed studies by Christoforakos et al. (2021) as well as Christoforakos and Diefenbach (2022), which could not detect a so-called saturation effect of the interaction with anthropomorphic technology on users' social needs assessed perceived anthropomorphism by explicit measures. Namely, the authors applied the Anthropomorphism Subscale of the Godspeed Questionnaire including five items (e.g., "machinelike"/"humanlike") to be assessed on five-point semantic differential scales (Christoforakos et al. 2021). In the other study, Christoforakos and Diefenbach (2022) assessed anthropomorphism by a self-constructed single item, that is, "To what extent does your smartphone make a humanlike impression?" on a five-point Likert scale (1 = "not humanlike at all"; 5 = "very humanlike"). Yet, as also supported by a study by Kim and Sundar (2012), applying such explicit measures might have caused psychological reactance within participants, leading to a possibly invalid measurement of perceived anthropomorphism and in turn potentially influencing the study outcome. Namely, in their study, Kim and Sundar (2012) found that most participants who were exposed to an anthropomorphic version of a website (a website with a guiding humanlike character) reported a lower degree of perceived humanlikeness than those exposed to the non-anthropomorphic version of the website (no humanlike character) (Kim and Sundar 2012). Therefore, the authors argue that participants who were exposed to the anthropomorphic version of the website intentionally denied treating the website in a human way, particularly when personifying the website with simple labeling. This is further supported by their insights showing that participants who denied treating the website in human terms when exposed to the character tended more to attribute personal characters to the website compared to those not exposed to the character (Kim and Sundar 2012). The authors conclude that anthropomorphism is rather mindless, i.e., a non-conscious tendency to treat computers as human beings than mindful, i.e., a conscious tendency to treat computers as human beings. Thus, explicit measurement of anthropomorphism to assess the perception of participants might impair the validity of insights. In general, this makes the assessment of anthropomorphism a challenging research objective as it appears difficult to measure it appropriately without probably influencing the measurement itself.

3.2 Assessment of social needs

In addition, from a methodological perspective, when exploring the potential of interaction with anthropomorphic technology to fulfill social needs, the measures applied to assess individuals' social needs can also naturally influence study insights. For example, Krämer et al. (2018) as well as Christoforakos et al. (2021) and Christoforakos and Diefenbach (2022) applied (an adapted version of) the scale to measure willingness to socialize, developed and validated by Krämer et al. (2018) as well as behavioral measures, that imply a certain degree of willingness to socialize (Christoforakos and Diefenbach 2022; Krämer et al. 2018). The scale was developed to measure the willingness to engage in social activities, including items clustering on the factors "desire" (e.g., "Now I feel like texting my friends") and "plan" (e.g., "I am going to text my friends today"). As also discussed by Christoforakos and Diefenbach (2022) ratings of specific items, such as "Now I would like to meet my friends.", or "I am going to meet my family today." are prone to be affected by contextual factors, such as the physical distance to one's family and friends or other plans, which may overwrite potential effects of an experimental manipulation.

Mourey et al. (2017) further focused on more indirect measures of need for social connection, for example, estimated number of Facebook friends or planned prosocial behavior. In this case, the authors based their interpretation solely on the behavioral intentions to socialize, which assumably influence the estimation of Facebook friends or prosocial behavior. Moreover, result interpretation based on the study designs and measures applied in the studies presented above (Krämer et al. 2018; Mourey et al. 2017) relies on the assumption that a sort of social need satisfaction is causal.

On a more conceptual level, even if a measure to assess the satisfaction of social needs, such as the General Belongingness Scale (e.g., "I feel like an outsider"; Malone et al. 2012), were applied, it is questionable to what extent the short-term interaction with an (anthropomorphic) technology could actually affect users' social needs. According to Baumeister and Leary (1995), the need to belong represents a central human need and is defined as the "need to form and maintain at least a minimum quantity of interpersonal relationships". Therefore, it is unlikely that an effect of the interaction with anthropomorphic technology on social needs can be observed in a cross-sectional study design.

Moreover, the social reconnection hypothesis posits that the experience of social exclusion (i.e., a primary threat to belongingness needs) motivates individuals to seek out new sources of social acceptance (Maner et al. 2007). Furthermore, study results show that when one's need for social belonging is threatened, people are faster at recognizing smiling faces in a crowd and focusing on positive, social faces as opposed to unhappy faces or positive, nonsocial images (DeWall et al. 2009). Thus, in many instances, threats to individuals' needs increase motivation to restore those needs directly. In accordance, to investigate the possible social saturation effect through interaction with anthropomorphic technology, social exclusion needs to be induced. Although most of the above presented studies exploring this interrelation include an according manipulation of social exclusion, especially in online settings it is difficult to ensure that participants are actually alone while participating at the study. Even in experimental settings, the simple presence of a researcher could counteract the effect of social exclusion. Therefore, even after experimentally inducing social exclusion, the need for social interaction might not be as salient as necessary to detect the assumed effect of anthropomorphic technology on social needs.

Finally, it appears worthwhile to reflect on the nature of the social needs construct that is in focus. First studies imply a possible effect on social needs in general (e.g., Mourey et al. 2017) by showing that there is less willingness to engage in social behavior after an interaction with an anthropomorphic product or technology. Still, it is not specified whether this observed effect is actually based on the satisfaction of a specific need. The fact that other studies have not found a so-called saturation effect on the willingness to interact with others through the interaction with an anthropomorphic technology, as well as previous research implying a positive relationship between loneliness and perception of anthropomorphism (e.g., Epley et al. 2008; Niemyjska & Drat-Ruszczak 2013) could speak for the potential of anthropomorphic technology to act as a social snack rather than saturate the need for interpersonal interaction.

In sum, the discussed limitations support the general complexity of the relationship between anthropomorphic technology and social needs. Moreover, the discussed methodological and conceptual challenges highlight that current research needs to be complemented by alternative approaches to foster deeper insight on whether the interaction with technology has the potential to address social needs and relevant underlying psychological mechanisms.

4 Empirical study

To complement previous experimental research on the potential of anthropomorphic technology to address users' social needs, and broaden the view on this interrelation, we conducted a qualitative interview study. In our interview study we aimed to explore whether technology has the potential to address users' social needs and what role anthropomorphism plays in this interrelation. Based on the above presented varying results regarding the interrelation of interest, we followed an explorative approach, to foster an unbiased investigation of our research question and capture a comprehensive image of what is truly at the heart of individuals' experience when interacting with technology. In addition, the above-presented methodological and conceptual challenges regarding our research objective speak for the application of alternative methods to traditional experimental research paradigms, in order to gain broader insights regarding our research question.

4.1 Methods

For our qualitative study we followed the approach of psychological phenomenology according to Moustakas (1994). A phenomenological study in general describes the meaning for several individuals of their lived experiences of a concept or phenomenon (Creswell 2007). In this, the focus lays on what all participants have in common regarding this experience. By means of a phenomenological study, individual experiences regarding a phenomenon can be reduced to a universally applicable essence. The hermeneutical phenomenology (van Manen 1990) as one type of phenomenology refers to "interpreting the 'texts' of life" (Creswell 2007) and thus reflects on essential themes of a phenomenon of interest in order for the researcher to write a description of it as well as make an interpretation regarding the meaning of certain lived experiences. Psychological phenomenology (Moustakas 1994) is mainly focused on descriptions of participants rather than interpretations of the researcher. Thus, the approach is characterized by the concept of bracketing, where researchers try to leave aside their own experiences in order to foster a fresh perspective with regards to the phenomenon in question.

As our research focuses on understanding the potential of technology to address individuals' social needs, the phenomenological approach allows deep insight into the experience of a number of individuals regarding their interaction with technology and the possible effect on their social needs. Furthermore, by applying the approach of psychological phenomenology by Moustakas (1994) the participants' experience can be focused by leaving aside as much as possible the researcher's perspective on the interrelation in question, which could for example be influenced by previous literature in this regard. At the same time, reflecting on existing literature regarding the effect of anthropomorphic technology on users' social needs prior to the study supports a basic understanding of relevant existing broader assumptions, which is necessary to conduct phenomenological research (Creswell 2007).

4.1.1 Participants

Eight participants (50% female, 50% male) between twenty-five and sixty-one years ($M = 36.88$; $SD = 12.24$) were interviewed. Daily interaction with interactive technology was the only precondition for participation. As a thank you for participation, interviewees received a twenty Euro Amazon coupon. The sample size was chosen based on our study's emphasis on in-depth understanding of experiences and according recommendations for phenomenological and interpretive research (e.g., Polkinghorne 1989; Thompson 1997). Participants had diverse academic backgrounds. Table 1 shows a detailed sample description.

4.1.2 Procedure

The interview study was introduced as a study on innovative technology in everyday life. Each participant was given a pseudonym and was assured of anonymity and confidentiality. During the interviews, participants could choose to talk about any products in the domain of technology/consumer electronics they found relevant to answer the questions. Most participants mentioned several products and later picked one which they focused on. These products, for example, included smartphones, smart washing machines, or even vacuum cleaners. The interview started with a short introduction for the participants to get acquainted with the topic. Participants were asked to describe personal interactions with technologies that resemble interactions with other humans as well as general effects of any technology on personal social needs.

After this introductory part, the main part of the interview focused on three overreaching, guiding questions, i.e., participants were asked to reflect on (1) similarities and differences in interaction with technology vs. humans with regard to users' social needs, (2) technology characteristics that could be relevant for an effect of interaction with technology on users' social needs and finally, (3) third party reactions to human-technology interaction resembling interpersonal interaction.

4.1.3 Data analysis

Our methodology followed the approach of a phenomenological analysis, revealing general themes as well as participants' experiences regarding a research subject. Specifically, for each guiding question, we conducted multiple steps, as suggested by Creswell (2007) and originally based on the phenomenological analysis by Moustakas (1994). First, transcriptions of the raw data were analyzed for significant statements, meaning "sentences or quotes that provide an understanding of how the participants experienced the phenomenon" (Creswell 2007), so-called level A statements. These statements were paraphrased and then organized into clusters of meaning (level B), which represented reoccurring issues within all participants' interviews. To be meaningful, issues must not necessarily be present in all participants' narrations. Even experiences from only a single participant can be theoretically important, and generality is not a primary concern of phenomenology (Creswell 2007). Finally, the clusters of meaning were organized into

Table 1 Sample description of empirical study
Tab. 1 Stichprobenbeschreibung der empirischen Studie

Participant	Gender	Age	Occupational Status	(Field of) Occupation	Housing situation
P1	Female	61	Employed	Computer Science, Executive Position	Living with others
P2	Female	25	Student	Art/Culture, Marketing/PR	Living with others
P3	Female	48	Employed	Art Consulting	Living with others
P4	Male	27	Employed	IT Project-Management	Living alone
P5	Male	39	Employed	Online Marketing & IT	Living alone
P6	Female	31	Employed	Research Assistant	Living with others
P7	Male	35	Employed	Engineer	Living with others
P8	Male	29	Employed	Asset Management	Living with others

Table 2 Findings on similarities and differences in interaction with technology vs. humans with regard to users' social needs (guiding question 1)
Tab. 2 Befunde zu Ähnlichkeiten und Unterschieden in der Interaktion mit Technologien bzw. Menschen in Bezug auf soziale Bedürfnisse der Nutzer (Leitfrage 1)

Themes (level C)	Clusters of meaning (level B)	Mentions (in participants)	Exemplary Statements (level A)
Description of interaction content with technology/human counterpart	Exchange of orders/instructions and answers with technology	6	"Because the way it is right now, a question is simply followed by a predefined answer." [P4]
	No emotional/content feedback/support from technology	4	"I don't feel loved by the technology surrounding me. [Technology cannot] show me the way or be there for me." [P2]
	No haptic interaction with technology	4	"What we cannot do (with technologies), is touch each other or so, meaning that the haptic component is definitely missing and that is not good on the long run." [P3]
	Emotional/content feedback/support from humans	3	"[A human can] show me the way and be there for me." [P2]
	No common history/leisure activities with technology	2	"With this thing one cannot (..), watch a DVD or go out for a beer." [P5]
	More unpredictability in interaction with humans	2	"With a human this is naturally different. I get everything back, maybe not the way I imagined it, but I give and receive something. And that's what is actually interesting, that it is not one hundred percent predictable (...)." [P7]
	No own will of technology in interaction	1	"Yes, it naturally doesn't have an own will." [P7]
	No judgement/observation through technology	1	"I would say when I am surrounded by technology, I am not being judged or seen." [P2]
	Similar interaction with technology and humans through modality of speech	1	"(...) that you can speak with a machine like you would with a human." [P1]
	Simple coexistence with technology	1	"(...) It's more like another person is in the room, who is looking in another direction and is occupied with something else." [P6]
Personal feelings regarding/evaluation of interaction with technology/human counterpart	No satisfaction of social needs with technology	4	"I don't feel fulfillment or social satisfaction afterwards (...)." [P2]
	Counteraction of temporary boredom/loneliness/frustration with technology	3	"[My smartphone] can counteract temporary boredom, it can counteract temporary loneliness". [P2]
	More superficial/distant interaction with technology	3	"I think that you maintain a polite distance to technology." [P2]
	No social responsibilities with technology	2	"When I speak with a robot, I am not limited or self-conscious regarding social norms. I can just have a go at it without being worried about how that makes him feel." [P6]
	More control over interaction with technology	2	"Yes, so it is still a thing that is operated by electricity and if I don't feel like it, I can pull the plug." [P4]
	Possible satisfaction of social needs through technology in future	2	"In theory yes [technology might be able to satisfy social needs] but I think that some time needs to pass for this to be achieved." [P4]
	Less need for social interaction after interaction with technology	2	"I think that if a technology spoke with me intensely and I talked about my day and how I was doing, I would actually have the feeling: I have conversed enough." [P4]
	Entertainment/education through interaction with technology	2	"And what he maybe can do, that would rather frustrate me with other humans, is that he actually educates me a little. (...). He educates me to be aware of my stuff lying around." [P5]
	Different quality of satisfaction or peace after interaction with technology	2	"I feel empty and exhausted [after the interaction with technology]." [P2]
	Interaction is more personal/intense with humans	1	"With humans everything is more personal." [P2]
	Affirmation through interaction with technology	1	"[Technology gives me] affirmation I would say. For example, my smart home would never insult me." [P4]
	Technology as a relationship partner	1	"[With my smartphone] it's just like in a relationship. When the partner is not there anymore, a part is missing." [P8]

larger information units that represented general themes (level C). This process is not a rigorous and unidirectional one. It rather consists of analytic circles, where new insights and reflection processes may lead to revisions of data organization (Creswell 2007). The themes and clusters of meaning were discussed and developed jointly by the first and second author.

4.2 Findings

The study findings are structured along the three guiding questions of the main interview part as described with regard to the study procedure (Sect. 4.1.2). Note that whenever participants' statements were relevant for a specific guiding question, they were considered in the data analyses, even if mentioned with regard to another guiding question. Moreover, it is possible that one participant might have made statements belonging to the same cluster multiple times within the interview. In this case, these statements were not counted multiple times.

4.2.1 Interaction with technology vs. humans with regard to users' social needs

Participants' statements regarding their relationship qualities to technology and respectively other humans formed two general themes (level C), namely, *description of interaction content with technology/human counterpart* and *personal feelings regarding/evaluation of interaction with technology/human* counterpart. The related clusters of meanings (level B) and corresponding exemplary statements are listed in Table 2.

In sum, regarding the first theme of descriptions of interaction content with technology/human counterpart, participants most frequently elaborated on how interaction with technology is an exchange of orders or instructions and according answers in return. One participant for example explained: *"Because the way it is right now, a question is simply followed by a predefined answer."*. In line with this, participants often mentioned how there is feedback or support from the technology missing on an emotional or informative as well as haptic level. In an exemplary statement, one participant said: *"(...) Communication means, that you can exchange feelings, information, and I think, that especially on the emotional level an object actually doesn't give you anything in return."*.

Referring to the second theme of personal feelings or evaluations regarding interaction with technology vs. a human counterpart, participants mostly explained that they did not feel a satisfaction of social needs with technology. Moreover, they frequently mentioned that an interaction with technology could counteract temporary boredom, loneliness, or frustration. In this regard, one participant for example explained *"(...) not every psychological aspect can be addressed through technology but a big part, at least sympathy, meaning 'not feeling alone' can be addressed through technology, I think."*. In the same frequency participants stated that they perceived interaction with technology to be more superficial or distant compared to interpersonal interaction.

4.2.2 Technology characteristics relevant for its effect on users' social needs

Participants' statements regarding characteristics of technology that might influence the extent to which it can affect users' social needs formed two general themes (level C), namely, *Technology characteristics resembling characteristics of (interaction with) humans/animals* and *other technology characteristics. The related clusters of meanings* (level B) and corresponding exemplary statements are listed in Table 3.

Regarding technology characteristics resembling characteristics of (interaction with) humans or animals, participants most frequently mentioned technology intelligence as well as (im)perfection or (un)predictability as a potential factor. In this regard participants for example explained: *"For example, Alexa, who speaks with me doesn't give me anything, she is simply too dumb."* or *"I think it's mainly because it's not perfect. It's cuter when it drives around in confusion than when it's one hundred percent effective in driving along its paths without me noticing."*. In the same frequency participants mentioned a general technology humanlikeness to be possibly relevant for technology to affect users' social needs. Amongst others they explained *"(...) I would say that technology needs to have humanlike characteristics to socially satisfy."*. Less frequently they mentioned technology interaction with users (through speech), as well as visual design cues suggesting humanlikeness as relevant to foster an effect on users' social needs. Moreover, in the same frequency participants mentioned how a combination of various humanlike characteristics would be necessary in this regard (e.g., *"I think appearance as well as empathy play a role, it has to be an interplay (...)")*. Regarding other technology characteristics, participants most frequently named a sort of modern, aesthetic, or appealing design as potentially influential, as well as less a certain timeframe of possession or frequency of use of a certain technology.

4.2.3 Third party reactions to human-technology interaction resembling interpersonal interaction

Participants' statements concerning reactions of third parties regarding an interaction with technology that resembled interpersonal interaction formed two general themes

Table 3 Findings on technology characteristics that could be relevant for an effect of interaction with technology on users' social needs (guiding question 2)
Tab. 3 Befunde zu Eigenschaften von Technologien, die für den Effekt der Interaktion mit Technologien auf soziale Bedürfnisse der Nutzer relevant sein könnten (Leifrage 2)

Themes (level C)	Clusters of meaning (level B)	Mentions (in participants)	Exemplary Statements (level A)
Technology characteristics resembling characteristics of (interaction with) humans/animals	Technology intelligence can play a role	4	"For example, Alexa, who speaks with me doesn't give me anything, she is simply too dumb." [P2]
	General technology humanlikeness can play a role	4	"(...) I would say that technology needs to have humanlike characteristics to socially satisfy." [P4]
	Imperfection/unpredictability in interaction/behavior can play a role	4	"I think it's mainly because it's not perfect. It's cuter when it drives around in confusion than when it's one hundred percent effective in driving along its paths without me noticing." [P5]
	Interacting (through speech) with the user can play a role	3	"I think it's about the way of interaction, the input options, such as voice assistants, who are designed to simulate this [humanlike way of interaction]." [P6]
	Visual design suggesting humanlikeness can play a role	3	"What probably evokes a completely different feeling is, when it has human characteristics on the outside." [P4]
	Combination of various humanlike characteristics necessary	3	"I think appearance as well as empathy play a role, it has to be an interplay (...)." [P6]
	Animallike design can play a role	2	"I can imagine that the doglike design helps in comparison to something totally abstract or more edgy." [P5]
	Reaction to user expressions/emotions can play a role	2	"Also giving feedback [could play a role]. Yes, for example I was thinking of colors. When one is unhappy or angry it could go towards red and success, for example, I would rather associate with green." [P7]
	Humanlike movement/posture of technology can play a role	2	"[The technology] should be moving in a humanlike manner and not just be a box of technology with no humanlikeness other than the voice." [P1]
	Modality of movement can play a role	1	"He moves and I just get this feeling [of a social interaction]." [P6]
	Modality of voice can play a role	1	"The voice [plays a role], that's probably the humanlikeness [of the technology]." [P1]
	Perception of goal motivation of technology can play a role	1	"It's that he does things and I attribute underlying goals." [P6]
Other technology characteristics	Modern/aesthetic/appealing design can play a role	5	"If it had a super modern and smooth design and were actually almost chic like an accessory in my home and in addition spoke and interacted with me, I would develop an emotional relationship to such [technology]." [P2]
	Timeframe of possession/frequency of use can play a role	2	"[Something that] you have owned for a long time and that has some sort of history [can affect social needs]." [P7]
	Perceived development effort of technology can play a role	1	"For example, a mechanic watch. When I imagine that it has hundreds of components and the precision and performance that that was invested." [P7]
	Technology adaptability to user can play a role	1	"I mean for someone who is aggressive [the technology] has to be aggressive as well." [P8]
	Expectation management regarding abilities of technology can play a role	1	"(...) Alexa was promoted as something that represents a friend at home and answers to questions etc. and I think that it is just not developed appropriately." [P2]
	Hedonic character of product can play a role	1	"Things that I use often, that are pleasant and less of working tools." [P6]

(level C), namely, *Rather negative reactions* as well as *Rather neutral or positive reactions*. In this, participants considered their own reactions as well as reactions of others. The related clusters of meaning (level B) and corresponding exemplary statements are listed in Table 4.

Regarding rather negative reactions participants most frequently mentioned reactions where the third party in question was irritated or showed lack of understanding. An example in this regard was: *"Because of the functionality of speaking to Siri, I have often received incredulous looks."*. Less frequently participants mentioned situations where the third party was annoyed or uncomfortable, such as: *"My boyfriend, with whom I lived together back then, was somehow a little annoyed."*.

Table 4 Findings on third party reactions to human-technology interaction resembling interpersonal interaction (guiding question 3)
Tab. 4 Befunde zu Reaktionen Dritter auf Mensch-Technik Interaktionen, die zwischenmenschlichen Interaktionen ähneln (Leitfrage 3)

Themes (level C)	Clusters of meaning (level B)	Mentions (in participants)	Exemplary Statements (level A)
Rather negative reactions	Third party is irritated/shows lack of understanding	5	"Because of the functionality of speaking to Siri, I have often received incredulous looks." [P4]
	Third party is annoyed/ uncomfortable	3	"My boyfriend, with whom I lived together back then, was somehow a little annoyed." [P2]
	Third party finds interaction ridiculous	2	"My husband sometimes says 'poor Harry' [to our car] but I find this a bit ridiculous." [P6]
	Third party has the feeling of another (strange human) entity in the room	1	"(...) and we actually didn't really fancy the idea and it was somehow as if there was another person in the room who did not belong." [P8]
Rather neutral/ positive reactions	Third party approves/does not disapprove of interaction	3	"Nobody has really disliked the interaction because I don't overstretch it." [P4]
	Third party is interested/enthusiastic	2	"I also have friends who are technophile, and they ask: How does this work? How can you manage this?" [P4]
	Third party gets involved in interaction	2	"(...) he would instead simply join the interaction." [P6]
	Third party pays attention/is surprised	2	"When you interact this way [with the technology, others'] attention is definitely steered." [P1]
	Third party encourages interaction	1	"When we meet up for a beer, he asks if I can make [the robot] drive around." [P5]
	Third party is accustomed to interaction	1	"Well, I am quite used to this interaction because I have one [e.g., Siri] myself." [P5]

With regard to rather neutral/positive reactions, participants most frequently mentioned situations where the third party approved or at least did not disapprove the interaction with the technology that resembled an interpersonal one. In this regard, on participant explained: *"Nobody has really disliked the interaction because I don't overstretch it."* Less frequently participants described situations where the third party was interested in or enthusiastic about the interaction (e.g., *"I also have friends who are technophile, and they ask: How does this work? How can you manage this?"*), or where the third party got involved in the interaction with the technology. In the same frequency participants described situations where the third party was surprised, or their attention was steered.

4.3 Discussion

Within our empirical study, we aimed at exploring whether technology has the potential to address users' social needs as well as the role of technology anthropomorphism in this interrelation. In this, we conducted interviews, where we mainly focused on comparisons of human-technology interaction that resembles an interpersonal one and actual interpersonal interaction, technology characteristics that could play a role regarding a potential effect of technology on users' social needs, and finally, reactions of third parties to interactions with technology that resemble interpersonal interactions.

While participants statements refer to different technologies and corresponding modalities of interaction, overall results show many differences in the perceived quality of interaction with technology that resembles interpersonal interaction and actual interpersonal interaction. The first and second most prominently found clusters of meaning included exchange of orders/instructions and answers with technology, no emotional/content feedback/support from technology, no haptic interaction with technology and no satisfaction of social needs with technology. These findings highlight that even though interactions with technology might oftentimes resemble interpersonal interaction, a central perceived difference concerns the dull character of interaction with technology and the accordingly missing reactions to the user on a content, emotional and physical level. This could be a possible reason for the found absence of satisfaction of users' social needs, even though modalities of interaction with technology can be quite similar to those known from interpersonal interaction.

Moreover, regarding technology characteristics that can play a role in addressing users' social needs, the first and second most frequently named clusters of meaning involved technology intelligence, imperfection/unpredictability in technology interaction/behavior, general technology humanlikeness, interacting (through speech) with the user, visual design suggesting humanlikeness, combination of various humanlike characteristics as well as modern/aesthetic/appealing design and timeframe of possession/frequency of use. It appears, that apart from an attractive design and the user involvement, e.g., through long possession or frequent use, known to generally influence product or brand engagement (e.g., Majeed et al. 2022), the rest of the mentioned clusters of meaning mainly concerned characteristics resembling humans and/or interaction with them. Such results stand in line with previous findings supporting the role of anthropomorphism for the effect of interaction with technology on users' social needs (e.g., Krämer et al. 2018; Mourey et al. 2017). Within these characteristics it seems that technology intelligence, its imperfection or unpredictability as well as its general humanlikeness are perceived to be most crucial for an effect on users' social needs. It is noticeable that these qualities are rather abstract in comparison to interaction through speech or visual design resembling a human. This finding could speak for the complexity of the relationship between interaction with technology and users' social needs. Additionally, it might underline the challenge for technology users to exactly grasp and verbalize what is really crucial for technology to even rudimentarily address social needs of users. Moreover, it could also explain why study participants often mentioned not having felt a social satisfaction through interaction with technology as those qualities are yet very difficult to implement in technology that we use in our everyday lives, such as voice assistants.

Finally, when asked about reactions of third parties regarding an interaction with technology that resembles an interpersonal one, the first and second most frequently mentioned clusters of meaning were third party is irritated/shows lack of understanding but also third party approves/does not disapprove of interaction. While these results imply that this type of interaction with technology is still novel and often subject of misunderstanding, under certain circumstances it is also accepted, and people come to terms with it. As one participant stated, "I have mostly heard someone say for example: Alexa, how long does the rice take to cook?, and the whole room needed that answer so it made sense.". This statement could for example imply, that when this type of interaction with technology is explainable, i.e., has obvious benefits for the user(s), the interaction could be evaluated positively. Such an interpretation stands in line with the relevance of explainability of innovative, complex technology to foster its acceptance (e.g., Smith-Renner et al. 2020).

4.4 Limitations

Our empirical study comes with certain limitations on a methodological and conceptual level. First, with regard to the methodology, as it is the case with most phenomenological studies, our results are based on a rather small sample size. Moreover, when asked about technologies with which participants interacted in a manner that resembled interpersonal interaction, each participant naturally considered different technologies. Accordingly, they also named different ways of interaction with these technologies that subjectively resembled interpersonal interaction. Thus, participants' reports each refer to a different basis of discussion, which should be considered regarding the generalizability of results. Although both aspects might restrict generalizability of result interpretation from a methodological perspective, we purposely decided to prioritize few but in-depth descriptions of relevant experiences by the participants including individually chosen technologies. Moreover, we have no reason to assume the revealed findings to be entirely specific to the present sample.

Second, as particularly outstanding experiences are very memorable (cf. Chandralal and Valenzuela 2013), it is possible that participants mentioned particularly positive or negative experiences and thus reports might have involved fewer neutral experiences regarding interaction with technology. In future studies the consideration of additional research methods, such as experience sampling (Zuzanek 2000), could foster a more detailed representation of relevant experiences.

Finally, on a more conceptual level, the qualitative approach might have allowed detailed illustrations of participants' experiences and fostered a broader understanding in this regard. Still, participants might have been inhibited about explaining whether and how interaction with technology addresses their social needs as they might have felt self-conscious about the topic's social acceptability. Although technologies increasingly slip into the role of social counterparts, actual satisfaction of social needs through the use of technology might still be frowned upon. Participants' statements such as *"When I talk to the robot, all my brain actually thinks is that it is just ridiculous what I am doing."* support the possibility of such perceptions. Moreover, admitting technologies could even partially satisfy needs in a similar manner to other humans, could cause technology to appear as a threat to humans. Thus, even if participants perceived an effect on their own social needs through the use of technology, they might have rationalized this perception and not shared such or stated otherwise. This conceptual limitation underlines the complexity of the interrelation of interest as a research objective. It furthermore highlights why the assessment of relevant variables, such as satisfaction of social needs, represents a central challenge.

5 General discussion

As technologies increasingly represent our social counterparts and our interaction with them oftentimes resembles interpersonal interaction in many ways, the question arises whether technology also has the potential of addressing users' social needs in a similar way as a human counterpart. Based on previous findings, technology seems to affect users' social needs in some way, especially when technology anthropomorphism comes into play (e.g., Krämer et al. 2018; Mourey et al. 2017). Yet, research in this regard shows varying findings and comes with certain methodological and conceptual challenges.

Our qualitative study results support a certain interrelation of interaction with technology and users' social needs but also highlight central differences between the quality of human-technology interaction and interpersonal interaction in this regard. For example, based on the clusters of meaning mentioned by participants, our findings imply that interaction with technology, which resembles interpersonal interaction, might help to counteract temporary negative user states, such as boredom, loneliness, or frustration. Thus, our results offer support for previous studies implying a certain connection between loneliness and anthropomorphism (e.g., Epley et al. 2007, 2008; Niemyjska and Drat-Ruszczak 2013). Moreover, our results could imply that found effects of interaction with anthropomorphic technologies on users' social needs within cross-sectional studies (e.g., Krämer et al. 2018; Mourey et al. 2017) are based on a counteraction of users' temporary negative states, such as felt loneliness.

Yet, findings also speak for an absence of satisfaction of users' social needs, possibly due to the described exchange of orders and answers in human-technology interaction and the missing feedback from the technology on a content, emotional and physical level, amongst others. These results stand in line with previous findings which do not imply an effect of interaction with technology on users' social needs (e.g., Christoforakos and Diefenbach 2022). Additionally, our findings could offer potential explanations for this missing effect through found differences in the quality of human-technology interaction vs. interpersonal interaction.

Moreover, our results imply a role of technology anthropomorphism regarding the interrelation of interaction with technology and users' social needs and support previous study findings (e.g., Epley et al. 2007, 2008). Specifically, mostly mentioned clusters of meaning regarding relevant technology characteristics for a potential effect on users' social needs concerned characteristics resembling human or animal behavior or interaction. Results also extend existing insights as to relevant combinations of humanlike characteristics for an according effect as well as other technology characteristics, such as modern and aesthetic design, that might play a role. The frequently named necessity of a combination of humanlike technology characteristics (e.g., visual design combined with the expression of empathy) to address users' social needs could also serve as a possible explanation for the missing effect of anthropomorphic technology on users' social needs within a few previous studies that only manipulated technology appearance (e.g., Christoforakos and Diefenbach 2022).

Finally, as discussed above, results show that when asked about third-party reactions to an interaction with technology that resembles interpersonal interaction, most frequent mentions concerned rather negative reactions. Thus, the interrelation of interest within the present paper might be one of questionable social acceptance. Such an issue could also offer an explanation for previous study findings, that did not show an interrelation between interaction with technology and users' social needs. Additionally, this further supports the complexity of this phenomenon as a research objective.

Further studies in this regard following different methodological approaches are needed to look closer into the relation of interaction with anthropomorphic technology and social needs. Future quantitative research could benefit from considering insights of our qualitative study and framing variables and items accordingly. For example, it could be beneficial to manipulate anthropomorphism by combining different technology characteristics or assessing social needs on a level of loneliness rather than complete social saturation. In this, the complexity of the interrelation of interest in this paper along with the respective challenges of assessment of central variables should be considered.

6 Conclusion

Current research offers varying insights on whether and to what extent technology can actually address users' social needs. Challenges in the assessment of technology anthropomorphism as well as social needs could be just one example of possible reasons for this current state of research.

The interview study presented in this paper partially stands in line with existing research but also extends such and offers first insights into possible reasons for previous study results. Namely, results imply that interaction with anthropomorphic technology could have the potential of—at least temporarily—addressing aspects of users' social needs. Yet, findings also underline technology's limits in this regard by highlighting crucial perceived differences to human interaction and implying that an actual satisfaction of social needs might not be possible through the interaction with technology.

Taken together, on a societal level, the picture that emerges from conserving previous literature as well as our empirical study could be considered a rather optimistic one. Namely, it appears that human interaction is rather unique in ways that technology to this moment cannot imitate to perfection, even if the interaction with such resembles the interpersonal one in many ways. For example, based on our results it seems that even by means of humanlike interaction, technology cannot offer emotional feedback or support and possibly due to this reason, amongst others, cannot offer satisfaction of social needs. Thus, technology does not appear as a substitute of other humans when it comes to social interaction and its consequences. According to our results, it could rather represent a practical solution to dampen negative effects of temporary user states, such as loneliness.

From a practical perspective it might therefore be advisable to focus on specifics of each entity instead of aiming for interchangeability. Whereas humans appear unique in giving emotional and physical feedback to their human counterparts, technology might be easily applicable to temporarily address boredom, frustration, or loneliness of their users. Technology might even be the ideal interaction partner in such situations, as according to Dörrenbächer et al. (2020) it could come with superpowers of being endlessly patient and non-judgmental. Such characteristics might be especially preferred when a user simply wants to be entertained in order not to feel lonely or bored, as also reflected in our findings, supporting that users feel no social responsibility when interacting with technology. In line with these reflections, fostering an ideal synergy of humans and technology by focusing on specificities of both might be a promising overall strategy for a desirable societal development where humans and technology do not compete but rather benefit from each other.

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