

Prerequisites for Human-Agent- and Human-Robot Interaction: Towards An Integrated Theory

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Abstract

Getting people to engage with robotic and virtual artifacts is easy, but keeping them engaged over time is hard and has therefore been widely ignored. Since social engagement is a complex phenomenon, the creation of long-term appealing robots/agents requires the integration of sound interdisciplinary theoretical foundations. Starting from knowledge from human-human relationships, we present an integrated theoretical framework of prerequisites for human-agent and human-robot-communication.

1 Introduction

For quite a while now, researchers have been working towards socially interactive agents and robots and have subsequently been interested in exploring the relation between humans and robots. However, both areas of research have predominantly focused on short-term interactions and effects. Recently, an increasing number of researchers have discovered long-term relationships to be important. In line with this, the SERA (Social Engagement with Robots and Agents) project explores long-term relations between humans and artificial entities like robots and agents. It deals with the prerequisites for establishing and maintaining relationships between humans and agents/robots beyond an initial interaction phase. Since humans are involved in these interactions, it is necessary to know about the conditions of human-human communication in order to be able to deduce specific design guidelines for the creation of artificial characters. Against this background, we discuss a rich repertoire of different levels of interaction and configurations of relations of human communication and work towards integrating them into a coherent model. The following overview about the resulting framework introduces the concept of need to belong and, more importantly, the Theory of Mind as essential components and discusses the implications for human-machine communication.

In doing this, as a central aspect of the framework, we focus on approaches dealing with the interpersonal di-

mension of human encounters, reasons and antecedents for interpersonal relations as well as the rules in communication. Furthermore, the specifics of nonverbal and verbal behavior will be addressed. Sociological considerations such as ideas on the sociology of emotion [Turner and Stets, 2005] might apply in this respect too, but will not be discussed in detail here.

2 Theory Framework

The theory framework incorporates, as its core piece, the theory of need to belong [Baumeister and Leary, 1995] and the concept of Theory of Mind [ToM; Baron-Cohen, 1995; Dennett, 1987] and their appendices. We propose that the fundamental need to belong, which will be explained in more detail in the following section, serves as an anchor point for the development of long-term relationships between humans and artificial entities since it can be understood as the basic motive leading humans to establish bonds with artificial entities. Driven by this need, humans are oriented towards others, striving to relate themselves, their thoughts and feelings to their environment. In the course of this, they are likely to form a theory about their counterpart to be able to engage successfully in meaningful communication as a basis for relationships. The need to belong can thus be considered to be an essential prerequisite and starting point for assuming that humans will establish bonds with a robot/agent.

The mechanisms comprising the fundamental parts are mediated by communicative events consisting of verbal and nonverbal information. The model (see figure 1) distinguishes mechanisms bound to perception on the one hand, and on the other hand aspects of production in communicative events. Production and reception of information in a given situation can be described with the help of assumptions derived from general systems theory. It can be assumed that perceived verbal and nonverbal information underlies the rules of Watzlawick's five axioms [Watzlawick et al., 1969] in the way that, for example, every message includes content and relationship information and therefore makes a contribution to the establishment of the relationship. More importantly, the

meaning of incoming messages is constructed against the background of personal experience as well as common ground information – taking into account the other’s perspective.

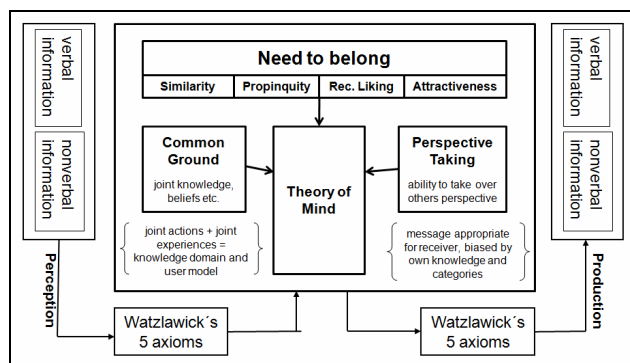


Figure 1: Theory Framework

Similarly, the sender of the message considers the other’s perspective to form a message. Thus, the outgoing message is built on the sender’s ToM about the receiver. This process will be further explained in the following sections.

It is important to consider that the following illustrations of the framework’s components can be distinguished into two categories that are guided by two central questions: Which findings from human-human communication can be made use of for the design of robots? Which characteristics and capabilities are essential to a long-term engaging robot? As a first approach one can think of giving the robot certain features and characteristics that will, according to the theories and findings discussed, lead to attraction. This may for example be physical attractiveness which can be implemented before the interaction starts and is a rather static feature of the robot. Another strategy that can be followed is the idea of implementing certain theoretical assumptions enabling the robot to act autonomously, which would be the case when giving the robot ToM capabilities.

3 Factors Assisting to Establish Relationships in Human-human Communication

Being fundamental to human nature, the need to belong can be made use of in human-robot communication as a basis for the establishment of long-term relationships. In their article on belongingness, Baumeister and Leary [1995] suggest that “human beings are fundamentally and pervasively motivated by a need to belong, that is, by a strong desire to form and maintain enduring interpersonal attachments [p. 522].” This human motivation has “multiple links to cognitive processes, emotional patterns, behavioral responses, and health and well-being” [p. 522]. Consequently, all of us are interested in having warm and positive relationships and making and maintaining friendships as key conditions for happiness [Berscheid, 1985; Berscheid and Reis, 1998].

As a deep-rooted pillar of human existence, the need to belong is thus the basis for the social orientation of human beings. In order to satisfy this need we seek company of others: we build groups (e.g. families, cliques), are interested in the other’s lives and help each other just because the satisfaction of the need to affiliate makes us happy. Especially in addition to other social company or to satisfy the need to belong in older or home bound people, a robot as a companion may show to be a valuable alternative.

However, since we do not build close relationships to everyone we encounter, there obviously are a number of pre-conditions influencing with whom we affiliate and under what kind of antecedents friendship and interpersonal attraction arise. These conditions have to be considered in designing robots/agents that are likely to be engaging over a long period. These aspects are subject of the following subchapters.

3.1 Propinquity

As one of the main factors leading to interpersonal attraction researchers described the propinquity effect, the tendency to form friendships or close relations to the people we often see and interact with. The propinquity effect is often explained by the mere exposure effect [Zajonc et al., 1989], i.e. the finding that the more we are exposed to a stimulus, the more likeable it becomes. However, if we initially dislike the stimulus our repulsion grows every time we are exposed to it again [Swap, 1977].

3.2 Similarity

Propinquity does affect whom we choose to be friends with. However, we do not become friends with everyone we often encounter in our direct physical surrounding. Thus, besides proximity, research has shown that it is similarity that draws people together [Berscheid and Reis, 1998; McPherson et al., 2001]. The more a person shares our attitude and opinions the more we like him or her. The same is true for similar experiences, interests and personality aspects as factors fostering the establishment of a common ground. Similarities regarding the interpersonal communication style determine to whom we are attracted and influence our evaluation of the relationship as well as the degree of satisfaction [e.g. Duck and Pittman, 1994].

3.3 Reciprocal Liking

Since we all like to be liked, we are attracted to others who behave as if they like us. No matter if the signals are nonverbal or verbal, whether we like a person or not depends on our judgment about the extent to which the other person likes us [Berscheid and Walster, 1978; Kubitschek and Hallinan, 1998]. Liking can even compensate the absence of similarity [Gold et al., 1984]. As Curtis and Miller [1986] demonstrated, reciprocal liking might as well be the result of a self-fulfilling prophecy. People, who believed they were liked by their counterpart, generally behaved more likeable and were at the same time liked more than the

participants who believed they were disliked. However, a person's self-esteem does affect this mechanism: In contrast to people with a positive or moderate self concept, people with a negative self concept tend not to respond to the friendly behavior of others and will accordingly provoke negative reactions affirming their negative self concept [Swann et al., 1992].

3.4 Physical Attractiveness

Physical attractiveness is another important determinant for liking. In general, we tend to like physically attractive people and ascribe positive qualities to them that are not connected to their outward appearance – the “what is beautiful is good” stereotype [Dion et al., 1972]. Physical attractiveness decides on liking and excels factors like intelligence, independence or sensitivity [Walster et al., 1966]. Since what we consider to be attractive is influenced by the media, it is not surprising that we share a certain number of criteria defining what is attractive.

3.5 Social Exchange Theory

A theory that brings together the different determinants of attraction is the social exchange theory [Homans, 1961; Thibaut and Kelley, 1959]. Assuming that relationships are comparable to a marketplace where costs and benefits are exchanged according to economic principles, this theory suggests that the feeling that we have about a relation does not only depend on the evaluation of the rewards and costs, but is determined by the comparison level [Kelley and Thibaut, 1978; Thibaut and Kelley, 1959] which takes into account the expected outcome of rewards and punishments the person is likely to receive in a relationship. Furthermore, the level of satisfaction also depends on your evaluation of the comparison level for alternatives, i.e. the assumption on what one would receive in an alternative relationship.

Resulting from criticism on the social exchange theory the so called equity theory was proposed. It assumes that people are concerned about equitable relationships in which the contribution of rewards and costs made by the partners are roughly equal [Homans, 1961; Hatfield et al., 1978]. Compared to inequitable relationships, in which the partners feel uneasy about the perceived imbalance, equitable relationships are the happiest and most stable relations.

3.6 Social Exchange in Long-Term Relationships

With regard to social exchange in close relations the investment model has been developed. It suggests that in long-term relationships not only the level of satisfaction with a relationship regarding rewards and costs, comparison level and the comparison level for alternatives play a role but also the perception of what has been invested that would be lost by ending the relationship [Rusbult, 1983]. Thus, in order to be able to predict the duration of an intimate relationship one has to know about these determining factors.

3.7 Implications

As these aspects mainly deal with human-human relations, the question arises what implications can be deduced for the relation between humans and robots and agents, respectively. In the beginning it was already mentioned that there are two different approaches that can be followed for the design of long-term relationships with robots. In line with the first “track” of implementing specific characteristics and features beforehand the following implications can be deduced. As a consequence of findings about propinquity, it can be suggested that in order to make use of the mechanism of mere-exposure, the agent/robot has to be within the user's reach and clearly visible as often as possible. The robot/agent should be designed in a way that it fosters interaction with its owner. Therefore, it should ideally have some similarities with the user, when believable, it could for example look human-like and conform to ideas of attractiveness, dress and speak in similar ways or show similar habits and interests. Studies with virtual agents have already shown that agents with similar personality traits, like e.g. introverted versus extroverted [Isbister and Nass, 2000] and similar appearance [van Vugt et al., 2006] like the user were evaluated more positive and likable. In line with findings about reciprocal liking the robot should give its user the impression that it likes him or her and appreciates his or her presence since this increases the likeability of the system, as long as this is authentically implemented. Depending on the setting this may well be realized with the help of ingratiation, i.e. by praising the user. For the design of robots/agents, attractiveness should be taken into account in order to increase the likelihood for the agent to be liked and to foster human motivation to establish a relationship with the robot. Finally, the robot/agent has to be of use for the user, so that he/she might at least initially feel a balance in the relation. A user's feeling of a balance between contributions and rewards from the interaction with a robot is important for the maintenance of the relationship in the beginning. However, it is important to create equitable, balanced relationships in order not to cause a bad feeling in the users and to make the relation as stable as possible.

After this initial phase in which a give-and-take rule is applied, the user hopefully perceives his/her relation towards the agent/robot as a communal relationship, so that equal contributions become less important. Ideally, the user feels a strong bond with his robot, so that he does not consider or rejects alternatives and feels bad about ending the relationship. Besides these features that generally can be implemented once before the interaction starts, a specific model of the user and the common “history” of user and robot will be needed in order to render ongoing communication, relationship management and development successful and satisfying.

4 Theories for Mutual Understanding

To be sociable, robots and agents need a representation of users, their social and cultural background, and of interaction situations and contexts. This representation (in the broadest sense) has to integrate ToM and emotionality, situational awareness and general behavioral patterns and has therefore to be more dynamic than the previously mentioned implementation guidelines. A key element is the capacity of being aware of and being able to manage socio-emotional relationships. What is meant here can aptly be illustrated by Wittgenstein's statement "If a lion could talk we would not understand it.", referring to the fact that it is useless to implement the ability of natural speech in robots while they are unable to understand concepts which are naturally shared by humans and are taken for granted in communicative interactions.

4.1 Common Ground

Clark [1992] describes common ground as the joint basis for communication: "Two people's common ground is, in effect, the sum of their mutual, common, or joint knowledge, beliefs, and suppositions" [p. 93]. Common ground is the basic requirement to interact with others. When there is no common ground then no communication or understanding takes place. One has to differentiate between *communal common ground*, which is derived from obvious similarities like human nature (people use language, live in groups, and have names), and *personal common ground*, which is built during interactions by joint perceptual experiences and actions. People try to ground what they do together to avoid discrepancies. According to Clark [1992] there exist several grounding principles that vitalize common ground and help to establish mutual knowledge, e.g. the *linguistic co-presence heuristic*: people assume that anything that has been said during the course of the conversation is known to the interaction partners [Clark and Carlson, 1981]; or the *principle of closure*: people try to collect evidence that they have succeeded in performing an action. Therefore, participants of a joint action give each other subtle feedback to form the mutual belief of a successful joint action. This need for feedback has also been described with regard to human-computer-interaction: Both, "telephone buttons that do not beep when pressed or a display that does not change when an action has been taken, are confusing" [Norman, 1988, p. 56].

4.2 Perspective Taking

Social perspective taking, i.e. understanding the feelings, thoughts and motivations of others, is an essential social skill that has been stressed by many researchers. According to Krauss and Fussell [1991] the role of knowing what others know is fundamental. The lack of taking the other's perspective can be the basis for misunderstandings and dispute. Thus, tailoring the message to the knowledge of the recipient is a prerequisite for successful communication [Krauss and Fussell, 1991]. Research has shown that by taking their

addressee's knowledge and perspectives into account when formulating messages speakers' accuracy of assessments of others' knowledge is fairly high but they seem to be biased in the direction of their own knowledge [see also Nickerson, 1999, see below]. Krauss and Fussell [1991] summarize that those people's assumptions of others' knowledge shall be deemed to be hypotheses that need to be evaluated and modified over time. During interactions conversational resources might serve as feedback to check one's own assumptions on the knowledge of others.

4.3 Imputing One's Own Knowledge to Others

Nickerson [1999] claimed that "imputing one's knowledge to a specific other is a *default* measure; ... If one has no direct knowledge of what another, whom one is addressing, does or does not know, and little or no knowledge that would provide the basis for making inferences in this regard, the only thing left to do is to use one's own knowledge as a default assumption as to what the other know" [Nickerson, 1999, p. 745]. The ability to impute one's own knowledge to others is thus crucial for meaningful human-human communication. He states that "[a]n obvious starting point for building a model of what another knows is what oneself knows, or think one knows" [p. 737]. This generally useful mechanism of knowledge imputation potentially includes the risk that people's erroneous assumption about others having the same knowledge causes communication difficulties.

4.4 Theories for Understanding Others

Theory of Mind (ToM) is the ability to see other entities as intentional agents whose behavior is influenced by states, beliefs, desires etc. and the knowledge that other humans wish, feel, know or believe something [Premack and Premack, 1995; Premack and Woodruff, 1978; Whiten, 1991]. ToM is also assumed to be fundamental to human nature: "We are 'mindreaders' by nature, building interpretations of the mental events of others and feeling our constructions as sharply as the physical objects we touch. Humans evolved this ability because, as members of an intensely social, cooperative, and competitive species, our ancestors' lives depended on how well they could infer what was on one another's minds" [Toby and Cosmides, 1995, p. XIII]. Baron-Cohen [1995] sums up that mindreading is useful because "aside from decoding the referent of each word (computing its semantics and syntax), the key thing we do as we search for the meaning of the words is to imagine what the speaker's communicative intention might be" [p. 27] which refers to the pragmatics of the spoken words. As was already alluded to earlier, current dialogue and agent systems are prone for misunderstandings and failed comprehension attempts. Although the reasons for this are manifold, an important explanation is the fact that basic needs and customs of the human users are neglected.

4.5 Implications

The obvious consequence of these considerations is thus to try to implement theory-of-mind-like abilities. This includes that the agent has to be “aware” of his own abilities and knowledge about the human interaction partner. Therefore a user model is needed which incorporates global knowledge on human needs and states. Containing basic knowledge on human abilities, knowledge, states, etc. and interaction abilities this ToM module enables the agent to verify the knowledge, beliefs, emotions, etc. of the user and to progressively build common ground with the user [Krämer, 2008].

Krämer [2008] summarizes that “it might be stated that the different models on common ground, perspective taking, imputing one’s knowledge and ToM show major similarities with regard to the fact that all propose that humans possess a direct but implicit knowledge on other humans (...) that form a starting point for mutual comprehension. Building on this, the dialog can be used to clarify and broaden mutual knowledge by means of grounding processes.” Most current agent systems lack both: a theory of its own mind and a complete user module that can be compared to a ToM. Krämer [2008] discusses a couple of approaches that implemented a ToM module in an agent [e.g. Marsella and Pynadath, 2005; Traum, 1996; Breazeal et al. 2004] and concludes that they are promising but will have to be broadened. To successfully implement a ToM module there it needs more than simply implementing rules or knowledge: “The bottom line of the idea of mentalising is that we predict what other individuals will do in a given situation from their desires, their knowledge and their beliefs, and not from the actual state of the world” [Frith and Frith, 2003, p. 6].

Within the state of the art of artificial intelligence it is a long way towards a successful development of a ToM module, but some principles promise efficient mechanisms to avoid misunderstandings in human-agent/robot-interaction. Also, the possibility of the system to give feedback should be fostered. Krämer [2005] observed that people repeated their utterances when the agent did not give feedback in an appropriate time insinuating the agent did not understand what they said. Thus the statement: “One cannot not communicate.” [Watzlawick et al., 1967] holds also for agents. Immediate feedback (also about the delay of appropriate feedback) is crucial to avoid misunderstanding and frustration.

5 Conclusion

In sum it can be stated that we have to carefully consider basic human abilities that we take for granted in everyday communication in order to be able to built artificial entities that are able to not only engage in sensible short time conversations but also develop relationships. With regard to the former, perspective taking and ToM will be crucial in order for the robot/agent to predict what effect a specific utterance will have on the user – given that the user will construct the meaning against the background of his/her human abilities. With regard to developing rela-

tionships, additionally a possibility to build common ground has to be established as the robot/agent has to have the ability to build on joint experiences and former dialogues.

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