‘Give me a hug’: the effects of touch and autonomy on people’s responses to embodied social agents.

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Abstract

Embodied social agents are programmed to display human-like social behaviour to increase intuitiveness of interacting with these agents. It is not yet clear to what extent people respond to agents’ social behaviours. One example is touch. Despite robots’ embodiment and increasing autonomy, the effect of communicative touch has been a mostly overlooked aspect of human-robot interaction. This video-based, 2x2 between-subject survey experiment (N=119) found that the combination of touch and proactivity influenced whether people saw the robot as machine-like and dependable. Participants' attitude towards robots in general also influenced perceived closeness between humans and robots. Results show that communicative touch is considered a more appropriate behaviour for proactive agents rather than reactive agents. Also, people that are generally more positive towards robots find robots that interact by touch less machine-like. These effects illustrate that careful consideration is necessary when incorporating social behaviours in agents' physical interaction design.

Keywords: social agents, human-robot interaction, social behaviour, touch, autonomy, proactive behaviour

Introduction

In recent years there has been an increase in the development of agents that behave socially towards their users. Social interfaces are designed to interact with the users in a way that takes advantage of principles from social interaction between humans in order to achieve more ’natural’ and intuitive interaction with complex systems. Conversational agents, ranging from voice agents to embodied on-screen animated characters and physically embodied robots, build on this concept. These agents use speech, gaze, gesture, intonation and other non-verbal modalities to emulate the experience of human face-to-face conversation with their users [1].

Authors such as Reeves and Nass [2] have shown that social processes resembling those in human communication occur when users interact with technology. Trust in systems for example is influenced by social aspects, such as system etiquette and ’politeness’, regardless of the reliability of the system [3]. When a system actually takes the form of a social character, expectations of social abilities may be even higher [4]. It is not yet fully clear how social behaviours displayed by embodied (either physically, or on-screen) agents influence user perceptions and attitudes. Social behaviours will be evaluated in combination with other design characteristics of the specific social agent. The increasing autonomy of agents is an interesting concept in this regard. When agents are more autonomous people also attribute more responsibility to agents for their behaviour [5]. It is possible that social behaviours have more pronounced effects in interactions with more autonomous agents. Investigating these effects can greatly improve the design of agents and the way they interact with users.

The study reported in this paper explores the way in which an agent's level of autonomy and social behaviours influence users' responses toward the agent. We address a social behaviour that is both expected from a physically embodied agent [6] and is an important aspect of human interaction: communicative touch. We discuss a survey-based, between-subject experiment with 119 participants that investigates the effects of touch and autonomy on user perceptions of and trust in physically embodied agents. We will first discuss the relevant literature background. We will then present our study, discuss its results and discuss a number of implications for the interaction design of social aspects of human-agent dialogues.

Background and motivation

Touch

The physical embodiment of robots makes it likely that humans will come into physical contact with them. Physical contact is an influential aspect of human encounters. Touch both influences and expresses interpersonal bonding; touch can communicate emotion, and can for example also decrease stress [7]. Physical contact can increase compliance with requests [8][9], even when a person is not consciously aware physical contact has occurred [10]. Touch between humans and other living creatures can also have a profound effect on humans' affective state. Petting an animal for example can decrease stress [11]. Touch and tactile qualities are also an important aspect of product design. Additionally, tactile interaction can offer possibilities for intuitive interaction with interactive products and systems, as explored in e.g. tangible interfaces [12]. Interaction using touch might even be expected by users when they encounters physically embodied agents [6]. The accompanying potential for interacting with robots via affective touch has lead to the development of robotic creatures that specifically aim to react to touch and/or offer haptic feedback. Haptic interaction with users is then implemented to achieve affective and social benefits especially in the context of therapeutic care, e.g. [13],[14].

However, humans will not only come into physical contact with robots specifically designed with affective touch capabilities. There are situations where physical contact might occur, 'by accident', or as part of social interaction, e.g. in human-robot collaborations (for instance consider a handshake, high five, pat on the shoulder, hug or elbow nudge). Since physical contact is a very powerful and complex aspect of human communication, we should also consider how touch might influence interaction with physically embodied agents. Physical contact is not always considered appropriate behaviour in every situation [7]. Personal preferences, cultural norms, familiarity, gender and social status all influence which physical distance is preferred in human interaction, how touch is experienced, how physical contact influences interactions and which types of tactile contact are considered appropriate ([7][15], also noted by [14] and [16]).

Given the importance of physical aspects of interaction between humans and the effects of touch on interpersonal bonds and e.g. compliance with requests, it is likely that physical contact will also have an impact on interaction between humans and physically embodied agents. What the effects of physical contact are on users' perceptions and attitudes towards social agents is however unclear. The importance of determining the suitable physical distance, or 'personal space', that robots should keep from users during interaction has been highlighted by e.g. [17] and [16]. However, only limited attention has been given to the effects of physical contact. It is still unclear whether touch in interacting with robots will fully resemble effects in human interaction or interaction with other living creatures. Especially when systems behave in a more autonomous fashion it is likely that users will react to these systems in line with affective and social processes resembling human-human interaction [2]. However, Walters et al. [17] show that some users keep smaller physical distances from robots than from humans. Conversely, negative attitudes towards robots can also increase users' preferred distance from robots [18]. It is unclear whether and when physical interaction might add to user trust and might be helpful in fulfilling social expectations. Studies into the effects of physical contact in combination with other social aspects of interaction are scarce as well. This, while the effects of touch also depend on social factors such as pre-existing bonds and attitudes towards other exhibited behaviours [7]. Research into the effects of physical contact with embodied agents is thus necessary especially when agents autonomously exhibit touch behaviours.

Autonomy

When systems behave in a more autonomous fashion, social processes can play increasingly important roles [2]. We expect that the level of autonomy displayed by embodied social agents will also influence how social and affective aspects of interaction, such as physical contact, are experienced. Perceiving others' needs and intentions and proactively acting on these perceptions are an important part of social interaction. Proactive agents that infer intentions from e.g. non-verbal, or contextual cues can potentially offer more intuitive collaboration with humans [19][20]. System autonomy however has a tensive relationship with predictability and user control [21] [22].

Autonomous behaviour and a loss of perceived user control can negatively influence attitudes and trust [23][24]. Control is also crucial in maintaining combined human-system performance, e.g. in recovering from system mistakes [25]. The willingness to work with autonomous agents, or the willingness to delegate tasks to an agent depends on trust in the outcome of this collaboration [24]. In-depth studies on how combinations of social behaviours, such as touch and proactivity influence user perceptions and trust, are still relatively scarce. Kim and Hinds [5] have found that people attribute more responsibility to a robot for its behaviour when the robot is more autonomous. This suggests that the effects of social behaviours such as touch and the perceptions of these behaviours as being (in)appropriate, could be amplified for more autonomous agents.

Research statement

Based on the literature described above, we expect that touch will have an impact on responses toward physically embodied autonomous agents. We also expect that the effects of social behaviours such as touch will be influenced by the level of agent autonomy. We specifically expect that people will perceive agents with a higher level of autonomy and that use touch as more human than machinelike, and that people will perceive the relationship between humans and such agents as closer. We also expect that people are more willing to comply to an agent's suggestions when it adopts communicative touch and that they will find the agent more dependable. The study we describe below tests these hypotheses. The study additionally investigates the effect of users' attitude towards robots in general on the way people perceive and trust the agent.

Study and Method

An online survey experiment was set up to explore how touch, proactivity and users' general attitude toward robots influences perceptions of and attitudes toward robots. The experiment investigated participants' responses to a video of an interaction between a user and a robotic assistant. The 2x2 experiment varied physical contact (touch, no touch) and robot proactiveness (proactive, reactive behaviour), resulting in four between-subject conditions. Participants were randomly assigned to one of the four conditions.

The online survey started with a set of items on demographics, computer and robot experience. Participants were then shown a movie specific to their randomly assigned condition. Afterwards, participants answered items addressing their perceptions of and attitudes towards the robot.

This study used scripted videos in investigating the attitudes of users towards embodied agents. Previous researchers [4][26][27] found few differences in participants' ratings of robots when viewing a video of or interacting directly with a robot. Ideally, participants would interact with embodied agents themselves, especially when investigating the effects of physical contact. However, robots or other social agents that can interact via touch in a natural enough manner are not yet widely available. Additionally, using such scripted scenarios is very suitable for controlled comparisons of the effect of specific agent behaviours on perceptions and attitudes. Therefore a video-based survey was deemed a appropriate approach for this exploratory study.

Video

For each of the four conditions, a one-minute scripted video was made, showing a user being assisted by a robot while using a computer in an office setting. Selected screenshots of the video can be seen in Figure 1. The female user in the video runs into a computer problem due to a program malfunction. The robot attempts to help by giving advice on how to proceed and how to recover a back-up of lost work. The robot head, arm and leg movements were mostly pre-programmed and remote-controlled during recording of the video. The videos were first taped, after which the vocal interaction between the user and robot were recorded and added to the video. The female user's own voice was used for her part of the vocal interaction. A text-to-speech generator was used to generate the robot's voice, resulting in a synthetic-sounding male voice with an American accent.

Conditions

To manipulate **touch**, the video in the touch condition showed four physical contact moments between the robot and user: the robot touched the user three times and the human touched the robot once. In the non-touch conditions, the robot and user made no physical contact at all. The four touch behaviours were: the user tapping the robot at the beginning of the interaction, the robot tapping the shoulder of the user, the robot and the user sharing a hug, and a high-five between the user and robot at the end of the interaction (see Figure 1 for examples).

The touch behaviours were noticed by participants. Participants in the touch condition reported higher scores for the number of times the human and the robot had tactile contact in the video in response to the question 'What number of times did the robot and the human touch in the movie?'. Scores were significantly higher (T=-12.068, p(1-tailed)$<$.001) in the touch condition (M=4.0, SD=1.3, N=69) compared with the non-touch condition (M=1.3, SD=1.1, N=50).

Proactiveness was manipulated by varying whether help was offered by the robot on its own initiative (proactive) or is offered on the user's request (reactive). In the proactive condition, the robot offered help without active prompting from the user, while in the reactive version of the movie, the user asked for the robot's help. The proactive-touch and reactive-touch videos were not different visually; only the audio differed.

The manipulation check for proactiveness consisted of a scale of two questions: 'If the robot sees that something is wrong, the robot doesn't wait to be asked before helping' and 'The robot proactively helps the user' (Cronbach's alpha(as measure of reliability)=.699, M=4.5, SD=1.4). Scores on the proactiveness scale were significantly higher in the proactive condition than in the reactive condition (T=-6.488, p(1-tailed)$<$.001, M(proactive)=5.2, SD=.97, M(reactive)=3.7, SD=1.4).

The amount of physical contact in the videos did not influence the perceived proactiveness of the robot and vice versa; the conditions were independent. Participants' scores on the (negative) attitude toward robots in general NARS scale [18] were not found to influence scores on the manipulation checks either.

Robot used

The robot used is the commercially available WowWee Robosapien V2, with both machine- and human-like features. Since the robot is commercially available and to an extent marketed as a toy, we wanted to make sure the robot was not perceived as too toy-like for our purposes. Therefore, participants were asked to rate pictures of the Robosapien used and five other relatively well-known robots on a scale of 1 (robotic) to 7 (toy-like). The included robots and their scores were: Honda's Asimo (M=3.12, SD=1.8), NEC's Papero (M=4.51, SD=1.9), Sony's Aibo (M=4.87, SD=1.7), Leonardo [28] (M=6.18, SD=1.2) and Ugobe's Pleo (M=6.57, SD=0.94). Of this collection of robots, only Asimo was perceived as less toy-like than the Robosapien (M=4.0, SD=2.0) used in this study. While a comparison on the basis of pictures and not behaviours is limited, this is an indication that when using a robot in a study using scenarios, laymen perceptions of agents might not always match actual capabilities. The robot used here is perceived as toy to a similar extent as other, more advanced, robots. We concluded that the robot used was suitable for such a scenario-based study.

Participants

In total, 119 participants completed the survey-based experiment. 19 participants were female (16%), 100 were male (84%). Their average age was 25 years (SD=6). The majority of participants (80%) were Dutch. No differences were found between conditions on participants' gender, age, education level, computer and robot experience.

Attitude towards robots in general

Participants' (negative) attitude towards robots in general was measured using Nomura's 8-item NARS scale [18], with items such as 'I feel comfortable being with robots' and 'I would feel uneasy if I was given a job where I had to use robots'(alpha=.825, M=3.4, SD=1.0).

Dependent measures

Dependent variables included human-and machine-likeness, perceived closeness of human and robot, compliance (willingness to follow-up on the robot's suggestion) and robot dependability. Items were measured on five or seven-point Likert-type scales ranging from strongly disagree to strongly agree.

Human- and machine-likeness. While machine- and human-likeness are often viewed as ends of the same scale, one of our pilot studies indicated that a robot can be simultaneously viewed as human- and machine-like (e.g. a machine-like appearance, while behaviour is perceived as more human-like). This is why we distinguish between human-likeness and machine-likeness in this study. *Human-likeness* was measured using 5 items adapted from Evers et al. [29] (alpha=.76, M= 3.8, SD=1.1). Example items included: 'The robot acts like a person', 'The robot has characteristics that you would expect of a human'. *Machine-likeness* was measured using 2 items ([29], alpha=.80, M=2.2, SD=.96): 'The robot has machine-like attributes' and 'The robot looks like a machine or a mechanical device'.

Closeness. The perceived closeness of the relationship between the user and robot was measured using a pictorial scale adapted from Aron et al. [30] (also used in an adapted form in [31]). The scale used here consists of six pictorial representations of the relationship between the human and robot. Both are represented by a circle; the more the circles overlap, the closer the relationship is perceived to be.

Compliance or willingness to follow-up on the robot's suggestion was measured using two items (adapted from [29], alpha=.75, M:3.4, SD:.80): 'To what extent do you think the person in the movie should follow the recommendations of the robot?' and 'If you were in the same situation as the person in the movie, would you follow the robot's advice?'.

Dependability of the robot was measured using three items adapted from [29] (alpha=.76, M=4.9, SD=1.1). Example items were: 'The robot was capable of performing its job' and 'The robot had knowledge about its task'.

Results

The results of this study indicate that user perceptions and attitudes towards embodied agents are influenced by how physical contact and proactive behaviours are combined. Three-way ANOVAs did not show significant interactions between all three factors robot proactiveness, touch and attitude towards robots in general. However, significant (two-way interaction and main) effects were found. These effects are discussed below.

Interaction effects proactiveness and touch

We expected the effect of social behaviours such as touch to be stronger when an agent is more proactive. Two-way, independent ANOVAs with proactiveness and touch as factors were used to check for interaction effects between proactiveness and touch. Significant interaction effects were found for perceived machine-likeness ($F(1,118)=6.66$, $p=.011$) and perceived dependability ($F(1,118)=4.66$, $p=.033$).

Simple effects analysis was carried out for both of these interaction effects. We found that the effect of touch on perceived machine-likeness was significant in both the reactive (F1,116)=3.98, p=.048) and proactive conditions (F(1,116)=5.81, p=.017). Interestingly, the 'inverse' combinations touch, reactive and non-touch, proactive scored highest on perceived machine-likeness (See Figure 2). Touch decreased machine-likeness for the proactive robot (proactive, touch M=1.9, SD=.76; proactive, non-touch M=2.4, SD=.80). In the reactive condition, touch instead increased machine-likeness (reactive, touch M=2.5, SD=1.1; reactive, non-touch M=2.1, SD=1.1).

Analysis of the interaction effect on perceived dependability showed that in the reactive condition touch influenced perceived dependability (F(1,116)=5.43, p=.022), while in the proactive condition it did not (F(1,116)=.24, p=.622) (See Figure 2). In the reactive condition perceived dependability was significantly higher for the non-touch version (M=5.4, SD=.80) than for the touch version (M=4.6, SD=1.0). In the proactive condition, the touch robot scored higher on perceived dependability (M=4.90, SD=1.03) than the non-touch robot (M=4.8, SD=1.2). However, this difference was not significant.

No interaction effects were found for perceived closeness of the relationship between the human and robot, human-likeness and compliance/willingness to follow-up on the robot's suggestion.

In summary, we found that in this study the effects of touch and proactivity interacted in their effects on perceived machine-likeness and dependability. Participants found the proactive robot less machine-like when it used touch, while they found the reactive robot less machine-like and more dependable when it did not use touch. This indicates that the way in which communicative touch behaviours are combined with proactivity will influence perceptions of physically embodied agents.

Interaction effects attitude towards robots

Participants were classified into two groups, either having a positive attitude towards robots with a score on the NARS scale below the mean of 3.4 (SD=1.0) and as having a negative attitude towards robots for higher scores. No significant interaction effects were found between participants' attitude towards robots in general and proactiveness. Interaction effects were however found between attitude and touch for perceived machine-likeness ($F(1,116)=5.36$, $p=.022$). The absence of touch resulted in differences ($F(1,116)=6.58$, $p=.012$) between how machine-like the robot was perceived by participants with a more positive attitude towards robots (M=2.5, SD=.98) and those with a more negative attitude (M=1.8, SD=.69). In line with our expectations, this indicates that when robots use touch, participants with positive attitudes toward robots see them as less machine-like (Figure 2).

Main effects attitude towards robots

Main effects were found for participants' attitude toward robots on perceived human-likeness ($F(1,118)=8.01$, $p=.006$) and perceived closeness of the relationship between the human and robot ($F(1,118)=6.80$, $p=.010$) (Figure 3). Participants with a more negative attitude toward robots perceived the robot as less human-like (M=3.5, SD=1.1 vs. M=4.0, SD=1.0) and the relationship with the human as less close (M=2.5, SD=1.3 vs. M=3.0, SD=1.1). Positive general attitudes toward robots thus were found to decrease the experienced social distance between humans and embodied agents.

Discussion and Conclusions

We argue that careful consideration is necessary when incorporating autonomy and social behaviours such as communicative touch in user interaction with social agents. Our results show that how these behaviours are combined can determine whether they have a positive or negative impact on attitudes toward embodied social agents. The proactive agent in this study was seen as less machine-like and more dependable when interaction was complemented with physical contact between the human and agent. The reactive robot however, was seen as less dependable when it engaged in physical interaction with the user. It appears touch behaviours are considered more appropriate for proactive, than for reactive embodied agents.

When designing interaction with embodied agents, user characteristics have to be taken into account as well. Negative attitudes toward robots decreased perceptions of human-likeness and closeness of the relationship between the human and robot. User characteristics can also influence the impact of social behaviours. For users with a positive attitude toward robots, touch appeared to be considered a more appropriate form of interaction; participants found a robot that does not engage in physical interaction more machine-like than participants with a more negative attitude. Future studies should therefore not only look at the effects of social behaviours such as touch alone, but should consider how they are combined with other characteristics of the robot, user and interaction context.

Limitations and future work

In this first study we only addressed the effects of touch and proactiveness on perceptions of the interaction; participants consciously watched a robot and user engaging in touch interaction. It is possible that specific aspects of the videos and their scenarios might have affected perceptions. Which specific touch behaviours are included in such an scenario can for example affect perceptions of an interaction. Touch behaviours can also result in more robot movement. How natural and smooth an agent's movements appear to users might affect their perceptions and attitudes towards the agent.

To further our understanding of interaction with physically embodied agents it is important to follow-up with studies in which participants actually experience the interaction; touching or being touched by an embodied agent themselves. This is for example important to further investigate the effects of unintended tactile contact on e.g. compliance and trust. The way an agent is embodied is also likely to influence interaction. Various tactile properties such as 'feel' of the robot's 'skin', force, duration and type of touch (e.g. handshake), combined with agents' physical appearance, offer additional challenges for future research.

For on-screen agents other intriguing questions can be raised. This study shows that viewing an interaction involving physical contact influences perceptions and attitudes. It would be interesting to consider whether such effects have to be taken into account when multiple animated on-screen agents interact. We may for example also need to consider how contact between social characters and a virtual representation of the user in virtual worlds can influence user attitudes. It is important to know how touches, whether physically experienced or observed, are understood and which intentions and messages might be communicated by physical contact. Touch is a heavily culture- and context-dependent aspect of interaction; therefore studies on physical contact between humans and social agents and autonomy in other settings and for different cultures, ages and gender combinations will be crucial.

While this study specifically focused on touch behaviours and proactiveness, its results indicate that agents' social behaviours cannot be developed in a vacuum. If social agents (whether physically embodied, or on-screen agents) engage in social behaviours, the perceptions and effects of these behaviours will be dependent on their combination with other characteristics and behaviours of the agent and user. The design of interactions with social agents can greatly benefit from better understanding of these effects.

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Figure 1: Selected screenshots. Left: interaction between user and robot, as in all conditions. Middle: shoulder pat, touch condition. Right: high five, touch condition.

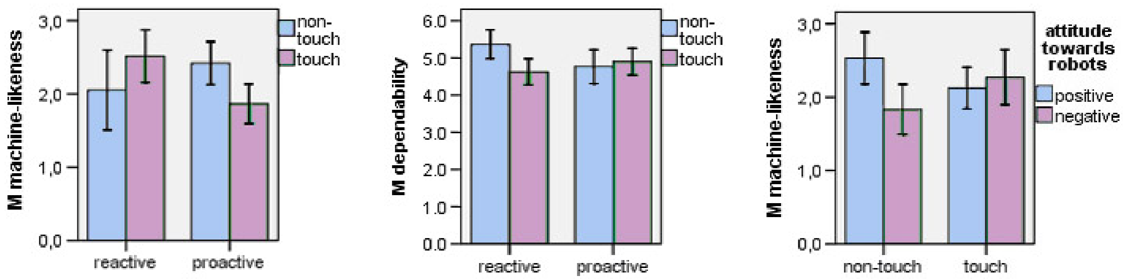

Figure 2: Interaction effects. Left: touch X proactiveness on perceived machine-likeness. Middle: touch X proactiveness on perceived dependability. Right: touch X attitude towards robots in general on perceived machine-likeness.

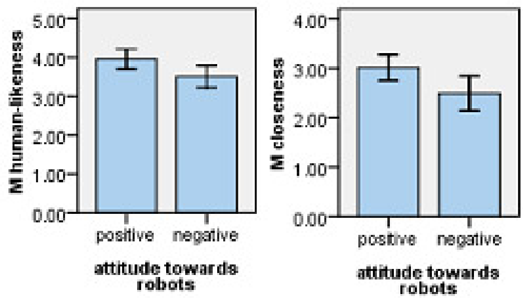

Figure 3: Effect attitude towards robots in general on perceived human-likeness and perceived closeness of the human-robot relationship