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Touched by robots: effects of physical contact and proactiveness

H. Cramer, N. Kemper, A. Amin, V. Evers

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P.O. Box 94079, 1090 GB Amsterdam (NL)
Science Park 123, 1098 XG Amsterdam (NL)
Telephone +31 20 592 9333
Telefax +31 20 592 4199

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ABSTRACT
Even though robots' physical embodiment makes it likely humans will come into physical contact with robots, the effects of touch on attitudes in human-robot interaction are still relatively unknown. This survey and video-based, experiment (N=199) investigates the effects of touch and robots interactions. Results show that physical contact and autonomous behavior interact in their effects on perceived machine-likeness and dependability. Attitudes towards robots in general also affected the influence of touch on perceptions of a robot.

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Touched by Robots: Effects of Physical Contact and Proactiveness

Henriette Cramer
Human-Computer Studies
University of Amsterdam
Science Park 107
1098 XG Amsterdam
hcramer@science.uva.nl

Vanessa Evers
Human-Computer Studies
University of Amsterdam
Science Park 107
1098 XG Amsterdam
evers@science.uva.nl

Nicander Kemper
Human-Computer Studies
University of Amsterdam
Science Park 107
1098 XG Amsterdam
nicander@gmail.com

Alia Amin
CWI
P.O. Box 94079
1090 GB Amsterdam
alia.amin@cwi.nl

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Abstract
Even though robots' physical embodiment makes it likely humans will come into physical contact with robots, the effects of touch on attitudes in human-robot interaction are still relatively unknown. This survey- and video-based, experiment (N=119) investigates the effects of touch and robots' proactive behaviour on people's perceptions of human-robot interactions. Results show that physical contact and autonomous behaviour interact in their effects on perceived machine-likeness and dependability. Attitudes towards robots in general also affected the influence of touch on perceptions of a robot.

Keywords
Touch, proactiveness, attitudes towards robots, embodiment, human-robot interaction

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Introduction
The physical embodiment of robots and their growing availability makes it likely that humans will come into physical contact with robots. Physical contact is a powerful aspect of human interaction. Touch can for example affect interpersonal bonding and the affective

experience of interactions (Fisher et al., 1976). Touch between humans and other living creatures can also have a profound effect on humans' affective state (Shiloh et al., 2003). The accompanying potential for interacting with robots via affective touch has lead to development of robotic creatures that specifically aim to react to touch and/or offer haptic feedback (e.g. Stiehl et al., 2006; Yohanan and MacLean, 2008). However, humans will not only come into physical contact with robots which design has specifically focused on affective touch. There are situations where physical contact might occur unconsciously, 'by accident', or might be a part of social interaction, e.g. in human-robot collaborations.

While the importance of determining suitable physical distances between robots and humans has been highlighted by e.g. Walters et al., (2005) and Tapus et al., (2008), only limited attention has been given to the effects of physical contact or touch per se. It is also unclear whether and when physical interaction might be helpful in achieving culturally appropriate interactions in which a robot fulfils social expectations by engaging in expected touch (e.g. hand shakes in many Western interactions). 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 (Fisher et al., 1976). The level of autonomy displayed by humanoid and zoologically inspired robots is one of the factors we expect to influence how social and affective aspects of interaction, such as physical contact, are experienced. Developing proactive robots, which appear to infer intentions of users from social, affective and contextual cues, and act without explicitly receiving commands from users, have been suggested as a route to more intuitive human-robot cooperation (e.g. Schrempf et al., 2005). When systems behave in such a more autonomous fashion, it is likely users will react to these systems following affective and social processes resembling human-human interaction (Reeves and Nass, 1997). Such effects are also relevant for robots that appear more zoomorphic than humanoid. These robots might combine physical interaction and proactive behaviours in emulating 'natural' behaviour. This can affect how intuitive interactions appear and to what extent users trust the services offered by e.g. zoomorphic companion robots. However, in-depth studies on how combinations of physical contact and proactive behaviour affect user perceptions and attitudes are still relatively scarce.

This paper discusses a survey- and video-based, between-subject experiment that illustrates how the interplay of touch and proactiveness can affect perceptions and trust of interactions between humans and robots. We discuss how participants' attitude towards robots in general also influences perceptions of human-robot interactions and moderates the effects of touch. Additionally, this paper discusses a number of implications for research into human-robot interaction and designing (non-verbal) aspects of human-robot dialogues.

Background

Touch is an important factor in human interaction. Touch can communicate emotion, decrease stress, express and increase trust and interpersonal attachment (Fisher et al., 1976). Touch can also increase compliance with requests (Patterson et al., 1986), even when a person is not consciously aware contact has occurred (Gueguen, 2002). Physical contact furthermore plays a role in human interaction with other creatures. Petting an animal for example can decrease human stress (Shiloh et al., 2003). Additionally, tactile qualities are an important aspect of e.g. product design. Tactile interaction can offer possibilities for intuitive interaction with interactive products and systems, as explored in e.g. tangible interfaces (Ishii and Ulmer, 1997). Touch is likely to also play a role in human interaction with physically embodied, social robots and might even be expected by users (Lee et al., 2006). It has to be taken into account however, that touch is not always considered appropriate in every situation. In human interaction, personal preferences, cultural norms, familiarity, gender and social status all influence which physical distance is preferred, how touch is experienced, how physical contact affects interactions and which types of tactile contact (e.g. hugs, handshakes) are considered appropriate (e.g. Major and Heslin, 1982; also noted by Yohanan and MacLean, 2008; Tapus et al., 2008). Given the importance of physical aspects of interaction and the effects of physical contact on trust and compliance with requests, it is likely that touch between humans and robots will affect interaction as well.

It is yet unclear whether touch in interacting with (semi-autonomous) robots will fully resemble effects in human interaction or interaction with other living creatures. Walters et al. (2005) for example show that some users keep smaller physical distances from robots than from humans. However, negative attitudes towards robots can also increase users' preferred distance from robots and increase the time taken to respond to a robot (Nomura et al., 2004). How autonomous behaviour of robots might interact with the effects of physical contact is unclear. Proactive robots that infer intentions from e.g. non-verbal, or contextual cues offer potentially more intuitive collaboration between humans and robots (Schrempf et al., 2005). Proactive systems work on behalf of the user and take initiative in an autonomous fashion (Salovaara and Oulasvirta, 2004). Robot proactivity can e.g. relieve the user from the burden of having to initiate robot actions. Systems' autonomy however has to be balanced with predictability and user control (Höök, 1997); autonomous behaviour can negatively affect attitudes and trust (Jameson and Schwarzkopf, 2002). Such negative reactions might in turn change reactions to touch; e.g. sudden touches from a robot that is acting unpredictable and cause users to perceive a loss of control, are not likely to have positive effects. Kim and Hinds (2006) also found that when a robot is more autonomous, people attribute more credit and blame to the robot for its behaviour. This might imply that the effects of social behaviours such as touch and the perceptions of them as being (in)appropriate, might be amplified for proactive robots.

Based on the literature described above, we expect that touch will affect human-robot interaction and attitudes towards decisions or suggestions made by (semi-) autonomous robots. Furthermore, we expect that how physical contact, autonomous behaviour and user attitudes towards robot are combined will also affect attitudes. The study described below illustrates the importance of the mix of these factors for perceptions of human-robot interactions.

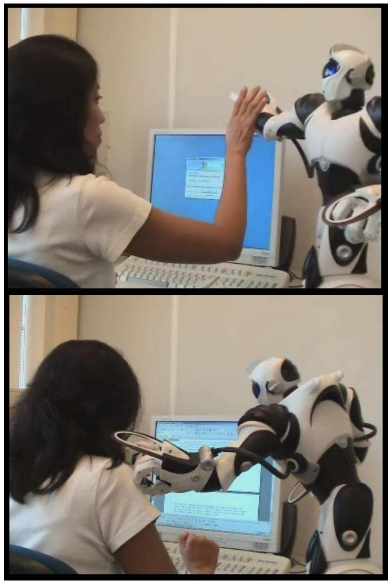

Figure 1 Selected screen shots touch condition.

Study: Touch, Proactiveness, Attitude

To investigate how touch, proactiveness and users' general attitude towards robots affect perceptions of and attitudes towards interaction with robots, we conducted an online survey-based experiment. The experiment investigated participants' attitudes towards a video of an interaction between a user and a robotic assistant (Fig 1). The 2x2, between-subject experiment varied touch and proactiveness resulting in four randomly assigned conditions. For each condition, a one-minute movie was made, showing a woman being assisted by a robot while using a computer (similar video-based methods are described in Woods et al., 2006). The user in the video runs into a computer problem and the robot attempts to help by giving advice on how to proceed and how to recover a back-up of lost work. The robot used is the relatively small WowWee Robosapien V2, with both machine- and human-like features. 119 (predominantly Dutch) participants completed the experiment survey (19 of which female, age M=25, SD=6, r=14-55), each participating in one condition.

Conditions and procedure

Touch was manipulated by varying the number of times the robot touched the user during the interaction shown: none for the non-touch condition videos, four in the touch condition. The touches included in the touch condition video were: the user tapping the robot, the robot tapping the user's shoulder, a 'hug' and a high five. *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). Scores of survey items on perceived proactiveness and reported number of touches showed both manipulations were successful (proactiveness $T=-6.488$, $p<.001$; touch $T=-12.068$, $p<.001$).

Measures

Participants' (negative) *attitude towards robots* in general was measured using Nomura's (2004) 8-item NARS scale, (e.g. "I feel comfortable being with robots"). Dependent variables included human-and machine-likeness, perceived closeness of human and robot and perceived robot dependability. *Human-likeness* was measured using 5 items ($\alpha=.76$, M=3.8, SD=1.1), e.g. "The robot acts like a person". *Machine-likeness* was measured using 2 items ($\alpha=.80$, M=2.2, SD=.96), e.g. "The robot has machine-like attributes". A pictorial scale was used for *perceived closeness* (Hinds et al., 2004); the more two circles representing the human or robot overlap, the closer the relationship is perceived. *Dependability of the robot* was measured using three items were adapted from Evers et al., (2008) ($\alpha=.76$, M=4.9, SD=1.1) e.g. "The robot was capable of performing its job". 7-point Likert-type scales ranged from strongly disagree to strongly agree.

Results

The study shows that how tactile interaction and proactive behaviour are combined affects robot perceptions and user attitudes. Three-way ANOVAs did not show significant interactions between all three factors robot proactiveness, touch and attitude towards robots in general. However, as discussed below, significant (two-way interaction and main) effects were found.

Interaction proactiveness and touch

Two-way, independent ANOVAs yielded interaction effects between proactiveness and touch for perceived machinelikeness (F(1,118)=6.66, p=.01) and perceived dependability (F(1,118)=4.66, p=.03). Interestingly, the 'inverse' combinations touch, reactive and non-touch, proactive scored highest on perceived machine-likeness. 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). Also contrary to our expectations, 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) (F(1,116)=5.43, p=.02). In the proactive condition touch seemed to increase perceived dependability, but this difference was not significant (F(1,116)=.24, p=.62). How touch and proactiveness are combined will thus affect perceived machine-likeness of a robot and whether it is perceived as dependable.

Effects attitude towards robots

Participants were classified as having a positive attitude towards robots with a score on the NARS scale below the mean of 3.4 (SD=1.0) and negative for higher scores. No significant interaction effects were found between participants' attitude towards robots in general and proactiveness. Interaction effects were 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 machinelike 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). It appears that when robots do not interact with touch, participants with positive attitudes see them as more machine-like.

Main effects were found for participants' attitude towards robots on perceived human-likeness (F(1,118)=8.01, p=.006) and perceived closeness between the human and robot (F(1,118)=6.80, p=.010). Participants with a more negative attitude towards 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=3.02, SD=1.06). General attitudes thus appear to affect the experienced social distance to robots.

Discussion and conclusion

We argue that careful consideration is necessary when combining social behaviours such as proactivity and touch in interacting with different types of users, as these combinations can have both positive and negative impacts on human-robot interactions. Our study shows that how touch is combined with proactiveness affects perceptions of robots and their interactions with humans. Proactive robots are seen as less machine-like when their interaction is complemented with tactile interaction. Surprisingly, the reactive robot was seen as less dependable when it engaged in physical interaction with the user. It appears users consider touch behaviours more appropriate for proactive, than for reactive robots. User characteristics are an important factor as well. Negative attitudes towards robots decreased perceptions of human-likeness and closeness between the human and robot. For users with a positive attitude towards robots, touch appears a more natural part of interaction; they appear to consider a robot that does not engage in physical interaction as more machine-like than users with a more negative attitude. Future studies should thus not only look at the effects of touch alone, but should consider how tactile contact is combined with characteristics of the robot, the user and their interaction.

We here only addressed the effects of touch and proactiveness on perceptions of an interaction; participants consciously watched a robot and user engaging in touch interaction. It did not involve participants actually experiencing the interaction, touching or being touched by a robot themselves. It is important to further investigate the effects of such (un)conscious tactile contact on e.g. compliance and trust when participants do physically experience the touches themselves. Other tactile properties such as 'feel' of the robot's 'skin', force, duration and type of touch (e.g. handshake) offer additional intriguing questions (and challenges) for future research. Additionally, we should also consider that touch is a heavily culture- and context-dependent aspect of interaction; therefore studies on touch and proactiveness in other settings and for different cultures, ages and gender combinations will be crucial. It is important to know how touches are understood and which intentions and messages might be communicated by physical contact, both from robots to human users, and from these users to a robot. The type of robot embodiment and its combination with touch and autonomy are likely to affect perceptions as well. Robots' physical form and appearance can also be expected to affect interaction (as considered by e.g. Stiehl et al., 2006). How associated expectations affect reactions to autonomous and physical behaviours is yet unclear.

We have shown that considering the effects of physical contact is not only relevant for projects that specifically focus on tactile interaction with robots. Physical contact and its combination with other aspects of an interaction, such as robot proactiveness, influence user perceptions and trust for other types of human-robot interactions as well. Thus, in order to improve interaction between humans and robots, it is important we consider the effects of tactile interaction for all robots that exhibit autonomous behaviour and might come into physical contact with humans.

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