That Robot Touch that Means so Much: On the Psychological Effects of Human-Robot Touch

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“Everything will be okay in the end.

If it's not okay, it's not the end.”

— John Lennon

ABSTRACT

Robots are unique compared to other forms of artificial intelligence because they own a physical body that allows them to get into physical contact with humans. There is a huge amount of literature and empirical work that demonstrates the importance of touch for the development of man as well as other species as monkeys. Especially, the positive impact of interpersonal touch on health, bonding and attachment has been frequently observed. Furthermore, positive evaluative consequences of interpersonal touch on the toucher, i.e., the initiator of touch, and the surroundings has been revealed, as well as an influence on compliance and helping. Taken together it seems as if touch is a powerful way of nonverbal communication that is capable to increase the well-being of the receiver, and the initiator of touch, too. Against the background of earlier work in the realm of human-computer interaction that demonstrated that people equate interactions with interactive media as computers or robots with interpersonal interactions (*media equation*: Nass & Moon, 2000; Reeves & Nass, 1996; see also Krämer & Hoffmann, 2016, for an updated overview), it is assumed that touch from a robot can result in comparable positive impacts on human well-being. As a prerequisite for the examination of the physiological and psychological effects of human-robot touch, basic research was first necessary to structure the field of human-robot touch in comparison to interpersonal touch. For that purpose, four empirical studies were conducted that untangled the perception of human-robot touch referring to research on interpersonal touch, to test whether the media equation also applies to a fundamental interpersonal phenomenon such as touch. Therefore, the perception of different forms of human-robot touch with different robots (Study 1 & 2) in different interaction contexts (Study 3) were first considered in the most controllable way by means of the observation and evaluation of photographs. In addition, the underlying appraisal process that decides upon the final reaction to robot touch was theoretically and practically considered based on *expectancy violations theory* (Burgoon, 1983; Burgoon & Hale, 1988) that originates from the field of interpersonal communication. Finally, actual touch initiated by a robot to participants in a laboratory experiment were regarded and analyzed with respect to the impact of robot touch on participants' subjective evaluation, as well as on observable reactions as laughing, compliance and helping (Study 4). In conclusion, influencing variables that determine the desirability of human-robot touch were revealed, namely

characteristics of the robot (morphology and size), characteristics of the person (e.g., attitudes towards touch, attitudes towards robots, touch expectancies), the intimacy and direction of touch, i.e., who touches whom, and the meaning assigned to human-robot touch regarding relational interpretations of closeness and affection. Finally, positive emotional reactions to actual robot-initiated touch, and heightened compliance have been observed in a laboratory experiment.

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I: INTRODUCTION

"*Tactile interaction is at the heart of human-robot relationships.*"
(Walker & Bartneck, 2013, p. 807)

In a recent article entitled "That human touch that means so much", Mandy Tjew-A-Sin and Sander Koole (Sin & Koole, 2013) discussed the importance and power of human touch on an emotional as well as a social level. They argue that interpersonal touch, although important, is becoming increasingly rare in modern societies, where large parts of life happen digitally. Ultimately, the authors raised the question as to whether emerging haptic technology might replace human touch in the future.

When we think of robots, it can be expected that they will become an increasing part of our daily lives in the near future. They may for example appear as receptionists or shopping assistants in public places, or as personal robots in our private households. David Levy forecasts that in the more distant future, humans will even develop personal relationships with robots comparable to interpersonal relationships, and these might thus involve intercourse and marriage, as in the title of his book "Love and sex with robots: The evolution of human-robot relationships" (Levy, 2009). This could imply that the frequency of human-to-human touch could decline still further. This is somewhat alarming, as it has been demonstrated that touch is a fundamental need in humans, and also some animal species (T. Field, 2010; Harlow & Zimmerman, 1959).

However, if we imagine being frequently surrounded by robots that possess a physical body, it is likely that we will make physical contact with them. Hence, the question arises as to whether touch with robots might fulfill human needs for touch.

As Walker and Bartneck (2013) empathized in the citation above, tactile interaction or human-robot touch (HRT) will become a core interaction feature and will shape our future relationships with robots. Although the psychological effects of other artificial characters, like virtual agents, have been widely examined, the ability to get into immediate physical contact with humans is unique to robots, and is thus of particular interest (cf. see Hoffmann & Krämer, 2013; Li, 2015 for overviews on the comparison of robots and virtual characters).

The application fields in which touch between humans and robots can be expected are diverse. For example, HRT could happen in functional contexts, where robots assist in transportation, washing, or collaborative assembly line tasks. Similarly, robot companions might get into physical contact with humans in rather affective contexts, where robots serve as everyday life companions or therapeutic devices (Libin & Libin, 2004; Shibata et al., 2001; Wada & Shibata, 2006). In the latter cases, touch does not fulfill a specific function, but is rather communicative or emotion-driven.

Extensive knowledge on the importance of touch in human development and its impact on diverse interaction outcomes is already in existence from interpersonal communication research. Efforts in this realm have revealed that touch has several positive effects on the well-being of the recipient (e.g., pain and stress reduction: Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005; Field, 2010; prevention of catching a cold: Cohen, Janicki-Deverts, Turner, & Doyle, 2014), as well as on the initiator of touch (e.g., a better evaluation: Fisher, Rytting, & Heslin, 1976); higher tips: Crusco & Wetzel, 1984); or stronger compliance to a request: Guéguen, 2007).

On the basis of the knowledge that interpersonal phenomena from interactions between humans, such as reciprocity and politeness, are similarly observed in interactions with interactive media (e.g., Fogg & Nass, 1997; Nass, Moon, & Carney, 1999), it seems reasonable to assume that touch with an embodied interactive technology such as a robot will evoke effects comparable to interpersonal touch.

With the aim of designing robots that are beneficial for human contentment and well-being, HRT seems to be a research area worth concentrating on. So far, research in the realm of human-robot interactions has demonstrated that touching a soft robotic seal leads to lowered depression, stress, and pain (e.g., Okita, 2013; Shibata et al., 2001; Shibata & Wada, 2010; Wada, Shibata, Saito, & Tanie, 2002); effects that have commonly been observed in therapies using living animals. Furthermore, the impact of reciprocal HRT and touch directed from a robot to a human have been investigated with regard to various subjective (e.g., evaluation of the robot: Cramer, Kemper, Amin, & Evers, 2009; Nie, Park, Marin, & Sundar, 2012) and observational outcome variables (e.g., the motivation to fulfill a task: Nakagawa et al., 2011; Shiomi et al., 2016). Overall, HRT appears to have an impact on humans, but until now, little importance has been given to the systematical examination of HRT: *How do humans interpret touch from a robot? Which forms of HRT are acceptable* *to humans? Which factors influence the appraisal of HRT? With which robots, and under which circumstances, is HRT acceptable?* And finally: *Can HRT positively affect human well-being, as interpersonal touch does?*

On the basis of these open questions, the present dissertation builds on interpersonal theories to explain how touch is perceived, interpreted, and evaluated, to contribute to the structured investigation of touch in interactions with physically embodied robots. Therefore, the theory section (II) firstly forms a brief summary of the media equation approach that serves as a foundation on which the study of HRT according to the literature on interpersonal touch is based (Chapter 1), before establishing a theoretical basis for the assumed effects. Chapter 2 then presents a definition of interpersonal touch and a summary of related work in this realm. Thereafter, approaches to explain the positive effects of interpersonal touch are delineated, leading to a short excursion into the effects of touch with, or through, technologies and objects different to robots. The development of a definition of HRT to distinguish it from interpersonal touch and object touch is elaborated on in Chapter 3, followed by a comprehensive overview of earlier work on HRT, which finally concludes with the derivation of the guiding research questions based on the gaps identified in earlier work (Chapter 5). Subsequently, four empirical studies were consecutively conducted to answer the research questions; these are presented in the empirical studies section (III), which is then followed by a global discussion (IV).

II: THEORETICAL BACKGROUND

1 Interpersonal Communication as a Theoretical Basis to Study HRT

Human–robot interaction represents a young interdisciplinary research field that brings together knowledge from various disciplines such as robotics, engineering, computer science, artificial intelligence, and psychology. One challenge for such a young and interdisciplinary field is the establishment of shared research methods, and the development of theories based on existing evidence. Due to the limited evidence, approaches from cognate disciplines are often applied to examine questions in a new field of research.

Within human–computer interaction, Clifford Nass and his colleagues were pioneers who established a research paradigm that allowed the application of established theories from sociology, psychology and communication sciences to human–computer interactions: the Computers-Are-Social-Actors paradigm (CASA paradigm; e.g., Nass, Steuer, & Tauber, 1994; Nass, Steuer, Tauber, & Reeder, 1993). One precondition of this approach is the assumption that humans equate their interactions with media (including computers, smartphones, virtual characters and robots) to real life interactions, because "… individuals' interactions with computers are fundamentally social" (Nass, Steuer, & Tauber, 1994, p. 72). Hence, the phenomenon has been termed *media equation* by the authors. One reason for this social reactions to media are the social cues that these technologies possess, such as a humanlike appearance and/or personality, the ability to communicate with natural language, and the adoption of a role typically fulfilled by humans (e.g., tutor or counselor, cf. Fogg, 2002). Because of the fundamental social nature of humans, and the presence of social cues that trigger social reactions in humans, social norms such as politeness and reciprocity have been demonstrated to apply to technologies, too (Hoffmann, Krämer, Lam-Chi, & Kopp, 2009; Nass & Moon, 2000; Nass, Moon, & Carney, 1999). For example, in line with the social norm of reciprocity, studies indicate that participants are more likely to help a computer that helped them before (Nass & Moon, 2000).

To examine the applicability of social phenomena in a new context like human–computer, or human–robot interaction, theories and methods from the interpersonal context have been used, while one person was replaced by a computer or robot in the experimental setup. If the same phenomena, e.g., reciprocity, was observed when one interaction partner was a computer or robot instead of another human, the media equation, i.e., the equation of human–technology with human–human communication, was successful (Nass, Steuer, & Tauber, 1994).

Up to now, plenty of experimental studies have been conducted in the realm of media equation research (CASA paradigm) that replicated most diverse interpersonal phenomena such as impression management, flattery, stereotyping, and politeness (see Reeves & Nass, 1996 for an overview of the native studies with computers and graphical representations, and Krämer, Rosenthal-von der Pütten, & Hoffmann, 2015 for a recent summary on social reactions towards virtual and robot companions).

Against this background, this dissertation assumes that the examination of touch between humans and robots can be based on earlier research on interpersonal touch in the realm of interpersonal communication research. Hence, research on interpersonal touch is outlined in the following chapter, as a theoretical and methodological basis. Especially, the positive effects of interpersonal touch are emphasized to facilitate a transfer to the investigation of robot touch, and its impact on human well-being.

2 Interpersonal Touch

2.1 Definition of Interpersonal Touch

"Touching is an intentional physical contact
between two or more individuals."
(Watson, 1975, p. 104)

By interpersonal touch, an intentional bodily contact between a human dyad is meant. As Watson (1975) stated, touching could also involve more than two individuals, but for simplification, the present theoretical section is narrowed to dyads. In the realm of this thesis the term interpersonal touch is interchangeably used for "human touch" (e.g., Bush, 2001), "social touch" (e.g., Thayer, 1986; Wilhelm, Kochar, Roth, & Gross, 2001), and "human physical contact" (Knapp & Hall, 2010).

According to Thayer (1986), interpersonal touch can be distinguished by the information that is immediately conveyed through touch, as the temperature of the skin, the texture, or the softness. Furthermore, qualities of the touch, such as the duration, frequency, or intensity are of importance. Likewise, it has been summarized as crucial by Thayer (1986), which parts of the body are involved (e.g., a touch from hand to hand, or hand to face), in which context touch happens (e.g., in private or in public, or at a crowded place), which other signals are present (e.g., eye gaze or speech), which relationship exist between the toucher and the recipient, and who initiated the touch (e.g., a higher or lower status person). Finally, it is meaningful whether touch is expected or not, and if it is reciprocated or refused (cf. Thayer, 1986, p. 13).

Other signals as eye gaze or verbal communication that accompany touch are one of several confounds that impede the controlled investigation of interpersonal touch (for a comprehensive overview see Lewis & Derlega, 1997). Consistent with Argyle and Dean (1965), it is known that individuals pursuit an equilibrium. If one's personal space is, e.g., violated by constant eye gaze, equilibrium theory predicts that one would likely compensate for the invasion with increasing distance, or averting eye gaze. Hence, the experimental investigation of touch is difficult, because even a professional actor might unconsciously show variations in her/his facial expression when touching a participant. The methodological problem could be overcome with the utilization of a robot whose nonverbal behavior could be fully controlled.

In the following, the different meanings of interpersonal touch that have been addressed in the literature are presented.

2.2 The Meanings of Different Forms of Interpersonal Touch

2.2.1 Affective and Functional Purposes of Interpersonal Touch

The purpose of interpersonal touch can generally be rather functional or affective. Functional touch follows instrumental functions and aims at achieving a goal beyond physical contact, e.g., putting the hand on another's forehead in order to take the temperature. In contrast, affective touch is less goal-oriented and has an emotional component as the expression of liking or affection (Caris-Verhallen, Kerkstra, & Bensing, 1999; see also Chapter 2.2.2 on the relational meanings of touch).

Earlier categorizations of touch that concentrated on the purpose and meanings of touch made even more fine-grained differentiations. For example, Heslin and Alper (1983) differentiated the purposes of interpersonal touch as functional/professional (e.g., the examination of a body part by a physician), social/polite (e.g., shake hands to neutralize status), friendship/warmth, love/intimacy, or sexual arousal. The latter are said to be easily misinterpreted and strongly dependent on the relational intimacy of a dyad. If the relationship is close, meanings of warmth, love or even sexual arousal are pleasant, whereas touch that is perceived as conveying love and intimacy in a non-intimate relationship evokes discomfort. Hence, a congruency between the relational intimacy and the intimacy of touch is necessary so that touch does not result in discomfort.

Also, Jones and Yarbrough (1985) studied touch in naturalistic contexts, and demonstrated that several meanings that are either affective (positive affect, playful, ritualistic touches), functional (control and task-related touches) or hybrid in nature, can be assigned to the same touches. Contextual factors are therefore crucial with regard to the interpretation of touch.

With regard to robots, it would usually be expected that touch will be rather functional in nature. But against the background that Levy (2009) forecasted that humans will develop personal relationships with robots in the future, it can be suspected that affective meanings of touch will also matter in interactions with an artificial companion or partner.

2.2.2 Communicative Functions and Social Meaning of Touch

Moreover, touch has been demonstrated to serve communicative and relational functions. For instance, Hertenstein, Holmes, McCullough, and Keltner (2009) revealed that distinct emotions like anger, fear, happiness and gratitude can be communicated through touch and are accurately decoded.

Besides, interpersonal touch has also been demonstrated to convey relational meanings. The role of relational messages and themes that are conveyed through touching have been largely discussed in the realm of relational communication (Burgoon, 1991; Burgoon, Buller, Hale, & de Turck, 1984; Burgoon & Hale, 1984). Relational interpretations thus always address several typical themes such as intimacy, similarity, dominance, composure, and formality (e.g., Burgoon et al., 1984; Burgoon & Hale, 1984).

According to Burgoon (1991) the relational interpretation of touch follows a social meaning model that is shared by the majority of humans. Due to the existence of this social meaning model, individuals share common interpretations of different forms of interpersonal touch. She investigated the different meanings of touch by showing photographs of two persons in different touch situations to observers, and asking them for a relational evaluation. Her results revealed that the absence of touch communicates less immediacy, affection, receptivity/trust, similarity/depth/equality and composure than the presence of touch (here: all other forms of touch). The touch to the face and handholding were evaluated as the most intimate forms that communicate greatest affection, receptivity/trust, immediacy, composure, similarity/depth/equality, and less formality. The handshake communicated most formality and also receptivity/trust in large part, but less dominance, immediacy, affection, composure and similarity. The remaining forms of touch (arm touch, arm around the shoulder, arm around the waist) were moderate in immediacy, affection, receptivity/trust, formality and composure. Finally, dominance was found to be greatest for arm around the shoulder, followed by face touch, and arm touch, while low ratings were observable for handholding and handshake.

In summary, the work of Burgoon (1991) demonstrates that individuals are able to make a relational interpretation based on the mere observation of two individuals that touch. Moreover, different kinds of touches were perceived as conveying different relational meanings.

In addition, Major and Heslin (1982) demonstrated that the question who touches whom (the direction of touch) even affects how observers perceive the involved individuals. The authors therefore showed slides that depicted non-reciprocal touch between two individuals to their participants. As a result, observers rated the initiator of touch as higher in status, more assertive, expressive and warm, than the recipient of touch. Furthermore, they revealed that the favorable ratings of the touchers were significantly higher compared to a no-touch control condition, while recipients of touch were rated significantly lower than the no-touch control condition.

Also, Nancy Henley (1973, 1977, 2012) argued that touching does not only carry meanings of affection and closeness, but also serves as a signal of status and power. Henley differentiates reciprocal and non-reciprocal touch. While reciprocal forms of touch often refer to intimacy and closeness, non-reciprocal touch is rather associated with status, power and dominance (Henley, 1973, 1977, 2012; see also Major & Heslin, 1982).

When a robot should, in conclusion, touch a human, it should be taken into account that this might increase its perceived dominance.

2.3 The Importance of Interpersonal Touch for Health and Development

Interpersonal touch plays an important role in human lives. Since the skin is the largest organ of the human body, and touch is the first sense that humans acquire, touch is important from early childhood until seniority. Physical contact is even more important for living beings than food, as Harlow, decades ago, demonstrated in studies with infant monkeys (Harlow & Zimmerman, 1959, 1958). In his famous experiments, he offered monkey babies surrogate mothers made of terry-cloth and wire mesh. There were different conditions in which one of these surrogates provided food and the other did not. The results were remarkable revealing that the monkeys preferred the terry-cloth mother over all conditions even if it meant not getting any food. In conclusion, touch stimulation was considered as being even more important to monkey infants than nourishment.

Among humans, Tiffany Field pointed to the importance of touch for the development of children and the usefulness of touch (e.g., massages) as a therapeutic tool (T. Field, 1995, 1998, 2002, 2014). Moreover, she summarized different negative ramifications that appear if individuals are deprived of touch, such as sleep disturbances, suppressed immune response, growth deprivation, tactile sensitivity, and allergic conditions (cf. Field, 2003, p. 59 ff.). Also, Burgoon and Saine (1978) mention the various benefits touch fulfills during infancy, namely: biological, communicative, psychological and social values. Interpersonal touch is thus responsible for the comfort and protection of the child, the satisfaction of basic needs as breast feeding, the experience of the world through touch, and the bonding with the mother or caregiver (cf. Burgoon & Saine, 1978, p. 66). The role of touch in bonding with the mother or caregiver is of particular relevance for the social development, because early attachment bonds have been shown to be decisive for the normal development of children, and the later development of adult attachment bonds with other individuals as well as objects (Reite, 1990): "The mother-infant bond is likely the prototype of future attachment bonds – peer-peer, adult-adult, and, in man, bonds to inanimate objects, concepts, and components of the sense of self." (Reite, 1990, p. 199).

This is of particular interest with regard to human–robot relationships, because it indicates that touch with robots might also strengthen the bond between the robot and its user or owner.

Beyond childhood, touch has several positive effects on human well-being, as the relief of pain, reduction of stress, and improvement of immune functioning (e.g., Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005; Field, 2010). Recently, Cohen, Janicki-Deverts, Turner and Doyle (2014) for instance demonstrated that hugging could actually fight a cold. They showed that the risk of an infection was significantly decreased when participants reported being frequently hugged.

The question arises whether such an effect might also be evoked by a hug from a robot. If that would be the case, huggable robots could (theoretically) be spread to defeat the common cold.

As Fisher, Rytting, and Heslin (1976) summarized: "touch is an essentially positive stimulus for the recipient to the extent that it does not impose a greater level of intimacy than the recipient desires (…) or communicate a negative message (…)" (p.417). Conclusively, interpersonal touch can be regarded as a favorable nonverbal behavior that can have several positive effects on development and health (see above) and further on other evaluative and behavioral consequences (see below).

2.4 Studies on the Effects of Interpersonal Touch

Fisher et al. (1976) remarked three criteria they assumed to be necessary for positive effects of interpersonal touch to occur: the level of intimacy needs to be comfortable for the touched individual, the message that is perceived should be one of care and concern, and touch has to be appropriate in the situation (cf. Fisher et al., 1976, p. 466). If these criteria are not fulfilled, touch could rather result in discomfort. However, several studies in the realm of interpersonal touch research so far found positive outcomes of touch, which should be regarded in the following. A selection of these studies is summarized, to give an overview of how touch has been manipulated and which outcome measures were considered.

Self-reported evaluations and feelings, observable behavior as compliance and helping, and physiological reactions to interpersonal touch have been considered in related studies so far. Overall the studies revealed that interpersonal touch, even between strangers, and even if it happens unconsciously, mostly has a positive impact on the toucher as well as on the recipient, and even on the evaluation of the surroundings.

The most popular field study on the effect of interpersonal touch has been published by Crusco and Wetzel in 1984. They examined the effect of a slight touch from a waitress to the palm or shoulder of a diner when returning change in a restaurant, on tipping. As a result, higher percentages of tipping were observable after a female waitress touched the diner at the palm or shoulder compared to no touch at all. However, no main effect of touching was observable with regard to the evaluation of the waitress, the dining experience and the restaurant atmosphere, assessed via questionnaires. The positive effect of interpersonal touch has been called '*Midas touch effect'* (Crusco & Wetzel, 1984) after the Greek myth about king Midas, who turned everything he touched into gold. Several studies in the same realm followed after the work of Crusco and Wetzel, and replicated the effect on tipping (Guéguen & Jacob, 2005; Hornik, 1992b). They also revealed further effects of interpersonal touch on purchasing behavior (e.g., shopping time and amount of purchase: Hornik, 1992a, 1992b; amount of impulse purchases: Peck & Childers, 2006; alcohol consumption: Kaufman & Mahoney, 1999). Above, Peck and Shu (2009) showed that touch to a product itself increase the wish to own it.

Numerous studies also revealed that interpersonal touch influences the evaluation of the toucher and the environment (an effect that was not found in Crusco and Wetzel's study). Fisher et al. (1976) instructed clerks of a library to touch the hand of students when handing the library card. A later inquiry of the students revealed that students who were touched by the library clerk felt significantly better (affective state), and evaluated the clerk and the library more favorable than students that were not touched. When they were asked during the debriefing whether they remarked a touch from the clerk, the majority did not remember being touched. Also, Guéguen (2002) tested the impact of touch on compliance considering touch awareness and concluded that awareness of touch is not necessarily a precondition for a positive impact on compliance. Hence, touch seems to have a positive impact even if it happens unconsciously. Comparable effects have also been reported by Hornik (1992a, 1992b) who observed that customers at a bookstore evaluated the store better if they were previously lightly touched at the upper arm by an experimenter. Furthermore, some studies also observed a positive influence of touch on the evaluation of the toucher (evaluation of a car seller: Erceau & Guéguen, 2007; evaluation of a school instructor: Wilson, Stadler, Schwartz, & Goff, 2009).

Alagna and Whitcher (1979) investigated the effect of interpersonal touch from a counselor during a counseling interview related to career issues. Therefore, a counseling situation was constructed during which the counselor touched the client seven times (handshake, hand on client's back, touch to the hand or lower arm) or not at all. As dependent measures an evaluation of the counseling experience was assessed. Clients that were touched during the counseling interview evaluated the experience better (e.g., good and valuable) than clients who did not receive touch during the counseling. The authors furthermore controlled the effect of client's general body accessibility and attitude towards counseling, and revealed that both did not affect the effect touch on the evaluation.

Also, individual's behavior has been reported to change in a positive sense after interpersonal touch. For example, Pattison (1973) reported that participants expressed more depth of self-exploration during a counseling interview when they were repeatedly (handshake, hand on back/shoulder, hand on lower arm, hand over hand) touched by the counselor compared to no touch. However, the perceived relationship between the counselor and the participant was not affected by touch. Furthermore, Steward and Lupfer (1987) demonstrated that touch from an instructor improved students' performance in an examination that followed a conference where they were either touched by their instructor or not.

The behavior that gained most attention in research on the effects of interpersonal touch is compliance. Compliance to different requests that follow touch have been frequently tested (Kleinke, 1977; Patterson, Powell, & Lenihan, 1986; Paulsell & Goldman, 1984; Smith, Gier, & Willis, 1982; Willis & Hamm, 1980). For instance, Patterson et al. (1986) showed that a touch from the experimenter to the participant increased the time participants agreed to help the experimenter after the official experiment. The experimenter therefore asked the participant whether s/he might help him/her with the hand-scoring of a pile of questionnaires. While asking the experimenter either touched the participant at the shoulder or not at all. As a result, participants who were touched helped the experimenter on average 3 minutes longer than those who were not touched during the request.

Willis and Hamm (1980) used a similar procedure in the field. In one study, they had confederates touch (or not) subjects on campus before they asked them to sign a petition for the renovation of a museum. In a second study, they had confederates ask shoppers at a shopping mall for help with filling in questionnaires. Both studies supported the assumed effect that touch increased the probability of compliance: those who were touched were more likely to sign the petition and willing to help with the questionnaires.

Compliance to requests after touch had further been demonstrated with regard to tasting and buying a product (e.g., olives: Guéguen & Jacob, 2006; a new snack: Hornik, 1992b; pizza: Smith et al., 1982), participation in a course (Guéguen, 2004), returning a dime that was left in a phone booth and lending a dime in a shopping mall (Kleinke, 1977), and watching after a large dog in front of a pharmacy (Guéguen & Fischer-Lokou, 2002).

Furthermore, Nannberg and Hansen (1994) demonstrated that touch after compliance to take part in a survey ensured higher quantity of responses in a long survey compared to subjects that were not touched after compliance. The authors hence concluded that touch after compliance can represent an incentive to perform well in a task.

Some authors also considered helping behavior after touch that occurred without direct request. Therefore, Paulsell and Goldman (1984) had a confederate pretend to accidentally drop surveys after s/he touched the participant at different parts of the body (shoulder, upper arm, lower arm, hand) or not at all, and observed whether the participants helped to retrieve the sheets. The results demonstrate that participants in general helped female confederates more often than they helped male confederates, regardless of the condition. If the confederate was male, no significant differences between different kinds of touch were observed, whereas for female confederates significantly more helping was observable after touch to the arm (lower arm, upper arm) than after no touch. Also, male participants helped female participants more frequently than female participants did.

2.5 Individual Differences in Terms of Interpersonal Touch

As already mentioned in connection with the related studies, different reactions to touch have been observed because of the sex of the toucher or the recipient. For instance, Wilson et al. (2009) showed that the positive effect of a handshake from a professor to the students depended on the sex of the students and the professor: a handshake from a female professor evoked favorable evaluations of the professor and the course, whereas a handshake from a male professor led to negative evaluations. The majority of the students in this study was female.

The results by Paulsell and Goldman (1984) demonstrate that participants in general helped female confederates more often than they helped male confederates, regardless of the condition. If the confederate was male, no significant differences between different kinds of touch were observed, whereas for female confederates significantly more helping was observable after touch to the arm (lower arm, upper arm) than after no touch. Also, male participants helped female participants more frequently than female participants did.

Furthermore, an individual tendency to avoid interpersonal touch in general, namely: *touch avoidance*, has been revealed in the literature (Andersen & Leibowitz, 1978;

Sorensen & Beatty, 1988). For example, Sorensen and Beatty (1988) demonstrated that individuals who have a general attitude against touch with others, evaluated an interviewer who touched them less favorable, than individuals who have a tendency to endorse interpersonal touch. In line with Andersen and Leibowitz's (1978) concept of touch avoidance, it can be concluded, that a tendency to approach or avoid touch affects individuals' response to touch.

With regard to human–robot interactions, it can be supposed that individual attitudes as well as the sex of the human user might also affect the perception and evaluation of touch with robots. On the one hand, individual attitudes towards interpersonal touch might apply to touch with robots, whereas on the other hand, individuals might develop a distinct tendency towards their preferences with regard to robot touch.

Since the majority of commercial robots is so far rather gender neutral, an effect of the robot's sex is unlikely, but not exclusionary because gender cues can be simply implemented into robots (e.g., voice: Nass, Moon, & Green, 1997, or appearance: Eyssel & Hegel, 2012).

2.6 Attempts to Explain the Positive Impact of Interpersonal Touch

Finally, prominent explanations for the positive effects of (interpersonal) touch are considered, because the knowledge about the genesis of positive reactions can further contribute to the estimation of a robot's potential to evoke positive responses in humans.

2.6.1 Affective response

One explanation is that a positive response to touch is caused by experiences in early childhood, where touch from caregivers is used to reduce stress in children (e.g., Reite, 1990). Therefore, a positive association between touch and positive feelings might result, that further builds linkages between skin receptors and brain areas that represent pleasant experience (Gallace & Spence, 2010). Accordingly, a general positive association between touch and positive feelings/experiences exists, what in turn evokes a favorable response to new touches. Thus, robot touch might potentially also evoke positive feelings in humans, if no further specifically human feature is necessary (cf. work of Harris & Christenfeld, 1999 on machine touch, outlined below).

2.6.2 Physiological Reaction – hormonal, pressure receptors

Another more physiological explanation, can be found in Field (2010). She explained the positive effects of massage therapy by a hormonal change that develops during touch: serotonin release increases, which in turn reduces cortisol - the stress hormone (cf. p. 375 ff.) Also, oxytocin – the 'bonding hormone' – was named as a potential explanation for the positive impact of touch. As Holt-Lunstad, and Birmingham (2008) showed, oxytocin increased in participants after cuddling. Since oxytocin is said to reduces the stress hormone cortisol, it further leads to reduced pain and anxiety (T. Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005).

2.6.3 A Reflex or the Interpersonal Component?

Harris and Christenfeld (1999) give a first indication of how individuals react to touch from a machine compared to touch from a human. The authors were in particular interested in the question whether a machine is able to tickle a person. Since it has been demonstrated that people cannot tickle themselves, two diverging explanations for this phenomenon originated: The *interpersonal explanation* assumes that one cannot tickle oneself because tickling is a social phenomenon that needs an interpersonal component, and thus only occurs in the presence of another person. The *reflex explanation*, however, supposed that tickling needs an element of unpredictability that is not given when one touches oneself. If the latter is true, a machine should also be able to tickle a human. To test theses opposing hypotheses, an experimental study was conducted by Harris and Christenfeld, in which participants were tickled at their feet. In the human condition, they were told to be tickled by a human confederate, whereas in the machine condition, they were told to be tickled by a machine. In fact, all participants were tickled by a confederate that was hided under a table, while in the machine condition mechanical sound was presented in addition.[1] The results revealed no difference in participant's response to tickling from a human or a machine. Hence, a machine is also able to tickle a person, what lends support to the reflex explanation.

The findings are encouraging with regard to the possibly positive reactions robot touch might evoke in humans, although tickling is a specific form of touch that might not be comparable to all other kinds of touches.

In conclusion, if touch with robots resembles interpersonal touch, physical contact with a robot might have unintended effects, e.g., perceived violations of personal space at an assembly line when a robotic arm gets too close to a human co-worker, or even the assignment of relational meanings to touch from a robot. On the other hand, comparable positive effects as in the interpersonal context could occur that contribute to the well-being of humans that use robots.

The next chapter thus deals with a definition of human–robot touch opposed to interpersonal touch, and touch to less interactive objects.

[1] Fun fact: Although one could be skeptical about the manipulation, Harris and Christenfeld (1999) noted that all participants reported that they believed the manipulation when asked a week later on the telephone. It would seem that a blind reviewer made them phone their anonymous participants in retrospect…

3 Human–Robot Touch

3.1 Definition

Human–robot touch (in the following: HRT) occurs if a human user and a physically embodied, co-located robot make bodily contact with each other. In contrast to interpersonal touch, touch with robots includes one non-human, and further inanimate object. In contrast to typical objects, robots often possess a body that is shaped like a human or an animal. They can also be equipped with social cues, such as a face, human sounding voice, or interactivity (Nass & Moon, 2000). Although the abilities of robots are quite similar to those of virtual characters, their material embodiment and embeddedness in the real world (Kerstin Dautenhahn, Ogden, & Quick, 2002; Pfeifer & Scheier, 2001) make them unique artificial entities that allow physical interactions.

Comparable to interpersonal touch, touch with robots can be one-sided, being directed from a human to a robot or vice versa, or reciprocal. Within this thesis, a touch from a person to a robot will be referred to as human-initiated touch, and a touch from a robot directed towards a human, as a robot-initiated touch. Furthermore, reciprocal forms of HRT occur when the human and the robot both play an active part and the initiative is mixed, e.g., a handshake. This differentiation is in line with Chen, King, Thomaz, and Kemp (2014), who distinguished human-initiated touch from robot-initiated touch and cooperatively-initiated touch, here referred to as reciprocal touch.

As visualized in Figure 1, HRT falls at an intersection between social touch that regularly happens between living beings, e.g., interpersonal touch or human-animal touch, and object touch, which is typically directed from a human to an inanimate object.

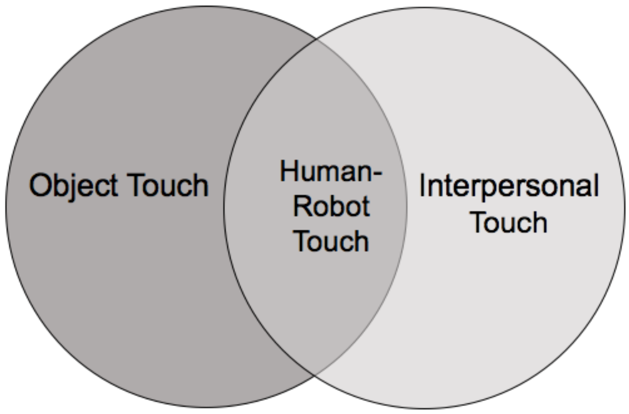


Figure 1. Graphical visualization of HRT as an intersection between social touch and object touch.

For this thesis, object touch and interpersonal touch are viewed as two sides of a continuum, where object touch represents the left end and interpersonal touch the right end of the theoretical continuum for touch (Figure 2). Object touch mostly occurs when a human touches an object, e.g., grasps a tool or a pen. On the continuum, touch to an abstract object like a box is less social than touch to a static object that has human like characteristics such as a doll; this is still non-social touch, but nearer to social touch, which reaches its climax in interpersonal touch. Touch between humans and other living beings such as animals can also be regarded as a form of social touch, although less pronounced than interpersonal touch; thus, human-animal touch is placed further to the left.

A hybrid between interpersonal touch and touch with technology is *mediated touch*. Mediated touch means touch between two persons via a technological medium that can for instance be an inflatable vest that allows a hug over distance (e.g., Mueller, Vetere, Gibbs, & Kjeldskov, 2005), or a vibrating arm strap that simulates a stroke (Haans & IJsselsteijn, 2009; for a review see: Haans & IJsselsteijn, 2006). Haans and IJsselsteijn (2009) used mediated touch to test whether a Midas touch effect (cf. Chapter 2.4) can also be elicited through a medium. Therefore, participants were touched at the arm via a vibrating arm strap before the experimenter pretended to need help while s/he dropped coins. The analyses of participants helping behavior after mediated touch pointed to the expected direction that helping was higher after touch, however, the difference was not statistically significant.

Also robots have been applied as a medium to convey touch, in this case a handshake (Bevan & Fraser, 2015; see below for more details on the experiment).

On the continuum, mediated interpersonal touch is less social than direct contact between humans (interpersonal touch) or touch between a human and an animal, but still more social than immediate touch between humans and autonomous robots. This is because mediated touch still connects two people via a medium or technological device, while no second social being is involved in HRT. Therefore, HRT is placed in the middle of the continuum, because it represents a hybrid form of touch with an inanimate object that has interactive abilities, and (could have) a human like appearance.

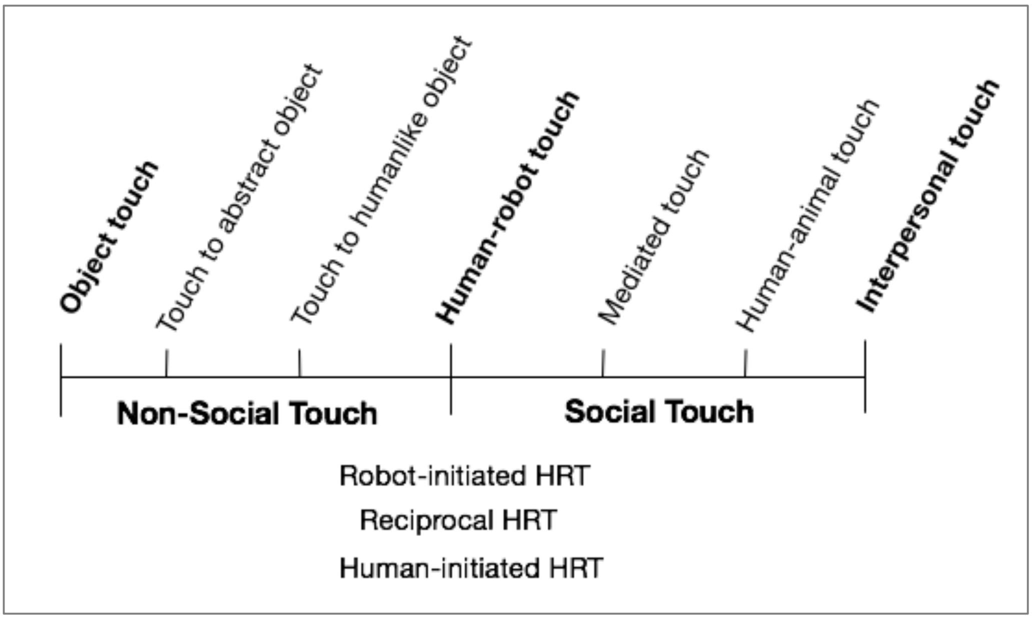


Figure 2. Theoretical continuum of touch, from object touch to interpersonal touch.

With respect to positive effects on human well-being that might be elicited by robot touch, touch that is initiated autonomously by a robot during an interaction is of special interest. Currently, only a few studies have investigated the impact of robot-initiated touch. The majority of work on touch with robots has focused on the calming effects of zoomorphic or pet like robots in the realm of robot assisted therapies (e.g., Shibata & Wada, 2010 for an overview), where robots have a rather passive role and touch is initiated by the human user (e.g., caressing or stroking the robot). Reciprocal forms of HRT, such as handholding (Nie et al., 2012) and shaking hands with a robot (Bevan & Fraser, 2015), have rarely been regarded in previous work.

The following sections first introduce the idea of robot therapy that utilizes tactile interactions with robots, followed by further related work on HRT with the aim of presenting an overview of previous methods, findings, shortcomings, and open questions.

3.2 Robot Therapy for Human Well-Being

Robots have already been adjudged to have a potential to contribute to human well-being. According to Libin and Libin (2004), robots are able to serve human needs as enjoyment, self-confidence, coping with difficulties and skills training. Interaction with a robot might hence result in higher emotional well-being, competence and autonomy, quality of life enhancement, as well as improvement of daily activities. Following animal therapy, *robot therapy* (Shibata et al., 2001; Shibata & Wada, 2010; Wada & Shibata, 2006), or *'robotherapy'* (Libin & Libin, 2004), has been invented as an approach in which therapeutic robots are used to engage impaired individuals with interventions tailored to their specific needs. Research on animal therapy already revealed that touch with animals is beneficial for individuals who suffer from high stress levels or loneliness. Studies for instance confirmed that contact with animals lowered individuals' stress levels and led to mood elevations (Collis & McNicholas, 1998). Certainly, animals cannot always be applied due to allergies, or hygiene regulations at care facilities and hospitals. Here robots come into play. As Libin and Libin (2004) outlined, robots can be therapeutic agents that allow tactile interactions and are capable to sense touch and respond to it. As with animal therapy, it is assumed that robot therapy can have psychological (e.g., mood, motivation), physiological (e.g., decreases in cortisol and blood pressure), and social effects (e.g., increased communication; Shibata & Wada, 2010). For therapeutic purposes, pet-like robots have already been successfully applied. For instance, Banks, Willoughby and Banks (2008) demonstrated that repeated interaction with a robotic dog (here: Aibo) reduced loneliness of elderly residents in a long-term care facilities just as well as interaction with a living dog compared to a no interaction control group.

Furthermore, robot therapy is often based on tactile interaction like caressing or stroking robots. Several studies in this realm have been reported by Shibata and colleagues, who developed Paro, a huge robotic seal with white fur fabric (e.g., Shibata, Tashima, &

Tanie, 1999; Shibata & Tanie, 2001; Wada, Shibata, Saito, & Tanie, 2002). The robot is further designed to respond to touch from humans. The interaction with Paro is hence focused on physical interaction, since the developers assumed that physical interaction with robots stimulates the senses of its users, and thus has comparable psychological, physiological, and social effects as animal therapy (Shibata & Wada, 2010). For example, evidence exists that the presence of the robot, and interaction with it, led to pleasure and relaxation (Shibata & Wada, 2010; for more findings consult Chapter 4.3.1).

Tactile interaction with a pet like robot only represents one possible form of HRT. Other possibilities of tactile interactions between humans and robots are discussed in the next chapter.

3.3 Empirical Studies on the Impact of Different Kinds of HRT

Earlier studies on HRT touch can in general be distinguished according to the type of HRT that was investigated (human-initiated, reciprocal, mixed, and robot-initiated, see Table 1). Furthermore, the robots that were used, the user group tested (participants), study design, experimental manipulation (if present), and the measurements performed, are all of interest for gathering an impression of the current state of research on HRT; hence, these are all summarized in Table 1.

The following paragraphs give further short summaries on the studies listed in Table 1; these are sorted according to studies on robots that were touched by humans (Chapter 4.3.1), work on robots that are designed to perceive and react to touch (Chapter 4.3.2), studies on reciprocal and mixed-initiative touch (Chapter 4.3.3), and studies on robot-initiated touch (Chapter 4.3.4). The studies and their findings are first described, before critical aspects and shortcomings are collectively discussed in Chapter 4.4 and 4.5, because some shortcomings concerned more than one study.

Table 1. Overview on related work that included touch between human participants and robots.

Authors, Reference	Robot Morphology	Participants	Method/Scenario	Manipulation	Touch form	Measurements
Human-initiated touch						
Shibata et al., 2001	Paro, Zoomorphic, baby seal	a) Exhibition visitors b) Children	a) Field study at exhibition hall b) Field study at university hospital for children	-	Free interaction	a) **Self-report:** Subjective evaluation b) **Self-report:** Mood (Face scale) **Observational:** Vital signs (blood pressure, pulse), comments by nurses (communication, appetite)
Shibata & Tanie, 2001	Paro, Zoomorphic, baby seal	Adults	Observation, Interview	-	Free interaction	**Self-report:** Evaluation of the robot before and after interaction (e.g., cuteness, willingness to touch)
Wada, Shibata, Saito, & Tanie, 2002	Paro, Zoomorphic, baby seal	Elderly females, with and without dementia	Field study at a day service center	-	Free interaction	**Self-report:** Mood (tension, depression, vigor), comments of nursing staff **Control:** Experiences with breeding pets, familiarity with the robot
Wada, Shibata, Saito, Sakamoto, & Tanie, 2005	Paro, Zoomorphic, baby seal	Elderly	Long-term field study in health service facility	-	Free interaction	**Self-report:** Mood**,** depression
Wada & Shibata, 2006	Paro, Zoomorphic, baby seal	Elderly	Field study at a care house	-	Free interaction	**Self-report:** Density of social networks **Physiological:** Stress (hormones in urine: 17-KS-S, 17-OHCS)
Okita, 2013	Paro, Zoomorphic, baby seal	Female pediatric patients (children) and their parents	Field experiment at hospital	Between-subjects Interaction: alone vs. together with parents	Free interaction (e.g., pet, hold, talk to)	**Self-report**: Pain, anxiety
Robinson, MacDonald, & Broadbent, 2014	Paro, Zoomorphic, baby seal	Older people	Field experiment in a residential care facility	Repeated measures: before, during and after interaction with the robot	Free interaction, robot placed on participant's lap	**Physiological:** Cardiovascular response (systolic and diastolic blood pressure, heart rate)

Chang & Šabanović, 2015; Chang, Šabanovic, & Huber, 2014	Paro, Zoomorphic, baby seal	Residents, staff, and visitors	Field study in a local nursing home	-	Free interaction	**Observational:** onsite coding (physical activity, willingness to interact with the robot, number of interactors and passersby)
Dougherty & Scharfe, 2011	Geminoid DK, Android	Adults or students	Laboratory experiment Trust game	Between-subjects: touch vs. no touch	Guiding touch from assistant to participant's arm; Touch from participant to robot's shoulder	**Observational:** Trust (risk taking in trust game), smiling **Control:** Presence, Immersive tendency
Park & Lee, 2014	Pleo, Zoomorphic, baby dinosaur	Students	Laboratory experiment Movie reception (sad/horror movie)	Between-subjects: warm temperature vs. intermediate temperature vs. cool temperature vs. no touch	Free interaction, hug, handle and interact with robot as with a pet	**Self-report:** Robot evaluation (intention to own the robot, perceived friendship, pet-likeness, anthropomorphism), emotional stability after the movie **Control:** social presence
Wullenkord, Fraune, & Eyssel, 2016	Nao, Humanoid	Students	Laboratory experiment Hand sign recognition task	2x2 between-subjects: Contact Type: actual vs. imagined vs. no contact; Contact Modality: touch vs. look vs. no contact	Participants touch robot's hand to feel hand signs	**Self-report:** Robot evaluation (anthropomorphism, robot-related judgements) **Control:** Liking of casual touch
Reciprocal touch						
Nie, Park, Marin, & Sundar, 2012	Robosapien RS-Media, Humanoid, toy like	College students	Laboratory experiment Horror movie experience	Between-subjects: warm robot's hand vs. cold robot's hand vs. no touch	Handholding (static)	**Self-report:** Robot evaluation (friendship, trust, human-likeness, fright from robot)**,** movie evaluation (enjoyment, fright from the movie)
Bevan & Fraser, 2015	Nao, Humanoid	University staff and students	Experimental study Negotiation task	2x2 between-subjects: Participant's presence: tele-present vs. co-located; touch: with feedback vs. without feedback vs no touch	Robot-mediated handshake; Remote control (tele-present participant)	**Self-report:** Willingness to mislead the seller (buyers only), trustworthiness, impressions of the negotiating partner **Observational:** Cooperation (proportion of the potential profit captured by the buyer)

Mixture of touch forms						
Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, & Evers, 2009	Robosapien V2, Humanoid, toy like	Mixed sample (14-55 years)	Video-based online survey Office scenario	2 x 2 between-subjects: robot's proactivity: proactive vs. reactive; touch: touch vs. no touch	Tap to the robot, tap to the human's shoulder, hug, high five	**Self-report:** Robot evaluation (humanlike, machinelike, dependable), perceived closeness **Observational:** Compliance (willingness to follow robot's suggestions) **Control:** Negative attitudes towards robots (NARS)
Robot-initiated touch						
Chen, King, Thomaz, & Kemp, 2014, 2011	Cody, Anthropomorphic (mechanical)	Students	Laboratory experiment Clinical setting	2x2 between design: Touch intent: functional vs. affective; prior warning: with vs. without warning	Rub to the participant's arm (towel was attached to the robot's hand)	**Self-report:** Emotional state**,** touch evaluation (e.g., enjoyable, necessary) **Physiological:** Arousal (GSR) **Control:** Negative attitudes towards robots (NARS)
Fukuda, Shiomi, Nakagawa, & Ueda, 2012	Robovie mR2, Humanoid	Students	Laboratory experiment Game scenario (ultimatum game)	Between subjects: touch vs. no touch	Stroke to back of participant's hand	**Self-report:** Acceptance of fair and unfair offers **Physiological:** Neuronal reaction to unfairness (MFN)
Walker & Bartneck, 2013	Nao, Humanoid	Mixed sample, (18-49 years) Adults	Laboratory experiment Massage scenario	Repeated measures within-subjects design: human massage vs. robot massage vs. self-massage	Head massage (through massage tool)	**Self-report:** Massage pleasure **Observational:** Happiness (Facial Expression) **Control:** Prior experiences with robots, negative attitudes towards robots
Nakagawa et al., 2011; Shiomi et al., 2016	Robovie mR2, Humanoid	Students	Laboratory experiment Task fulfillment	Between-subjects: active touch vs. passive touch vs. no touch resp. human touch vs. robot touch after human touch vs. no touch in the 2016 Journal paper	Static touch from human to robot's hand Stroke from robot's hand to human's hand	**Subjective:** Robot evaluation (friendliness) **Observational:** Task fulfillment (amount of time, number of actions)

3.3.1 Studies on human-initiated touch to robots

Human-initiated touch describes interactions in which the human is the active participant and touches the robot with the robot remaining passive. This form of non-reciprocal touching behavior can be typically expected in interactions with pet like robots such as Aibo (robot dog), Pleo (robot baby dinosaur), or Paro (robotic seal). Even if the robots are able to show at least some reactions to human touch, they are not able to touch humans back. This is mainly because pet like robots do not have arms like humans, so they are therefore unable to reach out to a human hand and shake it.

Shibata and colleagues, who developed Paro, a huge robotic seal with white fur fabric (e.g., Shibata, Tashima, & Tanie, 1999; Shibata & Tanie, 2001; Wada, Shibata, Saito, & Tanie, 2002), have reported on several studies in the realm of human-initiated touch. Their original objective was the creation of a mental commitment robot for therapeutic purposes. Paro is able to demonstrate proactive behavior and react to human-initiated touches or sounds e.g., with winking eyes, or looking in the direction of a sound. It also has a diurnal rhythm to resemble a lifelike character. The robot is predominantly used to engage ill and elderly persons in tactile interactions (Wada et al., 2002).

The first studies on testing the impacts of the robotic seal were made at a university hospital for children (Shibata et al., 2001), in which Paro was used for robot therapy – a replacement of animal therapy – to improve the well-being of children in the hospital. The results of the application demonstrated that the children's moods improved during the interactions with the robot. They also became more likely to talk to other children and caregivers, and some actually recovered their appetite while the robot was present in the hospital. Furthermore, Okita (2013) demonstrated that robot-assisted therapy for pediatric patients (children) successfully reduced pain and anxiety when the patients engaged in interaction with the robot Paro together with their parents.

Wada et al. (2002) investigated the impact of the robot at a day service center for the elderly. Paro was provided to the elderly people for three days a week for about 20 minutes a day over a period of five weeks. Comparable to the findings of Shibata et al. (2001), it was revealed that the mood of the elderly participants, which was measured before and after each interaction, significantly increased during the second and fifth weeks. The elderly participants reported significantly higher feelings of vigor after the interactions with

Paro, with this increase still being notable after five weeks. Beyond the self-reported changes to mood, the nursing staff reported that the elderly participants were excited about their interactions with Paro, and that the application of the robot prompted further conversations between them. In conclusion, these findings demonstrated that deployment of the pet-like robot in interactions that allowed human-initiated touch, had positive psychological (mood) and social (conversation) effects on children and elderly participants.

Wada and Shibata (2006) and Robinson, MacDonald, and Broadbent (2014) even reported physiological improvements resulting from the implementation of the robot. Robinson, MacDonald, and Broadbent (2014) demonstrated that the systolic and diastolic blood pressure of residents of a residential care facility significantly decreased when they interacted with Paro, and that diastolic blood pressure increased again when Paro was withdrawn. In accord with these findings, Wada and Shibata (2006) revealed that elderly participants who interacted with Paro in a care home, showed decreased stress hormones according to measurements from urinary tests. They also observed increased social contact among the elderly participants due to the application of Paro.

In work with cognitively impaired adults, Chang, Šabanovic, and Huber (2014) showed that physical interaction and the willingness to interact with the robotic seal Paro increased during eight weeks of sensory robot-assisted group therapy in a nursing home.

Moreover, it has been demonstrated that the effects of robot-assisted therapy are not just temporary. Wada, Shibata, Saito, Sakamoto, and Tanie (2005) demonstrated that the positive effects of the application of Paro in a health service facility for the elderly lasted over one year. Aged people at the facility became more active and more frequently engaged in communication with each other. Furthermore, better moods and lower levels of depression were noticeable after interactions with the robot over time.

Aside from studies that used the robotic seal Paro, Park and Lee (2014) experimentally investigated touch in interaction with the robotic baby dinosaur Pleo. In their experiments, participants watched a sad or scary movie in front of a TV together with the robot Pleo. In one condition, participants had no interactions with the robot whatsoever, while in the other three conditions they had physical contact with the robot whose skin temperature was varied (cold, intermediate, and warm). After the interaction, participants were asked to evaluate the robot and the movie. The analyses revealed that the perceived friendship and intentions towards owning the robot were highest if the robot had a warm skin, followed by intermediate and cool skin, while they were least when no physical interaction took place. Regardless of the specific temperature, participants always preferred having a robot like Pleo if touch was included in the interaction in comparison with no touch. The participants' emotional stability after watching the movie was also better when touch was included as opposed no physical interaction having taken place. The perceived anthropomorphism and pet-like nature of the robot was, however, not affected by touch or the temperature manipulation. The authors further demonstrated that the effect of robot touch on perceived friendship and emotional stability was mediated by the perceived social presence of the robot.

Recently, Sefidgar et al. (2016) demonstrated that a creature like robot applied to a participants lap increased participants' relaxation (measured by means of higher subjective valence, lowered anxiety, and physiological arousal) more when the robot simulated breathing like a pet when participants stroked it, than when it was turned off.

Another application of human-initiated touch to a male-simulating android robot (Geminoid DK) was reported by Dougherty and Scharfe (2011). In their study, they had participants negotiate in a trust game through an android robot that represented a tele-present negotiating partner. In this experiment, participants were either touched first by an experimenter on the arm, and then had to touch the shoulder of the android robot before the trust game started, or in a second condition, no touch between the participant, experimenter, or android took place. When touch was included during the game, significantly more trust was observed than with no touch. The authors hence concluded that a mixture of human-human and HRT can help to establish trust when a tele-present other is represented by an android robot.

Finally, Wullenkord, Fraune, and Eyssel (2016) demonstrated that touch to a robot can be utilized to reduce negative emotions towards robots. In the experiment, participants either imagined or experienced an interaction with a humanoid robot (Nao, Aldebaran) in which they should guess hand gestures from looking at or touching the hand of the robot that remained stationary. The results showed that each kind of contact reduced negative attitudes; however, a negative effect of touch was also observed if participants' negative emotions were high in advance of the interaction.

Beyond this, other attempts have been made to investigate how humans touch robots. For example, Haring, Watanabe, Silvera-Tawil, Velonaki, and Matsumoto (2015) observed how humans touch the hand of a female android robot (Actroid-F). The android robot asked the participants whether they would like to touch its hand during interaction. The touch gestures of the participants were afterwards analyzed by means of video-recordings. Stroking and squeezing the hand of the android were the most frequently used forms of contact.

A similar investigation was performed to determine the touching behavior of children towards a robot (Hensby, Wiles, Boden, & Heath, 2016). The authors observed children interacting with a prototype robot that had a humanoid shape (arms, hands, torso and head). The robot either prompted for contact (i.e., asked for touch) or not. Initial observations showed that children tended to touch the robot's hands during interaction when not prompted to make contact. Instead, when touch was prompted, they rather touched the torso of the robot where an interactive screen had been installed. The authors of the study did not further consider the impact touching had on the children.

3.3.2 Studies on robots that perceive human touch and react to it

Robotic features that are able to recognize and categorize human-initiated tactile interaction have already been developed. For instance, the Haptic Creature has been developed by Yohanan et al. (S Yohanan & MacLean, 2008; Steve Yohanan, Chan, Hopkins, Sun, & Maclean, 2005; Steve Yohanan & MacLean, 2009, 2012) that is able to perceive and interpret affective touch initiated by human users. User studies on the communication of emotions to the robot revealed that the meanings human users intended to convey could be categorized as protective, comforting, restful, affectionate, and playful (Steve Yohanan & MacLean, 2012). Above all, the results showed that participants expected the robot to mirror the emotions that they conveyed to the robot.

A teddy bear-like robot called 'The Huggable' has also been developed with the goal of improving the well-being of hospital patients (W. Stiehl, Lieberman, Breazeal, Basel, et al., 2005; W. D. Stiehl et al., 2006; W. Stiehl, Lee, Breazeal, & Nalin, 2009; W. Stiehl, Lieberman, Breazeal, & Basel, 2005). The robot is equipped with sensors that allow the detection of social affective touch forms, e.g., tickling, patting, squeezing, and mere contact; these are further categorized into six response types, e.g., pleasant and painful touch, light and strong punishment. The Huggable decides which behavior to perform according to the type of response, e.g., a pleasant touch leads to a positive response, but strong punishment evokes a pain response (W. Stiehl, Lieberman, Breazeal, Basel, et al., 2005).

3.3.3 Studies on reciprocal and mixed-initiative touch

Nie, Park, Marin, and Sundar (2012) investigated the effect of reciprocal affective HRT during the viewing of a horror movie. In their study, participants watched a clip from a horror movie together with a humanoid robot (Robosapien RS-Media). During the viewing of the clip they were either asked to hold the robot's hand, or not[2]. In addition, the physical warmth of the robot's hand was varied (cold or warm, with the help of an attached heat pad) in the touch condition. The results demonstrated that after holding a warm robot's hand, the perceived trust and human-likeness were higher than after holding a cold robot hand or not holding hands with the robot. Furthermore, participants perceived more friendship between them and the robot, but also more fright, after holding a warm robot's hand compared to no touch. The authors thus assumed that the temperature of the hand helps the robot to become more human like, but at the same time makes the experience of holding the robot's hand more eerie (cf. Mori, 1970 on the uncanny valley hypotheses). Alternatively, a mismatch between the robots' appearance (here: a toy like robot with gripper fingers) and the physical warmth that resembled a living being may have caused feelings of eeriness. In conclusion, robot touch has to be carefully designed in accordance with the robot's morphology and the purpose of touch, so that high acceptance and low rejection rates are reached.

Another form of reciprocal touch, namely a handshake, was investigated by Bevan and Fraser (2015) with regard to cooperation. In their experiment, two participants had to negotiate land in the roles of buyer and seller. One participant was present in a laboratory

[2] It can be argued that the touch is not reciprocal since the human was asked to hold the robot's hand, and the robot did not make any active movement. However, handholding per se can be regarded a reciprocal form of touch when compared to other non-reciprocal touch forms, although one interaction partner always initiates touch. Hence, this study is categorized as reciprocal HRT.

together with a humanoid robot (Nao, Aldebaran Robotics) that represented a tele-present second participant. The experimental manipulations included whether the participants shook hands or not before the negotiation started, and whether the tele-present participant received haptic feedback via a remote device. The analyses revealed that in contrast to no handshake, shaking hands through a humanoid robot in advance of the negotiation increased cooperation between the buyer and the seller measured according to the profit captured by the buyer. The handshake with feedback further resulted in higher cooperation than the handshake without feedback, although the difference was not significant. No differences in the perceived trustworthiness of the seller and the willingness to mislead the seller intentionally were caused by the handshake conditions.

Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009) studied the general impact of a mixed presentation of different touch forms on the perception and evaluation of a robot from mere observation. As the researchers were interested in the interplay between a robot's proactivity and touch, participants watched a video of a human user who had a problem with a computer. A humanoid robot (Robosapien V2) either proactively (without being asked) or reactively (on demand) offered help to the computer user. In addition, the interaction included either different forms of touch (human tapping the robot, robot tapping the human on the shoulder, a hug, and a high five) or no touch at all. The results showed that the robot that proactively offered help was perceived as less machine-like and more dependable when touch was included in the interaction (compared to no touch), whereas the reactive robot that only offered help on demand was perceived as more dependable and less machine-like when no touch was included in the video. Furthermore, proactivity and touch variations had no impact on the perceived closeness between the person and the robot in the video. The authors concluded that the evaluation of robot touch depended on the robot's proactivity. Only for a proactive robot did the inclusion of touch have a positive effect on perception and evaluation (here: dependability and human likeness), while touch in an interaction with a reactive robot had no such positive effects (more machine-like and less dependable).

3.3.4 Studies on robot-initiated touch

Finally, some studies have considered the impact of robot-initiated touch in different contexts, such as in a hospital setting. In these cases, the robot plays an active part and initiates a touch to the human user with a part of its artificial body, e.g., its arm or hand.

First of all, Chen, King, Thomaz, and Kemp (2011; Chen et al., 2014) investigated robot-initiated touch with a real robot in a clinical environment. They compared instrumental touch (e.g., cleaning) with affective touch (e.g., caressing) and also the interactions of touch with the presence or absence of a verbal warning from the robot (e.g., "I am going to rub your arm"). During the experiment, participants took the role of a hospital patient, and therefore lay in a bed while the robot approached them. The findings suggested that the instrumental touch without a warning was the condition favored over all others. Instrumental touch was perceived as significantly more enjoyable, necessary, and less arousing than affective touch. To the contrary, participants in the affective touch condition indicated significantly more often that they preferred it when the robot had not touched them at all. With regard to the verbal warning, participants were significantly more aroused and preferred the robot not to touch them when a warning preceded the touch. The positive affect was also significantly higher in the no warning condition. However, regardless of the assigned condition in the first trial, all participants allowed the robot to touch them again in a second trial (Chen et al., 2014).

Another study on robot-initiated touch was made by Fukuda, Shiomi, Nakagawa, and Ueda (2012). They tested the Midas touch effect (cf. Crusco & Wetzel, 1984) in HRI using EEG to measure feelings of unfairness during an ultimatum game. On the basis of pre-existing knowledge that medial frontal negativity is associated with feelings of unfairness, participants were confronted with fair and unfair offers from a robot, while their neuronal reactions were assessed via EEG. The results indicated that robot-initiated touch (in this case stroking the back of the human participant's hand) inhibited feelings of unfairness, as medial frontal negativity was lower when the robot touched the human while offering an unfair proposal than with a similar proposal without touch. However, in all conditions the participants accepted the same amount of fair offers and rejected the same number of unfair ones, regardless of the presence of touch. Hence, the findings indicated that robot touch had an effect on a physiological level, although made no difference to the immediate behavior during the ultimatum game.

Recently, Walker and Bartneck (2013) used Aldebaran's Nao robot to investigate whether a head massage by a robot is able to enhance human well-being. They conducted a study in which participants were consecutively massaged with the aid of a head massaging tool by a human masseur, a robot masseur (Nao), and themselves. The results illustrated that head massages by a human masseur were evaluated as more pleasant than those by a robot or by oneself. However, more happiness, as measured by facial expressions, was observed in the robot condition than in the self and human masseur condition.

Shiomi et al. (2016; see also Nakagawa et al., 2011) studied the impact of robot touch on human motivation. Participants were required to communicate with a small humanoid robot (Robovie-mR2) before they had to work on a monotonous drag and drop task. The robot either only verbally motivated the participants to do the task (no touch condition), or asked the participants to put their hand on the robot's hand while motivating them verbally. In one touch condition, the robot remained passive when the human touched the robot's hand (passive touch condition, in Nakagawa et al., 2011; human touch condition in Shiomi et al., 2016), while in the other condition, the robot put its second hand above the participant's hand and stroked it while saying motivating words (active touch condition in Nakagawa et al., 2011; robot touching human after human touched robot in Shiomi et al., 2016). The data analysis revealed that participants in the active touch condition, in which the robot stroked the participant's hand, continued the task for a significantly longer period of time (working time and number of actions) than those who only touched the robot's hand (passive touch) or did not touch it at all. Passive human-initiated touch did not significantly differ from no touch with regard to motivation. The authors thus concluded that a robot's active touch can motivate human users to continue a task (Nakagawa et al., 2011). The robot's perceived friendliness in the active touch condition was significantly higher than in the no touch condition. Hence, active/robot-initiated touch seems to evoke better evaluations of a robot (comparable to findings from interpersonal literature e.g., Erceau & Guéguen, 2007; Fisher, Rytting, & Heslin, 1976; Steward & Lupfer, 1987; Wilson, Stadler, Schwartz, & Goff, 2009), and this in turn seems to increase motivation.

3.4 Summary on Previous Work on HRT

The overview of related studies (Table 1) illustrates that those studies that investigated human-initiated touch were mostly conducted using zoomorphic robots such as Paro and Pleo. Obviously, robots that resemble animals invite tactile interactions, like stroking and patting (cf. Austermann, Yamada, & Funakoshi, 2010; Austermann, Yamada, Funakoshi, & Nakano, 2010), and are intuitively less capable of initiating touch by themselves. In contrast, reciprocal and robot-initiated touch was exclusively investigated using humanoid robots and focused on touch between the robot's hand and the participants' hand or arm, except for Walker and Bartneck's work (2013), where a massage to the participant's head via a massage tool was considered.

Furthermore, human-initiated touch has often been investigated in field studies with special user groups and environments, such as children in hospitals or elderly people in care facilities. In many cases the findings were therefore gathered without experimental controls, but with higher external validity. The interactions between the participants and the robot (mostly the robotic seal Paro) were not predefined, and it is therefore unclear how much touch was included in the interactions. However, physiological reactions to interactions with robots indicate that zoomorphic robots have a calming effect on human users comparable to that of animal touch (e.g., Shibata et al., 2001; Wada et al., 2005; Wada, Shibata, Saito, & Tanie, 2002).

To the contrary, reciprocal and robot-initiated touch have always been investigated in laboratory experiments, and mostly with students, except for Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009) who conducted their experiment online with a mixed sample. The scenarios used in the laboratory studies were manifold, depending on the outcome variables that were examined. For example, reciprocal touch was investigated in a movie watching scenario with the dependent measures being the evaluation of the robot and the movie, while the impact of robot touch on motivation was investigated using a task fulfillment scenario.

Overall, the findings suggest that touching a (zoomorphic) robot has positive effects on humans, recognizable through a better mood, lowered depression, and reduced stress, pain, and anxiety (see studies by Shibata, Wada and colleagues, Table 1). Touch to robots also altered participants' evaluations (Park & Lee, 2014; Wullenkord et al., 2016) and increased trust in the person behind the robot (Dougherty & Scharfe, 2011). Furthermore, a positive impact according to the warmth of a robot's hand during reciprocal handholding was demonstrated (Nie et al., 2012), while a positive influence of shaking hands with a robot was revealed by Bevan and Fraser (2015). In the latter case, it has to be remarked that the robot in the study was used as a medium to represent another participant. However, the finding demonstrates that shaking hands through a robot can still increase the perceived presence of an absent person and heighten cooperation. Finally, robot-initiated touch has been demonstrated to affect participants' emotional states and their evaluations of the robot, with impacts on participants' motivation to continue a task, and physiological and neuronal reactions to touch, having been reported (cf. Table 1).

The following section covers the potential shortcomings present in earlier investigations, and which provided motivation for the current thesis.

3.5 Shortcomings of Earlier Studies on HRT

Most studies (regardless of the touch form or direction that was considered) assessed subjective and objective measurements, while only a few concentrated only on observations or self-reports. It is noticeable that even the experimental studies rarely considered the influence of other variables, such as touch avoidance tendency or touch comfort (e.g., Andersen & Leibowitz, 1978), as well as experiences and attitudes towards robots (e.g., Nomura, Shintani, Fujii, & Hokabe, 2007; Nomura, Suzuki, Kanda, & Kato, 2006) that might be crucial in regard to the evaluation of touch from or with robots. For instance, only Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009), Chen et al. (2014), and Walker and Bartneck (2013) considered participants' attitudes towards robots as an influential variable. Wullenkord, Fraune and Eyssel (2016) further included a measure of the participants' general liking of touch. As in interpersonal touch research, one possible reason for this could be that researchers have been cautious about asking such questions, in order not to prime participants, as trait variables should generally be measured in advance of an experimental experience. However, if participants were asked about their attitudes towards touching in advance, it might have raised suspicion on the experimental manipulation of robot touch.

Furthermore, some crucial points concerning the individual studies on HRT reported above require commenting on. Firstly, the work of Bevan and Fraser (2015) investigated a special form of touch between two human participants who shook hands with each other via a robot. Although this portrayed a form of mediated interpersonal touch through a robot, it indicates that touch to a robot's hand can be effective to increase the presence of a tele-present person, and that this is accompanied by increased cooperation; albeit different results may have been observed if no second participant was involved and the participant interacted directly with the robot as a negotiating partner.

Similarly, Walker and Bartneck (2013) considered a special kind of touch through a massage tool. Although their findings suggest that massages by robots can increase an individuals' happiness, it should be noted that this specific kind of physical contact via a massage tool cannot be automatically equated to immediate touch by robots.

With regard to the meaningfulness of the results of Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009), it can be argued that different forms of HRT were included in the videos, but that these were not separately evaluated. The effect of a hug compared to a tap to the shoulder might make a huge difference with regard to the perceived closeness, and this may further affect the evaluation of the touch and the robot. It is also possible that a reciprocal high five might be perceived as a human-like gesture, whereas a touch directed from the human to the robot might be typical for human-machine interactions, and could thus leave a more machine like impression of the robot. Beyond this, the direction of touch – whether the human touches the robot or vice versa – may have affected the perceived reactivity of the robot, e.g., a robot that touches a human could be perceived as more proactive than a robot that is touched by a human user. In conclusion, the study opens up questions with respect to a sophisticated reflection of the different forms of HRT, as a mix of different forms have been presented.

The work of Chen et al. (2014, 2011) can be further criticized, because the warning message that was included in the affective and instrumental condition was confounded by the information that touch will happen in the instrumental condition. In the instrumental touch with a warning condition, the robot said that it is going to rub the participants arm in order to clean it; however, no reference to touch was given in the affective touch condition; the robot only said "Everything will be all right, you are doing well." Hence, it can be argued that a warning of a forthcoming touch was only announced in the instrumental touch with a warning condition. Moreover, this means that a justification of touch was present in both instrumental conditions (with and without warning), and this might have caused a higher acceptance of instrumental touch. The inclusion of a justification for robot-initiated touch thus seems crucial for its acceptance, and it is also sufficient if the explanation follows the touch, albeit certain situations are imaginable where a warning in advance is necessary to prevent injury, especially when sensitive parts of the human body are included, e.g., a touch to a human face.

In addition, the finding that all participants allowed the robot to touch them again in a second trial, even though some of them stated that they preferred the robot not to touch them, might have been caused by the experimental situation. Participants typically try not to disturb an experimental procedure, and might therefore have allowed the robot to touch them just to avoid disrupting the experiment. It remains unclear whether they still preferred the robot to not touch them.

In Nakagawa et al. (2011), it is unclear whether the motivation increased after active touch due to the fact that the robot actively initiated a touch and stroking gesture, or whether it was because the robot's touch followed the human's touch, which might have been interpreted as a reciprocation of touch. If so, reciprocity might have caused the robot to be perceived as more friendly, albeit friendliness did not significantly differ between the active and passive touch conditions (only between active and no touch), contrary to this idea.

In their later publication (Shiomi et al., 2016), the authors admitted that the active touch from the robot that followed a touch from the human could not be clearly distinguished from mere human-initiated touch. Due to practical and safety reasons, a touch from the human to the robot had to precede the touch from the robot to the human, in order to guarantee that the robot was able to reach and safely stroke the hand of the participant. However, one cannot rule out the possibility that reciprocity of touch was more important than the question of who initiated the touch. Beyond this, it can be argued that the stroking of the participant's hand by the robot is a more intimate form of touch than the static touch from the human to the robot's hand, and that this might have further affected the perception and behavior of the participants. This could have been overcome with an equal static touch from the robot to the human, instead of stroking, or by asking the human to stroke the robot's hand.

In summary, related studies have so far focused on very specific questions, such as combinations of touch and proactivity or warnings, while general questions regarding touch in human–robot interaction were not the focus of the research. Currently published studies have revealed that the presence of other people, the robot's temperature and proactivity, the function or intent of a touch, a warning prior to touch, and the direction and reciprocity of touch, are crucial for the evaluation of HRT. Beyond these, the morphology of a robot seems to further determine which form and direction of touch is expectable. While zoomorphic robots have typically been considered in settings where they were touched, e.g., stroked by humans, other robot morphologies such as humanoid or android forms were used in studies on reciprocal and robot-initiated touch, although they of course still allow human-initiated touch.

With regard to the comparability of earlier findings, different interaction scenarios, types of robots, and varying operationalizations of touch are all critical.

Finally, currently published work has so far yielded information on the effects of touch on several outcome variables, such as the evaluation of the robot, motivation, or physiological arousal, but it remains unclear how these effects are accomplished.

4 Synopsis of the Theoretical Background and Global Research Question

In conclusion, the theoretical background on interpersonal touch research demonstrated several positive consequences of interpersonal touch on individual well-being, as well as evaluative consequences on the toucher and the surroundings. Furthermore, work of Burgoon and colleagues (e.g., Burgoon & Walther 1990; Burgoon, 1991) yielded insights into the relational meanings that are convey through different forms of interpersonal touch. As an explanation for the positive effects of touch a cognitive and a physiological approach have been discussed. The first one assumes that positive reactions to touch are cause by a positive association between touch and pleasant feelings that develop from childhood, whereas the other approach assumes that hormonal changes are caused by touch that reduce stress, increase bonding, and thus increase well-being.

In addition, the work of Harris and Christenfeld (1999) has been mentioned, in which the authors demonstrated that a machine can tickle a person as well as another human. The results supported a reflex explanation of tickling more than an explanation that assumes that an interpersonal or social component is necessary for the sensation of tickling. Although tickling is a special form of touch, the findings support the supposition that touch from a robot will also have an effect on humans.

Against the background of media equation (Nass, Steuer, & Tauber, 1994; Reeves & Nass, 1996) that assumes that interpersonal phenomena transfer to interactions with technology, it was of interest to test whether this propositions also applies to touch in the realm of human–robot interaction. Therefore, theories from interpersonal communication research are adopted and translated to the context of HRI.

Because robots possess a physical body that allows them to be touched and (depending on their morphology) to touch humans, it seems reasonable to consider this modality as a fruitful basis to exploit their full potential. Since humans have a basic need for touch (cf. Field, 2010) and robots have the unique ability to fulfill this need (e.g., compared to on-screen agents), the question arises whether robots can be utilized to enhance human well-being. According to the aforementioned assumption that HRT represents an intersection between interpersonal touch and object touch, it can be assumed that robots have a high potential to evoke comparable effects than interpersonal touch (cf. Figure 1 & 2).

The major question that should therefore be addressed in this dissertation is whether HRT can be used to enhance humans' well-being due to the positive effects that have been frequently revealed with regard to interpersonal touch and also in the realm of robot therapy (e.g., Shibata et al., 2001; Shibata, Tashima, & Tanie, 1999; Wada et al., 2005).

Besides the question of whether HRT can contribute to human well-being, it was of interest whether the perception, interpretation, evaluation and final reaction to HRT resembles interpersonal touch, and which other variables influence the perception of HRT. Therefore, the following general questions (GQ) should be clarified:

GQ1: How do humans interpret touch from a robot?
GQ2: Which forms of HRT are pleasant and acceptable to humans?
GQ3: With which robots, and under which circumstances, is HRT acceptable?
GQ4: *Which factors influence the appraisal of HRT?*
GQ5: *Can HRT contribute to human well-being, as interpersonal touch does?*

The concrete empirical approach to address these questions is presented in detail in the next chapter.

III: EMPIRICAL STUDIES

5 Introduction to Empirical Studies

Based on the media equation approach (Nass & Moon, 2000; Reeves & Nass, 1996), it is assumed that crucial aspects of interpersonal touch as described in Thayer (1986), are also decisive factors for the perception and evaluation of HRT. Besides the mere information that is physically conveyed (e.g., texture, temperature), the quality of HRT as the intensity, duration and roughness can influence the perception. Furthermore, HRT can also occur in different forms that depend on the morphology of the robot, and the body parts involved (e.g., a pet like robot would be rather stroked, whereas a humanoid can shake the hand, or touch the face of a human, cf. Burgoon & Walther, 1990; Burgoon, 1991 for the different perception of different forms of interpersonal touch). HRT forms can further be distinguished according to their reciprocity and direction. Here the question is whether the human touches the robot, the robot touches the human, or if they mutually touch each other as during a handshake or embrace. In addition, the interaction context in which HRT occurs should likewise be considered crucial for the perception, interpretation, and evaluation of HRT. Ultimately, characteristics of the robot (e.g., its appearance) and the human (e.g., touch avoidance tendency) can further affect the perception of HRT.

Conclusively, the present thesis aims to explore HRT from the beginning, under the systematical consideration of the aforementioned aspects of touch that have been revealed as crucial in the realm of interpersonal touch (Thayer, 1986). To go beyond, methodologies and theories from interpersonal communication were applied to HRT to examine the psychological effects of HRT more systematically.

To address the overall question whether HRT touch can be perceived as pleasant, and may thus improve the well-being of humans, a research program was designed to cover distinct perspectives on HRT, from initial perception, interpretation, and evaluation, through to the immediate reaction to robot touch. Hence, the empirical studies first addressed preconditions that determine the evaluation of HRT from a controlled observational perspective, before actual reactions to robot-initiated touch were investigated on the basis of earlier gained knowledge on the evaluation of HRT.

5.1 Diverging Perspectives on Touch: Observation Versus Participation

The decision to primarily approach HRT from an outstanding observer perspective was based on earlier work in interpersonal touch research that demonstrated that observers share a social meaning model of touch (Burgoon, 1991); moreover, this social meaning is correlated with participants' interpretations of touch (Burgoon & Newton, 1991). Although no immediate reaction to touch can be measured from the mere observation of HRT, it is assumed that observers are capable of evaluating HRT from observations, and that these evaluations are in the same direction as participant ratings (cf. Burgoon & Newton, 1991). Additionally, evaluations of HRT are considered as important information, because it can be presumed that positive evaluations are reliable predictors for positive reactions to HRT (see Figure 3; Burgoon & Walther, 1990; Burgoon, Walther, & Baesler, 1992). Furthermore, the observational view allowed the controlled manipulation of several touch gestures (forms) that have been investigated in interpersonal touch research (e.g., Burgoon, 1991), gestures that were not realizable using different robots in real-time.

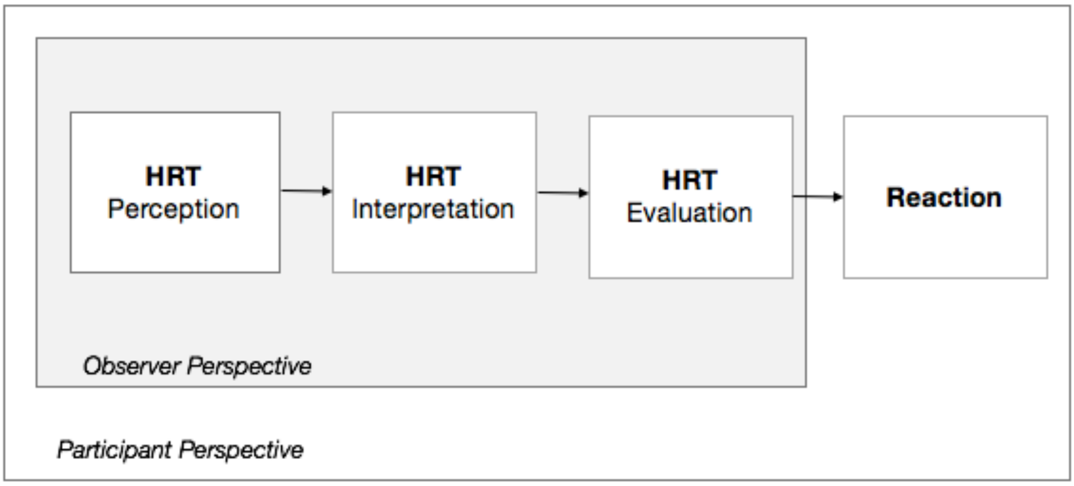


Figure 3. Assumed process that directs the appraisal of HRT.

5.2 Methodological Approach of the Present Thesis

A mixed-methods approach was chosen to understand the process of how humans react to HRT from the beginning. An advantage of the mixed approach is that it facilitates a more comprehensive understanding of a research topic by means of the integration of qualitative and quantitative results. Furthermore, qualitative approaches and methods are able to gather more in depth information, while quantitative data is more generalizable (Creswell, 2014). While the strategies for studying touch presented by Thayer (1986) were often pursued in isolation, it seems commendable to combine different strategies in order to benefit from their various advantages.

In consequence, the present thesis incorporates different strategies to gain a comprehensive understanding of the perception, interpretation, evaluation, and finally, the reaction to HRT, from different perspectives. Qualitative and quantitative methods were chosen in an exploratory sequential order (Creswell, 2014), whereby qualitative interviews were conducted first to gather general opinions and impressions from nonbiased interviewees. The impressions gained were then translated into quantifiable measurements, which were then tested with broader samples in different studies with a varying focus.

Overall, four empirical studies were conducted, focusing on the perception, interpretation, and evaluation of HRT from mere observations (Studies 1-3), as well as on the active experience of robot touch (Study 4). Figure 4 gives an overview of the order of the consecutive studies and the methodological approaches that were applied.

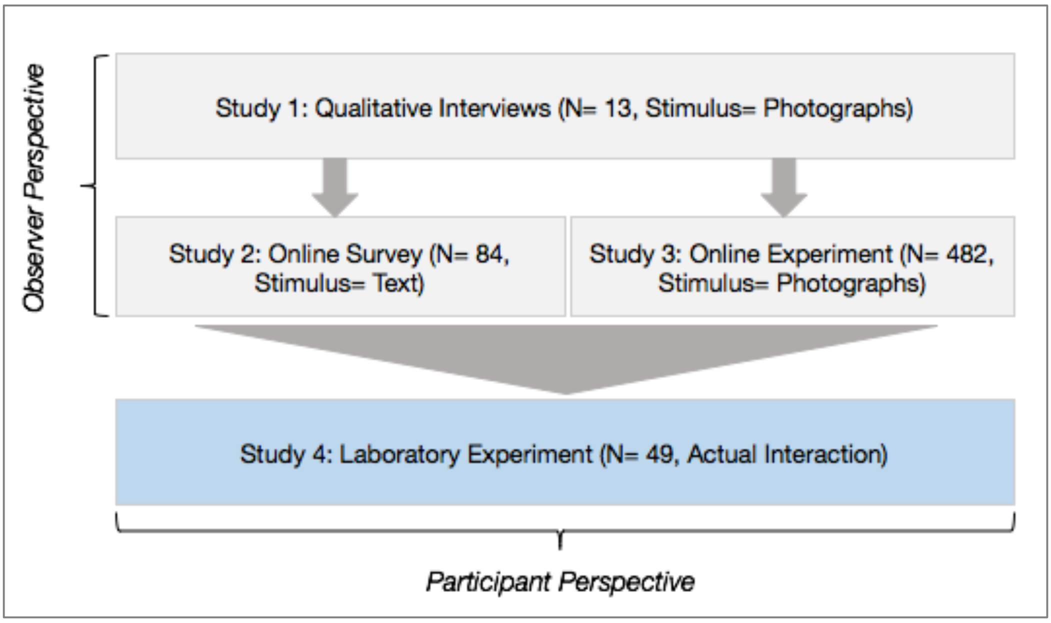


Figure 4. Overview of the methodological approaches and perspectives used to explore HRT.

An interview study was conducted to begin the exploration of HRT from an observer perspective. This used a primary qualitative approach that included photographs of different types of robots in different touch situations with a human actor (e.g., handshake, embrace; Study 1). On the basis of the findings from the interviews, two additional studies were designed to quantify the impressions formed by the analysis of the interviews, with a focus on a) determinants for the acceptance of HRT (Study 2), and b) the impact of contextual factors on the perception, interpretation, and evaluation of different forms of HRT presented on photographs (Study 3).

Finally, a laboratory experiment was implemented with the purpose of testing whether human participants react to actual robot-initiated touch in a manner comparable to interpersonal touch, performed under consideration of the HRT evaluation process that was revealed in the preceding studies (Study 4).

A detailed presentation of each study follows in the subsequent chapters.

6 Study 1: *Qualitative Interviews on the perception, interpretation & evaluation of HRT from an observer perspective*

As HRT has not been systematically researched in its facets so far, a qualitative approach was chosen as a starting point to explore how individuals react generally to touch between humans and robots (here: from an observer perspective). Different forms of touch and different types of humanoid robots have therefore been included to gain first insights into how these variations (form of touch, size and appearance of a robot) alter the perception, interpretation, and evaluation of HRT. Moreover, the aim of the interview study was to figure out whether a social meaning model, as has been supported in interpersonal contexts (cf. Burgoon, 1999), also applies to the perception and interpretation of touch in HRI – as the media equation would suggest.

6.1 Specific Research Questions & Hypotheses

Since this study is exploratory, general opinions about robot touch are questioned first, followed by initial reactions to the observation of HRT.

To the end that robot touch can only be beneficial to humans if there is at least a minimum degree of acceptability for touch by robots, it seems worthwhile to explore the general acceptance of robot touch first. Based on the work on body accessibility (e.g., Heslin, Nguyen, & Nguyen, 1983; Jourard, 1966) that demonstrated that individuals are diversely ready to accept touch to different parts of their bodies by distinct others (e.g., same versus opposite sex friends; friend versus strangers), it is of interest how willing individuals are to accept touch from a robot. Therefore, the first research question is:

RQ1: How acceptable is HRT to humans?

RQ1a: How acceptable is robot touch to different parts of the human body?

RQ1b: How does the acceptability of robot touch differ from that of human touch?

Based on the qualitative approach, it is also of interest to learn which rationale individuals explicate for the acceptance or rejection of robot touch.

RQ1c: Which reasons determine the acceptability of robot touch?

Moreover, the interviews focus on the perception, interpretation and evaluation of HRT from an observer perspective (cf. Burgoon & Walther, 1990; Burgoon, 1991). It was of interest to gather insights about individuals' spontaneous thoughts when they are confronted with HRT. Is their first reaction receptive or hostile? Are individuals initially surprised if they recognize touch between a human and a robot? Is the display of HRT perceived as offensive or alarming? Thus, the following research questions were formulated:

RQ2: How is HRT perceived from an observer perspective?

RQ2a: How evaluative are the descriptions of HRT?

RQ2b: How surprising and alarming is the observation of HRT?

As in the work of Burgoon (1991) the question whether the observation of touch between humans and robots also elicits interpretations that have a social or relational meaning, was also important. The overall question was:

RQ3: How is HRT interpreted from an observer perspective?

As it has not so far been investigated whether HRT affects the judgments individuals make about human-robot relationships, it was questioned if HRT is relationally interpreted, and furthermore, if the interpretations resemble those found in interpersonal touch research, which would support the applicability of a social meaning model of touch to HRT (Burgoon, 1991).

RQ3a: Do humans interpret HRI relationally, and are the interpretations comparable to interpersonal relationships?
RQ3b: Does a social meaning model pertain to touch with robots?

With regard to the evaluation of HRT, the question is how individuals might react emotionally to HRT. Since no real interaction with a robot takes place within the interview study, but earlier work demonstrated that individuals are more involved and have physiological reactions to touch if they actually participate in an interaction instead of merely observing it (Burgoon & Newton, 1991), the question focused on anticipated feelings in an imagined interaction with a robot to enable a higher involvement on the side of the interviewees.

RQ4: How is HRT evaluated based on personal feelings?

Moreover, the influence of the touch form as well as the appearance and size of a humanoid robot are considered as influential factors. Although the interview study is exploratory, hypotheses with regard to the impact of the touch form and robot type can be derived from related work. Given the assumption that HRI equals interpersonal interactions (cf. Chapter 1) it is supposed that different forms of touch are distinctly perceived, interpreted, and evaluated (cf. Burgoon, 1991):

H1: The form of HRT alters the perception, interpretation and evaluation of HRT.

In detail, it shall be clarified whether interactions that include different forms of touch with a robot are perceived positively, negatively, or as alarming or surprising. As the work of Burgoon and Walther (1990) suggests, different forms of interpersonal touch differ in their perceived pleasantness and expectedness. Regarding different forms of HRT, it is hence hypothesized:

H1.1: Different forms of HRT are perceived differently.

H1.2: Different forms of HRT are differently surprising and alarming.

Research in the context of relational communication pointed out that different relational meanings are ascribed to interpersonal relationships depending on the form of touch that is included in an interaction (e.g., handshake or embrace portrayed on photographs, see Burgoon, 1991; Burgoon & Walther, 1990). Also, Heslin et al. (1983) demonstrated that the meaning that is assigned to a specific kind of touch depends on the relationship between those who touch (e.g., higher invasion of privacy by touch from strangers than from close friends). Hence, it is presumed that different forms of touch between humans and robots also create different relational attributions by human observers.

H1.3a: Different forms of HRT lead to different relational interpretations.

H1.3b: Different forms of HRT are associated with different relational themes.

It is further assumed that the evaluation of HRT should also vary according to the form of touch that is included in an interaction, as demonstrated by Burgoon and Walther (1990).

> H1.4: Different forms of HRT are evaluated differently in terms of how an individual would feel in the situation.

Furthermore, characteristics of the interaction partner such as sex (Alagna & Whitcher, 1979; Fisher, Rytting, & Heslin, 1976; Whitcher & Fisher, 1979), status and physical attractiveness (Burgoon & Walther, 1990) have been shown to influence the perception and evaluation of interpersonal touch. In human–robot interaction research, the appearance and size of robots have also been considered as influential factors for a permitted approach distance. For instance, it has been revealed that individuals allow shorter approach distances to mechanical looking robots than to humanoid robots (Syrdal, Dautenhahn, & Walters, 2008). In short-term interactions, the permitted distance has further been demonstrated to be influenced by the preferred robot size (robot height: Walters, Koay, & Syrdal, 2009). Since touch can be regarded as an extreme form of approach with zero distance, it is expected that the size and appearance of a humanoid robot also influence the perception, interpretation, and evaluation of HRT.

> H2: The size and appearance of a humanoid robot alter the perception, interpretation and evaluation of HRT.
>
> H2.1 The size and appearance alter how HRT is described.
>
> H2.2 The size and appearance alter how surprising and alarming HRT is perceived.
>
> H2.3 The size and appearance alter the relational interpretation of HRT.
>
> H2.4 The size and appearance alter how individuals evaluate their anticipated emotional state.

In the next section, the methodological approach to answering the research questions and testing the hypotheses is explained in detail.

6.2 METHOD

Starting with a qualitative approach, semi-structured interviews were performed in combination with a think aloud technique (van Someren, Barnard, & Sandberg, 1994) in order to gather as much information as possible about the human subjects' first impressions of HRT.

6.2.1 Interviewees

Interviewees of different age groups and professions were recruited via announcements on online platforms (forums, social networking sites: Facebook) and direct invitations on campus or via email. In total, 13 individuals were interviewed (6 females and 7 males) aged from 27 to 68 (M = 38.08; SD = 15.61; *Median*= 28). The average duration of the interview sessions was 1 hour and 25 minutes (01:25:26). An overview of the interviewees and their professions can be found in Table 2.

Table 2. Overview of interviewees.

No.	Sex	Age	Profession	Stimulus set	Duration
1	Male	27	IT specialist	1	1:27:37
2	Male	36	Post doc researcher in computer science	2	2:00:24
3	Female	27	Management assistant in real estate	2	1:50:40
4	Female	57	German teacher (secondary modern school)	1	1:54:42
5	Male	68	Engineer in the automotive industry (retired)	1	1:37:52
6	Female	27	Social education worker	2	1:29:08
7	Female	55	Middle school teacher	1	1:22:47
8	Male	26	PhD candidate in psychology	2	1:09:18
9	Male	29	Job center employee	1	1:14:18
10	Female	33	Social worker (on maternity leave)	2	1:04:29
11	Female	27	Industrial management assistant	1	0:52:21
12	Male	24	Chemist	2	1:01:36
13	Male	59	Technician	1	0:51:11

6.2.2 Application of Observer Perspective

In a study conducted by Burgoon (1991), photographs were taken for the purpose of evaluating different forms of touch between humans and robots from an observer perspective. Although reactions to actual robot touch cannot be inferred from mere observations of HRT, it is supposed that general assertions from an observer perspective are useful to gain an insight into the perception, interpretation, and evaluation of several forms of HRT, in combination with different robots, which would not have been possible in real interactions at this stage. In line with a social meaning model as described in Burgoon (1991), judgements about the meaning of touch have been revealed as quite stable among individuals, and also among observers and participants (Burgoon, 1991; Burgoon & Newton, 1991). In addition, Burgoon and Walther (1990) claimed that individuals involved in touching as well as observers share *"cognitions about what is normatively expected and what is socially desirable or undesirable behavior."* (Burgoon & Walther, 1990, p. 243). Hence it can be expected that the assertions of the interviewees, which are based on the observation of photographs, are quite reliable in estimating opinions and meanings of HRT.

6.2.3 Stimulus Material

With regard to the question of how the form of touch (H1), as well as the appearance and size of a robot (H2) alter the perception, interpretation and evaluation of HRT, photographs of different HRI situations were included as stimulus material. With the aim of eventually investigating the effects of robot-initiated touch, robots that are able to initiate touch are considered from the beginning. As a consequence, robots that mainly serve as recipients of touch, e.g., pet like robots such as Paro (see Shibata & Tanie, 2001; Shibata et al., 2001; Shibata, Tashima, & Tanie, 1999; Wada, Shibata, Saito, Sakamoto, & Tanie, 2005; Wada, Shibata, Saito, & Tanie, 2002; Wada & Shibata, 2006), were excluded a priori. Because the different forms of touch being investigated in this study required the presence of humanlike body parts such as arms, hands and a head, only humanoid robots were chosen.

Different forms of touch between a human actor and different humanoid robots were therefore staged and photographed. Each photograph depicts the same human actor and one robot in one touch position (handshake, handholding, embrace, arm touch and face touch). The choice of touch forms was based on those reported in Burgoon (1991). In addition, the direction of touch, whether the human touches the robot or the robot touches the human, was varied for the touch to the arm and face. In total, 40 different photographs resulted from the combination of eight touch forms (no touch, handshake, handholding, touch to robots' arm, touch to humans' arm, touch to robots' face, touch to humans' face, embrace) and five humanoid robots of different sizes: a) Lego NXT (4.6 inches), b) Robosapien (13.5 inches),

c) Nao (23 inches), d) iCub (41 inches), and e) RHONI (71 inches; all stimulus pictures can be found in the digital Appendix).

The photographs were taken exclusively for the purpose of this study at the locations of the robots in Germany (Lego NXT and RHONI: Hochschule Niederrhein, Krefeld, Robosapien and Nao: University of Duisburg-Essen, and iCub: CoR Lab, Bielefeld University).

Two sets of 20 pictures were created from the 40 photographs (see Table 3), of which one set was presented to each participant to avoid interviewee fatigue. Each interviewee thus saw four pictures of each robot in four different touch situations (e.g. Lego with no touch, handshake, touch to robot's arm, and touch to robot's face in set 1). The photographs were presented in random order to avoid order effects.

Table 3. Labeling of the stimulus pictures and division into sets.

	Robot Type				
Touch form	(A) Lego	(B) Robosapien	(C) Nao	(D) iCub	(E) Rhoni
No touch (1)	**A1**	**B1**	**C1**	**D1**	**E1**
Handshake (2)	**A2**	**B2**	**C2**	**D2**	**E2**
Handhold (3)	**A3**	**B3**	**C3**	**D3**	**E3**
Touch to human's arm (4)	**A4**	**B4**	**C4**	**D4**	**E4**
Touch to robot's arm (5)	**A5**	**B5**	**C5**	**D5**	**E5**
Touch to robot's face (6)	**A6**	**B6**	**C6**	**D6**	**E6**
Touch to human's face (7)	**A7**	**B7**	**C7**	**D7**	**E7**
Embrace (8)	**A8**	**B8**	**C8**	**D8**	**E8**

Note. Blue = set 1, grey = set 2.

6.2.4 Interview Procedure and Protocol

In order to conduct semi-standardized interviews, the interviewer was equipped with an interview protocol (see Appendix; The guiding questions are listed in Table 4). This included questions that should be posed during the interview, and checkboxes to note down additional ratings for the stimulus pictures that were given by the interviewees during the interview session. The interview protocol was designed with respect to the research questions. According to the semi-standardized approach, the interviewer was allowed to change the order of questions and add questions that came up during the interview session (Berg, 2001). Each interview was audio recorded with the help of a notebook and a microphone and saved as mp3 files for later transcription.

At the beginning of each interview, the interviewer noted down demographical information about the interviewee (age, sex and profession) and assigned a running number to the interviewee which was used to identify and match the audio recordings, transcripts and interview protocols later on. The interviewer than handed a body chart which depicted the front and back of the human body with numbered body parts, similar to those used in (Heslin & Alper, 1983; Jourard, 1966) to the interviewee, who was then asked to color each body part according to how acceptable touch to the different parts of their own body was by a human who was not a parent or a romantic partner. As robots are strangers to humans in the first place, strong ties were excluded from the analysis.

Three colors were predefined: red for areas where touch is undesirable and not acceptable, yellow color indicates a body part where touch is acceptable under certain circumstances, and green highlights parts of the body where touch by another human is noncritical. Once the interviewees had finished coloring the body chart, the interviewer asked for further explanations as to why the different body parts were colored green and red, and under which circumstances touch to the yellow colored body region would be/is acceptable.

In order to gather information about touch acceptability for robot touch, the interviewer then substituted the sheet with the colored body chart with a new (blank) body chart and asked the interviewee to repeat the task, but this time imagining the toucher to be a robot. The robot was not precisely defined, except that it was said to have body parts that would allow it to touch a human. The interviewees then had to color the body chart again and the interviewer asked for the reasons why they had chosen each color afterwards (RQ1c). The main idea behind the inclusion of two body charts for human and robotic touchers was the direct comparison of interviewees' readiness to permit touch by a robot to their accessibility to touch by a human (stranger) (RQ1a, RQ1b).

After this part, the think aloud part started which should serve as an unbiased report of the initial encounter with HRT (RQ2). But first, a short verbal loosening up session was included to prepare the interviewees to verbalize their thoughts about the stimuli (van Someren et al., 1994). For the warm up, interviewees were asked to verbalize what they thought about pictures they were confronted with. First, a photograph of David Hasselhoff and his car K.i.t.t. from the TV series *Knightrider* (see Appendix) was presented. A second picture was chosen from the movie Robot & Frank (2012) to introduce a situation in which a human and a humanoid robot are involved, but where no touch was present. Again, interviewees were asked to verbalize what first came into their mind when they saw the picture.

After loosening up (the warm up), the main think aloud session started. Now, interviewees were confronted with the stimulus pictures and had to continue commenting on what they were thinking. Each picture was separately presented to the interviewees and the interviewer repeatedly asked: *"Please describe what you see in the picture. Think loud and verbalize what first comes to your mind while you observe this situation."* (cf. Table 4). If the interviewee stopped describing the picture, the interviewer asked if the interviewee would like to add something before she continued with the next question.

Thereafter, interviewees were asked to rate their perception of the picture with respect to the expectedness (surprising) and desirability (alarming) of the presented situation (RQ2). They were told that they should base their ratings on how they would feel if they entered a room knowing only that a human and a robot would be inside and then being faced what was depicted in the picture: *"Imagine you enter a room and you are told that there will be a human and a robot in the room. Then you see a situation as in the picture. Would it surprise you? Is the situation alarming in your opinion?"*

Five-point Likert type scales were used to access whether the situation was surprising (1= not surprising at all, 5= very surprising), or alarming (1= not alarming at all, 5= very alarming). In order to not interrupt the fluency of the verbal interview ratings were not collected via paper-and-pencil questionnaires, but the interviewer presented the scales to the interviewees on printed cards, and verbally asked them to make their rating. The experimenter then marked the ratings (1-5) in the interview protocol (see Appendix).

Subsequently, an assessment of the relationship between the human and the robot was sought with the question: *"How would you describe the relationship between the human and the robot in the picture?"* This question was intended to test if a human-robot relation is ever relationally described in terms of an interpersonal relationship, and if so, whether the description resembles the social meanings and relational dimensions assigned to interpersonal touch (RQ3a-c, cf. Burgoon, 1991).

After that interviewees were asked to imagine being the person in the picture and to evaluate the situation based on their anticipated emotional state (RQ4).

"Please imagine you are the person in the picture. How would you feel?

Answers to the question were collected by means of the Self-Assessment Manikin (SAM: Bradley & Lang, 1994), which consists of three pictorial 5-point scales that represent valence, arousal, and dominance (see Appendix). The pictorial subscales were also presented to the interviewees on single printed cards. The interviewer noted down the interviewees' ratings on the interview protocol (from left to right: valence: 1= good - 5= bad*; arousal 1= highly aroused - 5= calm*; and dominance: 1= inferior – 5= superior).

This procedure was repeated for each of the 20 pictures (think aloud, first assessment, relational interpretation and evaluation; steps 4-7 in Table 4).

Finally, questions were asked about the interviewees' general attitude towards robots, and what they thought the purpose of the interview was, before they were fully debriefed and thanked for their participation (for an overview of the sequence and questions asked refer to Table 4).

Table 4. Overview of the interview procedure.

Interview part	Questions asked	Duration
Introduction & Demographical data	Number Date Time (start) Sex Age Profession	2-3 minutes
Acceptability of touch	*"Please indicate by means of the colors how acceptable touch to each body region is to you…* Human touch *…by a human toucher.* Robot touch *… to you by a robot.* *Use green for regions where touch is uncritical, yellow if touch is only acceptable under certain circumstances, and red if touch to this region is not acceptable at all."*	8-10 minutes
Think aloud warm up	Picture of David Hasselhoff *"Please look at this picture and speak out loud what spontaneously comes to your mind."* Picture from the movie Robot & Frank *"Please study the situation in the picture. Describe what you see and what comes to your mind while you view the picture."*	2-3 minutes
Main think aloud part, Perception of the situation	Stimulus picture (1-20) *"Please describe what you see in the picture. Think aloud and verbalize what first comes to your mind while you observe this situation."* *"Would you like to add something?"*	60-90 sec. (20-30 minutes in total)
First assessment of the situation	*"Imagine you enter a room and you are told that there will be a human and a robot in the room. Then you see a situation as in the picture.* *"Is the situation surprising?"* (5-point scale*)* *"Is the situation alarming?"* (5-point scale)	30 sec. (10 minutes in total)
Relational Interpretation	*"How would you describe the relationship between the human and the robot in the picture?"*	30-60 sec. (10-20 minutes in total)
Evaluation of anticipated emotional state	*"Please imagine you are the person in the picture. How would you feel?* (SAM, 5-point pictorial scale) *Would you feel rather good or bad?* *Would you feel rather aroused or relaxed?* *Would you feel rather inferior or superior?* (5-point pictorial scale)	1 Min. (20 min. in total)
General questions	*See Appendix*	3-5 minutes
	Avg. duration:	**1 hour 25 minutes** (85 minutes)

6.2.5 Data Preparation and Analyses

6.2.5.1 Transcription

The audio recordings of the interviews were fully transcribed with the transcription software F5 for Macintosh. Hesitation sounds like “um” or “err” were left out. Interruptions or unfinished sentences were noted by two slashes (//) and pauses by dots in parentheses (...). Laughing was also transcribed in parentheses (e.g., (laughs)) as well as connotations to interjections (e.g., scared; excited)[3].

6.2.5.2 Content Analysis

Qualitative content analysis (Schreier, 2012) was then used to analyze the transcripts. For this purpose, a coding frame was built upon the research questions and interview sections. The software MAXQDA (Version 11, Release 11.0.2) was used for the coding and analysis of the transcripts. Categories were built inductively as well as deductively. Thirty percent of the material was additionally coded by a second rater. Inter-rater agreement (Cohen’s Kappa between 0.69 and 1.0 for all categories) was substantial to almost perfect according to Landis and Koch (1977). Detailed values for each category are provided below.

6.2.5.3 Additional Scale Ratings

The additional scale ratings (*surprising, alarming,* and *affective state)*, were statistically analyzed. Therefore, the ratings from the interview protocols were entered per picture into a data sheet. Then the ratings were cross checked with the transcripts to ensure that the interviewer had not mistakenly noted a wrong answer. Afterwards, the scale ratings for the different stimuli were analyzed with SPSS 20.

6.2.5.3 Coding Frame and Units of coding

The coding frame was developed iteratively. First of all, the material was structured by selecting the relevant parts from the transcripts in MAXQDA. The transcripts were then divided into meaningful units of analysis (Schreier, 2012), which corresponded to the

[3] Note that the interviews were conducted in German so that the original transcripts in the appendix are German too; example quotes which were presented in the running text have been translated from German to English.

research questions, namely: acceptability of touch, perception valence, first assessment relational interpretation, and evaluation (cf. Table 5).

In order to distinguish between repeated units for different stimuli (all units except acceptability of touch), context codes for each stimulus picture were additionally assigned to each section that referred to one stimulus picture (e.g., A1 for statements that referred to Lego NXT without touch, or E8 for RHONI touched at the face by the human actor, see Figure 3 for the labeling of the stimuli).

Subsequently, subcategories were introduced as units of coding within the structuring units of analysis. They were partly driven by the research questions (deductively introduced at the beginning), and partly built inductively from the material (during coding). The subcategories summarized the main assertions that were made by the interviewees (e.g. the valence of the descriptions was pronounced positive, negative, mixed or neutral) and were iteratively created through examination, summary and reduction of the given material (cf. Mayring, 2010; Schreier, 2012).

The final coding frame consisted of five main categories that were further split into subcategories with further (sub-) subcategories in some cases. An overview of the main categories can be found in Table 5.

Table 5. Overview of the main units of coding.

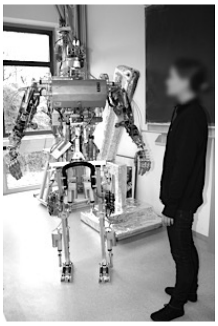
Unit of analysis	**Sub code**	**Description (Content)**
Acceptability of touch	Human touch Robot touch	Comments on the body chart for touch by a human other. Comments on the body chart for touch by a robot.
Perception valence	---	Think aloud descriptions of the stimulus pictures.
First assessment of the situation	Surprising Alarming	Comments on the rating question: Is the situation surprising? Comments on the rating question: Is the situation alarming?
Relational interpretation	---	Answers to the question how interviewees would describe the relationship between the human and the robot in the picture.
Self-assessed emotional state	SAM valence SAM arousal SAM dominance	Comments on the anticipated valence ratings. Comments on the anticipated arousal ratings. Comments on the anticipated dominance ratings

6.3 Interview Results

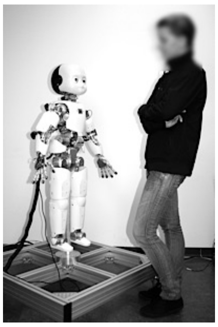
In the following, the results of the qualitative content analysis (QCA) are presented along with the descriptive analysis of the quantitatively accessed scale ratings[4]. The presentation of the results follows the order of the research questions. Each section is dedicated to one question (RQ1-4), while the influence of the touch form (H1) and the robot type (H2) were considered for the perception, interpretation and evaluation, respectively. But first, general impressions of the different robot types are summarized, because the robot type is repeatedly considered afterwards with respect to the different dimensions.

6.3.1 General perception of the different robot types

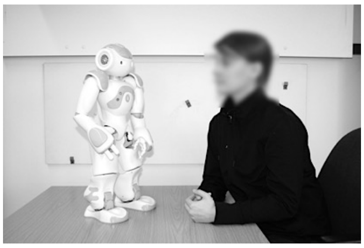
This section covers the descriptions of all robots, to give a brief introduction on how interviewees initially perceived their different appearances. Figure 5 depicts one photograph of each robot in the no touch control situation.



Rhoni, 71 inches

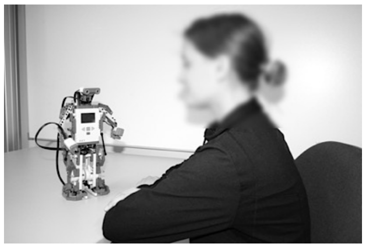


iCub, 41 inches



Nao, 23 inches

Robosapien 13.5 inches



Lego NXT, 4.6 inches

Figure 5. Example pictures of each robot in the no touch control position.

Rhoni (Figure 5) was generally described as the typical exemplar of a robot with a mechanical look that shows wires and buttons. Furthermore, its huge size was mentioned

[4] Note: No inferential statistics were calculated due to the small sample size that is, however, common for a qualitative approach.

many times. The fact that the robot is taller than the human in the picture seemed especially noteworthy. Some also described the robot as dominant, threatening and male.

> "The robot is humanoid but more like a 'Terminator' without a skin cover. Technically speaking, hydraulics, motors and wires. That seems quite severe. Lots of steel, bare steel (…) In any case taller than the human and wider. Thousands of tubes, buttons and other things. It doesn't look humanlike but rather as the typical bad guy in a movie." (male, 24, chemist)

iCub (Figure 5) was described as less mechanical, more humanlike and rather childlike. Its big head and humanlike face were often pointed out. Again, the size of the robot was addressed. The robot is smaller than the person and its size was said to be comparable to that of a child. Its big hands with the long mechanical fingers were also often mentioned, as well as the partial lining that covers its mechanical interior. Unlike Rhoni, iCub was described as friendly, although some interviewees were scared of the childlikeness.

> "It looks like a child! (scared) My God! Something like this already exists? That's creepy, whereas the robot itself doesn't look creepy, but it looks just like a child. Quite humanlike traits because of the shape of the head, the nose, the eyes // Strongly humanized." (female, 27, management assistant in real estate)

Nao was described as a small, filigree character with big round eyes and humanlike traits. It has a bright body which is covered with plastic and resembles a toy. Nao was perceived as friendly, cute, and even cuddly.

> "He is strong in physique but looks gentle. The shape of the head is cute and due to the speakers at his ears he seems quite nice. The colors are also lovely. His brightness makes him appear friendly and a little bit cuddly because of the round shapes. (female, 27, management assistant in real estate)

Robosapien. The Robosapien robot (Figure 5) was described as a nice mini-robot that looked humanoid but remarkably technical. Its appearance was declared as modern, abstract and toy-like. Some compared the robot to a 'Transformers' or a small animal. Its gripper finger was perceived as peculiar but the robot as a whole was not perceived as threatening.

> "This one looks interesting, more modern than the other one, relatively small and thus not threatening." (female, 27, industrial management assistant)

Lego NXT. The Lego NXT robot (see Figure 5) was perceived as a small, delicate and fragile technical-toy. It reminded some interviewees of robots and the like which were known from the movies. For instance, they mentioned E.T. and Wall-e from the eponymous movies. Furthermore, Lego NXT was described as unfinished and mechanical without lining. Lastly, the robot was characterized as cute and likeable.

> "It looks like E.T. Seems immediately familiar to me. He is also quite small, the robot." (male, 24, chemist)

> "This one is delicate… cute somehow… As if he's wearing a backpack and travelling through the region. He's quite nice, but much smaller than the other one which was similar in style but taller, because the others were covered with linings and this one is completely naked like the big one. But this one doesn't seem threatening because he's so small and delicate and appears fragile." (female, 27, management assistant in real estate)

In summary, the size of the robot was mentioned in all cases, mostly in comparison to the size of the human in the picture. The robot that was taller than the human (Rhoni) was perceived as more dominant and threatening than all the other robots, which were smaller than the human and hence more positively described. The smallest ones (Lego, Robosapien and Nao) were furthermore described as friendly and not threatening. The iCub robot reminded the interviewees of a child, at least the head was often described as childlike. How these differences in the perception of the different robot types affects the evaluation of HRT will be revisited in the following sections with regard to the perception, interpretation and evaluation. The sections are organized according to the research questions.

6.3.2 Acceptability of Robot Touch

In order to answer the question whether robot touch to different parts of the human body is accepted by human interviewees (RQ1), and how the acceptance differs from human touch (RQ1a), touch to different body regions was analyzed by means of the coloring of the body charts and associated explanations for the color choices that were found in the interview transcripts (RQ1b).

For the analysis of the data, the frequencies of color choices for each body part were quantified and summarized in Table 6 for touch by a robot and a human. Then the statistical mode for each body part was determined (underscored numbers in Table 6).

Table 6. Frequencies of color choices for human and robotic touchers.

	Robot-to-human touch			Human-to-human touch		
Body region	acceptable green	dependent yellow	unacceptable red	acceptable green	dependent yellow	unacceptable red
1	2	6	5	2	7	4
2	0	4	9	0	5	8
3	0	5	8	1	4	8
4	0	5	8	0	5	8
5	0	4	9	0	5	8
6	1	5	7	1	7	5
7	7	3	3	3	7	3
8	4	4	5	2	4	7
9	5	3	5	1	5	7
10	0	3	10	0	1	12
11	5	4	4	2	7	4
12	6	6	1	4	7	2
13	7	6	0	6	6	1
14	5	6	2	4	6	3
15	11	2	0	11	2	0
16	11	2	0	12	1	0
17	11	2	0	13	0	0
18	3	6	4	2	7	4
19	3	5	5	2	6	5
20	8	4	1	5	7	1
21	7	5	1	4	8	1
22	1	3	9	0	3	10
23	5	4	4	1	7	5
24	8	4	1	6	6	1

Note: Underscored numbers represent the mode for each body part (per row).

In order to visualize the average color choice for both human and robotic touchers, two new body charts were created based on the modes determined from Table 6 (see Figure 1 and 2). The color that corresponds to the mode was used as the average color, except when two colors were chosen equally often (e.g., region 19 for robot touch). In these cases, the region was striped in both colors (e.g., green and yellow for robot touch region 12).

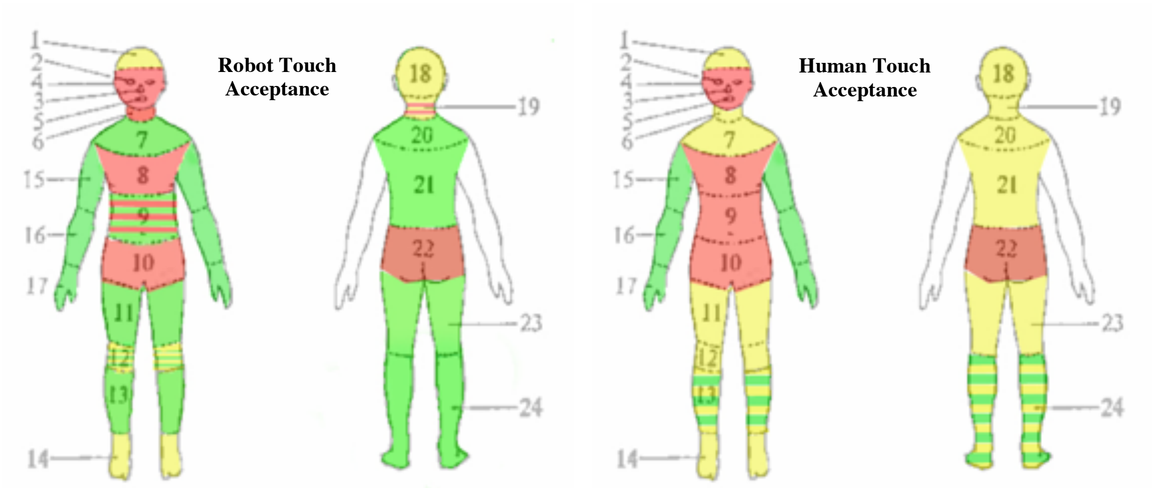


Figure 6. Average body charts for the acceptance of robot touch (left) and human touch (right). Green= acceptable, yellow= equivocal, red= unacceptable.

In addition, Table 7 summarizes the amount of green-, yellow-, and red-colored body regions for anticipated touch by a robot or human.

Table 7. Amount of green, yellow, and red body regions in the average body charts.

	Acceptable Green	Equivocal Yellow	Unacceptable red
Robotic toucher	**11**	4	9
Human toucher	4	**12**	8

Note. Body parts with the same number of color choices for two different colors were counted as 0.5 (e.g.: green-yellow parts are counted as 0.5 green and 0.5 yellow)

As Figure 6 and Table 7 illustrate, most body areas (11/24) are color-coded in green which means that touch to these regions by a robot is acceptable (RQ1a). However, many areas are also said to be inaccessible to robotic touch (9/24 red), and a few regions were on average touchable depending on the situation (4/24 yellow). Critical body areas that should not be touched by a robot (red color) were face and throat (2-6), the chest (8), parts of the stomach (9) and the private parts (10, 22). The back of the head, the front, the feet and parts of the knees were only accessible to robot touch under certain circumstances, e.g., *"… if I knew that nothing could happen, then I would accept a touch to the head and maybe at the cheek (…)"* (male, 29, job center employee) (further reasoning about robot touch acceptance is discussed below). The remaining regions, however, were less critical with respect to robot touch. Hands, arms (15-17), and shoulders (7), as well as the legs (11-13), and almost the entire back of the body (20, 21, 23, 24) were allowed to be touched by a robot.

In the case of an anticipated human toucher, most body regions are exclusively permitted to be touched under certain circumstances (12/24 yellow). Eight regions were further marked as not touchable at all (8/24 red), while only four were acceptable (4/24 green).

When contrasting the average acceptability for robot and human touch to answer RQ1b (Figure 6, Table 7), it becomes obvious that interviewees permit touch from a robot more often (11/24) than from a human (4/24). The interviewees agreed that parts of the face (eyes, nose, mouth, ears), the chest and the private parts are in general not accessible to touch by humans (strangers) and robots. Furthermore, the hands and arms seem to be uncritical areas to be touched by both humans and robots. For the cases in which the interviewees imagined being touched by a robot, most parts of the legs and the back of the body were generally also seen as uncritical and acceptable (green), while in the case of a human toucher these regions were said to be accessible only under certain circumstances (yellow).

After it was revealed that robot touch to some body areas is more acceptable than human touch, the comments on the interviewees' color choices were examined further with regard to reasons why robot touch is or is not acceptable (RQ1c).

Four major issues were identified that determine the acceptance or rejection of robot touch according to the assertions of the interviewees. These were then summarized and added as subcategories, namely: *lower inhibition threshold, task-relatedness of touch, fear of damage & uncertain controllability,* and *familiarity & trust in technology* (Table 8).

Table 8. Coding Frame for the reasons to accept touch by a robot (or not).

Sub-category	**Description**	**Example**	**Kappa**
Lower inhibition threshold	The explanation for the acceptance of robot touch includes a reference to a lower borderline or inhibition threshold for robot touch compared to human touch.	"Because a robot ordinarily doesn't have any ulterior motive, a touch is considered less nasty." (female, 27, management assistant in real estate) "I think I would not have as many inhibitions facing a robot, because I know that a robot is not a living creature." (male, 29, job center employee)	1.0 (100%)
Task-relatedness of touch		"If it seemed it would be good at cutting hair, then the back of the head, yes, but not the feet. For massages, such a robot could also not be so bad either… I directly associate it with practical aspects." (female, 33, social worker) "If it is a robot which is working for a doctor… maybe when I'm injured." (female, 27, industrial management assistant)	
Fear of damage & uncertain controllability		"Because the toucher is a robot, I guess that the touch is more uncontrollable compared to a human." (male, 26, PhD candidate in psychology) "Not on the face, at least not the eyes, because I wouldn't know how fine motoric the robot acts finely tuned the robot is), and whether something might go wrong (…)." (male, 29, job center employee)	
Trust in technology		"If I knew that nothing could happen, then I might allow the robot to touch my head and maybe my cheeks (...)." (male, 29, job center employee) "… if it is guaranteed that the robot couldn't hurt me, so that I could assume that he wouldn't prick me in the eye or elsewhere. Although, no, not on the face. (…) I wouldn't accept a touch to the face because it is somehow humanlike if a robot were to touch me like that." (female, 27, management assistant in real estate)	

The category *lower inhibition threshold* summarizes comments which state that touch by a robot is more easily accepted than human touch because of a lower inhibition threshold due to a lack of emotions. Interviewees explained that they would not feel uncomfortable if a robot were to touch them, because robots do not have intentions and emotions that might make touch feel inappropriate. Furthermore, the fact that a robot is a thing, and having contact with things does not involve emotions, led some interviewees to the assumption that touch with robots is uncritical compared to interpersonal touch (example explanations are listed in Table 8).

The second reason that was mentioned is summarized in the category *task-relatedness of touch*. Comments that were assigned to this category referred to robot-initiated touch as instrumental and therefore justified (e.g. touch head to cut hair, touch back to give a massage, Table 8). In addition, the importance of the context in which touch happens was stressed in several comments. Overall, robot-initiated touch was said to be acceptable if it serves a specific task, e.g. help or assistance in a functional or professional context.

In contrast to the reasons for a high acceptance of robot touch, some statements indicate that robot-initiated touch is unacceptable (red), because individuals are worried about being hurt if a robot were to touch parts of their body. Sensitive parts like the eyes or the face were specifically mentioned. In addition, uncertainty about the roughness and controllability of the robot's movements was brought up (for examples see Table 8). All comments in this line were summarized under *fear of damage & uncertain controllability*.

Interviewees also said that a robot that is allowed to touch them should be familiar to them. Moreover, they preferred being familiar with the robot's functions. Also, trust in the technology itself was said to be necessary to permit robot touch. Interviewees for instance reported that they would accept a robot touching their head or face if they could be certain that nothing bad could happen. Statements in this realm were summarized under the category *trust in technology*.

Overall with regard to RQ1b, a higher acceptability of robot touch, compared to human touch, was most frequently explained by a lower inhibition threshold for robots due to the fact that robots are inanimate objects that do not have emotions, intentions or ulterior motives (5/15). Individuals therefore would not feel uncomfortable when they were touched by a robot, whereas touch by a human stranger with emotions and intentions is more likely to be perceived as harassment and thus is less acceptable. Furthermore, the acceptability of robot touch was justified multiple times (4/15) by its expected instrumentality or task-relatedness, which makes it a necessary act for specific contexts. Also, trust in the technology itself was mentioned four times (4/15) as a prerequisite for accepting robot touch, especially to sensitive body regions. Related to trust, a reason against acceptance, which was mentioned twice (2/15), was the uncertainty about how predictable and controllable a robot might be, accompanied by the fear of being damaged.

Having discussed the general question of robot touch acceptability, the focus is now directed to the impressions and reactions to the stimulus material, i.e. the photographs.

6.3.3 Perception of HRT

The first dimension that is considered is the perception of HRT. The guiding question is: How do individuals perceive an interaction between a human and a robot that includes touch (RQ2)? Therefore, the first impressions of the interviewees, manifested in the think aloud comments, as well as the answers to the questions how surprising and alarming the situation in the picture appeared, are analyzed.

7.3.3.1 Perception valence (think aloud)

The think aloud comments were categorized with regard to their valence (RQ2a), with the objective of gathering an unbiased view on the interviewees' thoughts when they were confronted with HRT (resp. one specific form of HRT with a specific robot) for the first time. The valence of the comments was initially (deductively) categorized as a *positive, negative* or *value neutral* comment. During the coding, additional (sub-) categories were inductively added (see Table 9).

Value neutral comments were further divided into *neutral* statements and others which contain uncertainty (*uncertain,* see Table 9). Within the positive and negative categories, a differentiation was further made with respect to what the comment referred to: If it referred to the robot the code *positive/negative robot* was assigned. If it referred to the situation or the form of touch, *positive/negative situation(touch)* was assigned. Lastly, *positive/negative both* was chosen if the robot and the situation were mentioned within one think aloud unit. In addition, the category *mixed valence* was introduced for comments that included positive as well as negatively judged statements (see Table 9 for the description and examples of each category).

Table 9. Coding for the perceived valence of HRT.

Interview Question: "Please describe what you see in the picture. Think loud and verbalize what first comes to your mind while you observe this situation."

Main Category: Perception valence

Subcategory	Description	Examples	Decision rules	Cohen's κ
Value neutral				**κ= 0.75**
Neutral	The description is neither positive nor negative.	"The robot bends down to the woman as if he would tell her something. Also, he grasps her at the shoulder." (female, 27, industrial management assistant)	Unambiguous statements like "not threatening" are treated as neutral. If a statement ends with a relational description as "intimate relationship", the statement is still treated as neutral so long as the relational definition does not directly refer to the touch gesture (e.g. "The robot embraces the human, in this case their relationship has to be intimate, otherwise an embrace wouldn't happen.")	
Uncertain	The description contains no valued statements and further points out that the situation is unclear.	"A person is sitting at a table, her hands are on the table, and a robot is sitting opposite her. The robot is standing on the table. He's at the same height as the head of the person. The situation is hard to interpret. It's hard to recognize if the robot or the person is moving, if they are moving towards each other or away. That's why I would assume that the relation of the interaction is at the very most verbal. I can't tell how both relate to each other emotionally or otherwise." (male, 26, PhD candidate in psychology)		
Positive				**κ= 0.74**
Positive - Situation	The description of the stimulus is favorable because of the situation itself.	"It looks as if the person touches his upper arm and says: 'Glad you're here.' He looks in her direction. It seems familiar." (female, 33, social worker)	Negations as "not threatening" are coded as neutral and not interpreted as the opposite valence (here: positive)	
Positive - Robot	The description of the stimulus is favorable because of the robot, its appearance and gesture.	"This robot is quite more humanlike. Just because of the face that can be recognized. He also looks friendlier than the other one before." (male, 29, job center employee)		
Positive - Both	The description of the stimulus is favorable because of the situation and the robot.	"They seem very intimate. The person bows downwards and the robot stretches its arm towards the face and seems to care. It seems familiar. The robot appears motherly (laughs)." (female, 27, social education worker)		

Negative			*κ*= **0.91**
Negative - Situation	The description of the stimulus is negative due to the situation.	"Know it's getting strange, because the robot doesn't look humanlike but is now put in this embrace situation. Well, you stroke pets, too, but you would rarely embrace them in such situation. Seems strange." (male, 36, post doc researcher in computer science)	
Negative - Robot	The description of the stimulus is negative due to the robot.	"The robot looks arrogant because they are holding hands, and the human faces him but the robot turns away with a sleepy look." (male 24, chemist)	
Negative - Both	The description of the stimulus is negative due to the situation and the robot.	"I think the robot is angry (…) because he looks that way, and it seems as if he's turning away but the person tries to comfort him. As if she would grasp his arm and say 'turn this way'. So I think that the relationship is troubled or negatively influenced at the moment." (female, 27, social education worker)	
Mixed	The description of the stimulus contains positive and negative parts.	"Know she's patting his cheek. They definitely touch. The patting appears caring, but it would be nicer if he pats her too, but he doesn't." (female, 33, social worker)	*κ*= **1.0**
		Overall reliability	**κ= 0.82**

In order to get an initial impression of the interviewees' opinions about the pictures that include touch, in comparison to the control stimuli without touch (*no touch*), the frequencies for the occurrence of each valence category were calculated.

Table 10. Frequencies for the perceived valence of the think aloud descriptions.

	value neutral			**Positive**				**negative**				**mixed**
	neutral	un-certain	**total**	situation	robot	both	**total**	situation	robot	both	**total**	
No touch	23	1	**24**	4	1	0	**5**	1	3	0	**4**	**0**
Touch (cumulated)	103	19	**122**	49	9	5	**63**	11	15	4	**30**	**12**
Total	**126**	**20**	**146**	**53**	**10**	**5**	**70**	**12**	**18**	**4**	**34**	**12**

Note. Lower frequencies for no touch result from a lower total number of comments (*n*= 33) compared to the cumulated comments for all kinds of touch (*n*= 227 comments).

As Table 10 reveals, the majority of the comments are value neutral descriptions. About 72% (24/33) of the *no touch* stimuli and 54% of the touch stimuli (122/227) were categorized as *value neutral*, which means that neither a positive nor a negative value was assigned to the human-robot interaction depicted in the pictures. *Mixed valence* statements containing comments that combine positive and negative aspects were not observed for *no touch* control stimuli, and in only 5% (12/227) of the cases that included touch.

Even more interesting with regard to the question how HRT is perceived from an observer perspective (RQ2), are those statements that are categorized as evaluative (positive or negative). For touch stimuli, the amount of positive valued comments outnumbers the negative ones (positive = 63/227, negative = 30/227; Table 10). A closer look at the subcategories reveals that most positive valued comments (78%) referred to the situation (49/63), and only a few (14%) mentioned the robot (9/63), or both (8%, 5/63). On the contrary, half of the negatively valued comments (15/30) referenced the robot (its appearance or size) as the cause of the negative perception, while the situation was less frequently referenced in 37% of the cases (11/30). Both situation and robot were mentioned together in 13% of the negatively valued comments (4/30)

6.3.3.2 Perceived valence according to touch form

For a more detailed analysis of the influence of the different touch forms (H1.1), the frequencies for each touch form are now looked at separately (Table 11).

Table 11. Frequencies for each sub-category of the perception valence.

	Perceived valence											
	Value neutral			Positive				Negative				Mixed
Touch form	Neutral	Un-certain	**Sum**	Situation	Robot	Both	**Sum**	Situation	Robot	Both	**Sum**	
Handshake	17	0	**17**	6	2	0	**8**	1	6	0	**7**	1
Handhold	21	2	**23**	4	0	0	**4**	0	4	0	**5**	1
Touch to human's arm	12	7	**19**	6	1	0	**7**	4	2	0	**6**	0
Touch to robot's arm	19	3	**22**	4	2	1	**7**	1	1	2	**4**	0
Touch to robot's face	11	1	**12**	12	2	2	**16**	0	1	0	**1**	4
Touch to human's face	12	4	**16**	6	2	1	**9**	3	1	1	**5**	2
Embrace	11	2	**13**	11	0	1	**12**	2	0	1	**3**	4
Touch total	**103**	**19**		**49**	**9**	**5**		**11**	**15**	**4**		**12**

When considering the frequencies presented in Table 11, more *value neutral* than evaluative comments were countable for reciprocal hand touches (*handshake*, *handhold*) as well as for arm touches (*touch to human's arm*, and *touch to robot's arm*). In contrast, the more intimate touch forms, *touch to robot's face, touch to human's face* and *embrace* led to more judgmental comments (positive, negative, and mixed) than value neutral ones (cf. Table 11).

The most positively valued comments were observable for intimate touches to the face (*touch to robot's face*: n = 16, *touch to human's face*: n = 9) and *embrace* (n = 12). The fewest positive descriptions were given for *handholding* (n = 4) and *no touch* (n = 5). Touch to the face of the robot and embrace were often described as a sign of attachment, intimacy and trust between the human and the robot:

> "That is also cute. It looks as if the human is treating the robot quite gently and stroking its cheek. Well, showing attachment to the robot." (male, 27, IT specialist)
>
> "The person touches the robot's head. They are attached to each other. The person appears as if she's taking care of the robot, like a doll, or (laughs) I almost said like a child." (female, 27, social education worker)
>
> "The person touches the robot at its so-called head or eyes. This interaction is more intimate, because in my opinion the head is a sensitive part of the body and therefore I would expect even more trust from the person to the robot." (male, 26, PhD candidate in psychology)
>
> "Nice. They seem quite intimate together because he embraces her and she reciprocates it. They seem to like each other and have feelings for the other … somehow." (female, 27, management assistant in real estate)

Reciprocal touch between humans and robots thus seems to be associated with positive close relationships (see also Chapter 6.4).

Negatively valued comments were most often observable for *handshake* pictures (n = 7) and robot-initiated touches (*touch to human's arm*: n = 6, *touch to human's face*: n = 5), while the few negative comments refer to human-initiated touch, especially to the face of the robot (*touch to robot's face:* n = 1). Reciprocal touch forms remain in the middle (*embrace*: n = 3; *handhold:* n = 4).

With regard to the negative comments that addressed *handshake* stimuli, it is noticeable that only one out of seven negative comments refers to the touch (or the situation), while the other six refer to the robot. The appearance of the robot caused most of the negative perceptions, e.g. if the robot in the picture (here: Rhoni) is compared to a villain from a science fiction movie such as the 'Terminator', or if its appearance is too humanlike (e.g., iCub).

> "The robot is humanoid but more like a ‚Terminator' without skin. Technically speaking you can see many hydraulic presses, motors and cables. It looks really bad. Much steel, sheer steel (...) One could say the thing at the chest is a chest protector. Looks like a Science Fiction movie. Because of the size and stature, this robot could belong to the evil side in an action movie. (...) (male, 36, post doc researcher in computer science, on Rhoni)

> "I'm personally afraid of figures that have such humanlike faces. Others might think differently, but this is why I don't like this robot. He looks quite humanlike. The face, the eyes and so on, (…) there I would be a little bit anxious. (…) he`s a little bit too scary for my taste." (female, 27, industrial management assistant, on iCub)

Comments with *mixed valence* often contained relativizing statements. For instance, one interviewee mentioned that the robot in the picture (Rhoni in this case) looked frightening, but because of the reciprocal touch (handholding, handshake) the whole situation looked harmless.

> "The robot looks like a big male robot, he looks a little bit threatening, but in this situation not threatening, because the person seems relaxed standing next to him, holding his hand, so that you think it's harmless. And she doesn't seem afraid because otherwise she wouldn't let him touch her hand and stay next to him looking so relaxed." (female, 55, middle school teacher on handholding with Rhoni)

"Slightly like a big male robot that looks rather threatening, but not in this situation because she is standing there quite relaxed, shaking hands with him, so that you think the situation is probably innocent." (female, 55, middle school teacher on handshake with Rhoni)

In conclusion to H1.1, the findings support the notion that different touch forms are differently perceived (also RQ2). Intimate touch forms such as embrace or touch to the face of the robot or the human elicited the most positive comments and are associated with attachment and closeness. Negative comments prevailed for pictures that show a handshake or a touch initiated by the robot. In addition, comments by the interviewees revealed that a negative impression caused by an unfavorable robot appearance can be compensated for by means of a pleasant (reciprocal) touch gesture, at least from an observer perspective.

6.3.3.3 Perceived valence according to robot type

Since the preceding analyses revealed that the valence of the perception of HRT is often related to the robot presented in the pictures (subcategories *positive robot* and *negative robot*), this section focuses on the comparison of the different robot types with regard to the perceived valence (H2.1).

Within the positively valued comments, it has been demonstrated that only the minority (14%, 10/70) were related to the robot, whereas more than half of the negatively valued comments (53%) are caused by aspects related to the robot (18/34).

When comparing the frequencies of the positive comments that refer to the robot among the five robots (Table 12), it becomes obvious that no positive robot comment referenced the tallest and mechanical looking robot Rhoni. On the contrary positive references to Nao (n = 4), iCub, Robosapien and Lego NXT (n = 2 each) were sometimes made. By contrast, the highest number of negative comments with reference to a robot were for pictures of Rhoni (n = 9), followed by pictures of iCub (n = 6). Only a few negative comments referred to the robots Lego NXT (n = 2) and Robosapien (n = 1), and none at all to Nao (n = 0).

Table 12 Frequencies for the perceived valence per robot.

	Valence						
	Positive			Negative			Mixed
Robot	situation	robot	both	situation	robot	both	
Rhoni	1	0	1	5	9	2	4
iCub	10	2	0	3	6	1	3
Nao	16	4	1	1	0	0	2
Robosapien	9	2	1	3	1	0	2
Lego NXT	17	2	2	0	2	1	1

Rhoni. In line with the general finding that more negative comments referred to the huge robot Rhoni, the analysis of the frequencies for each category per robot demonstrates that also more negative (n = 16) than positive (n = 2) comments are observable for pictures of *Rhoni*. Within the negative comments on pictures with Rhoni, the majority (9/16) addressed the robot as a reason for the negative valence. The appearance and construction of the robot especially were named, as well as its size. In terms of the appearance, the kill-switch at its center was mentioned twice as a worrying sign.

> "Oh my god, that looks terrible (horrified). (…) There's a kill-switch in the middle. As if he will kill everyone eventually. (…)" (male, 27, IT specialist)

> "This robot is definitely taller than the human and wider. Thousands of tubes and buttons and so on. It doesn't appear humanlike but rather as the typical bad guy from the movies." (male, 24, chemist)

iCub. Pictures with the robot iCub were more frequently categorized as positive (n = 12) than negative valued (n = 10). However, only two of the positive comments directly mentioned the robot, while six of the negative comments referred to it.

The comments that addressed the robot in a positive way mentioned the human-likeness and its perceived friendliness:

> "(The robot) looks more humanlike. Solely because the face is recognizable. And this robot also seems friendlier than the one before." (male, 29, job center employee)

However, negatively categorized comments also mention the robot's appearance as a source of negative perception. Its mechanical look (male, 27, it specialist), the staring expression (female, 57, German teacher), and the humanized appearance scared the interviewees (female, 27, management assistant in real estate).

> "I personally don't like figures that have such humanlike faces, … just because of that I don't like this robot." (female, 27, industrial management assistant)

Nao. Regarding the medium sized robot *Nao*, only one negatively valued comment was observable in the material, which, however, referred to the situation and not to the robot. Within the positively valued comments (n = 21), four interviewees mentioned positive aspects that included the robot. For instance, the robot was perceived as funny (female, 33, social worker), harmless and friendly (male, 29, job center employee). Also, the small size of the robot was further perceived as pleasant:

> "The robot seems more harmless than the previous one (LH: Rhoni) because he's much smaller and the mechanical system is covered. The robot has a nice plastic lining with nice rounded edges. He appears friendlier than the one before."

Robosapien. In total, 12 statements that were collected with regard to the toy like robot Robosapien were positive, and only four negative. Two of the positive comments were related to the robot, but only one of the negative valued ones (Table 12). Positive impressions were again caused by the small size of the robot, which led to characterizations as cute and funny.

The one negative comment that referenced the robot concerned touch to the face of the Robosapien robot. The interviewee in this case explained that she would not make such an intimate gesture towards an inanimate object:

> "That's not an object which you would be fond of, or that you would pet. Thus, it appears quite surprising and uncommon to me." (female, 55, middle school teacher)

Lego NXT. Finally, the pictures that showed the smallest robot, Lego NXT, were categorized as positive 21 times and only three times as negative. Below two positive and two negative comments directly referred to the robot.

The positive ones also (mainly) focused on the small size of the robot, while the negative ones mentioned the wires as an unattractive detail about the robot's appearance.

> "This one doesn't appear threatening, because he's so small and delicate, and seems fragile." (female, 27, management assistant in real estate)

In addition, one interviewee reported that the robot's hand looked like a weapon, and thus the situations seemed threatening to him.

> "It seems as if the human has a pistol pointing close to his head. Because of the architecture of the robot it doesn't look favorable. (…) It really seems as if the robot is threatening the human. (…)" (male, 27, IT specialist)

With regard to hypothesis H2.1, concerning the influence of the robot type, it can be noted that the perception of HRT was affected whichever robot was involved. The size (large, small) as well as the outward appearance (mechanical, humanlike, visible wires) has been revealed as influential for the perception valence of HRT. Smaller sized robots were more favorably perceived than taller ones. Uncovered mechanical parts, steel and visible wires were sometimes negatively perceived, although a too humanlike appearance, e.g., childlike face as in the case of iCub, was negatively perceived, too.

6.3.3.4 Expectedness and harassment of HRT

Besides the think aloud comments, direct questions were asked with respect to each picture in order to capture additional quantitative data on the first impression of HRT from an observer perspective. The interviewees were therefore asked to say whether the situation in the picture was either as they expected an interaction between a human and a robot to be, or it was surprising, and whether it appeared alarming to them (RQ2b). It was of particular interest to see if specific (e.g., more intimate) kinds of touch are perceived as more peculiar and unexpected than others. For that purpose, mean ratings for each form of touch were calculated for the expectedness (how surprising) and harassment (how alarming) ratings (see Table 13, 16).

6.3.3.5 Expectedness according to touch form

With regard to how expected different forms of touch were perceived (H1.2), the mean ratings (see Table 13) illustrate that *no touch* control stimuli were on average perceived as less surprising than stimuli that included touch. Among the touch stimuli, *touch to robot's arm, handshake*, and *handhold* were on average also expected and not surprising (mean values below 2.5), while touches initiated by the robot (*touch to human's face, touch to human's arm*), *embrace,* and t*ouch to robot's face*, were perceived as surprising (mean values higher than 2.5).

Table 13. Descriptive statistics for the question: Is the situation surprising? on a Likert-type scale from 1-5.

Touch form	*M*	*SD*
Touch to human's face	3.40	1.02
Embrace	3.38	1.17
Touch to human's arm	2.94	1.19
Touch to robot's face	2.82	1.03
Handhold	2.42	0.87
Handshake	2.33	0.93
Touch to robot's arm	2.18	1.07
No touch	1.85	0.80

The following paragraphs explore further the reasons why interviewees perceived a specific touch form as surprising or not.

Regarding *touch to robot's arm*, *handshake*, or *handhold*, which were perceived as not surprising according to the means (Table 13), many interviewees explained that they would behave in the same way as the person in the picture, and are hence not surprised.

> "No, I would touch him too and shake his hand, because he looks a little bit humanlike." (female, 57, German teacher)

Touch initiated by the robot (*touch to human's face*, *touch to human's arm)*, *embrace*, and *touch to robot's face* were in contrast perceived as highly surprising (Table 13) and can as a consequence be regarded as less expected behaviors in HRI. Some interviewees explained that the situation appeared surprising to them, because they had difficulty thinking of a situation in which such a gesture would be appropriate, instead a functional reason would be given.

> "Because I can't imagine any specific situation in which you would touch the head of a robot, other than needing to press a button." (male, 26, PhD candidate in psychology)

Moreover, several interviewees explained that they would not touch or embrace a robot, because they thought that humans and robots cannot develop strong trusting relationships that lead to embraces.

> "... because I can't imagine a situation in which you would have such a strong bond to a robot that you would embrace him." (male, 26, PhD candidate in psychology)

Apart from that, some interviewees did not interpret the *embrace* as an emotional act but rather as a functional one, and hence did not evaluate it as unexpected. For these interviewees, the human was working with the robot, or protecting its body from the surroundings.

> "I think she might check something at the back. Whether a cable or else is still in the right place. So, it's not surprising." (female, 27, industrial management assistant)

> "I might be surprised at first, but then I would certainly think that she's working on it somehow, so she would embrace him, but I don't see it that way." (female, 57, German teacher)

With regard to the robot-initiated touches (*touch to human's face* and *touch to human's arm*) interviewees wondered about the reasons why a robot should touch parts of the human body, and said that they were surprised by the active role the robot adopted in these situations:

> "Quite surprising because it is an obviously emotional expression by a clearly recognizable machine." (male, 36, post doc researcher in computer science)
>
> "… because he's in motion now. Before he was an inanimate object and now he's doing something." (female, 55, middle school teacher)
>
> "Okay, that would rather surprise me because it is a sensitive part of the human that the robot is grasping, and that the human is approving it, that is surprising." (male, 68, engineer in automotive industry)

Overall in line with H1.2, reciprocal touches and less intimate touches such as the handshake were perceived as foreseeable and thus less surprising, while more intimate forms of touch such as the embrace or touches to the face of the human and the robot are surprising for the interviewees. Furthermore, touch that is initiated by the robot (touch to human's arm and face) was less expected than human-initiated touch, which was often described as more reasonable, because the interviewees reported that they would also touch a robot on its arm or face.

6.3.3.7 Harassment ratings according to touch form

The second question concerning the first assessment of the situation (RQ2c) asked whether the HRT is alarming using a five-point scale (1= not alarming). Mean ratings between 1.62 and 2.53 (Table 14) illustrate that all kinds of touch were on average perceived as not alarming. In comparison to *no touch* stimuli, pictures that show robot-initiated (*touch to human's face, touch to human's arm*) and reciprocal touches (*embrace, handshake, handhold*) were rated as more alarming, while human-initiated touch pictures (*touch to robot's face, touch to robot's arm*) were generally rated as less alarming than *no touch* pictures (Table 14).

Table 14. Descriptive statistics for the question: Is the situation alarming?

Form of touch	*M*	*SD*
Touch to human's face	2.53	1.06
Touch to human's arm	2.20	1.07
Embrace	2.06	1.01
Handshake	1.95	1.07
Handhold	1.88	0.80
No touch	1.74	0.73
Touch to robot's arm	1.65	0.68
Touch to robot's face	1.62	0.71

One reason that was mentioned why robot-initiated touch to the human's face seemed alarming, was uncertainty about the movements of the robot when it gets close to vulnerable body parts such as the eyes.

> "A little bit, because he is near to the eye. I assume that the robot acts autonomously and is not controlled by someone. Then it is somewhat alarming." (female, 27, industrial management assistant)

One interviewee even stated that the situation looked like a punch to the face at first glance (male, 26, PhD candidate in psychology). In this case, it is understandable that the interviewee evaluated the situation as alarming.

Furthermore, robot-initiated touch to the human's arm was often perceived as the assertion of dominance by the robot, which was rated as rather alarming by the interviewees.

> "Because it looks as if he is holding her down against her will. Because she looks kind of surprised. And he doesn't look as nice as in the other pictures." (female, 27, industrial management assistant)

> "It's alarming, because here I see an action by the robot for the first time. Maybe it correlates with the height that the robot expresses some kind of dominance through the… touch to the lower arm." (male, 26, PhD candidate in psychology)

The reciprocal touch forms were seldom perceived as alarming, only if the interviewees interpreted the behavior of the person as abnormal.

> "This seems pathological to me. I just thought about dolls that look like real children or babies…" (female, 27, social education worker)

> "I'm conflicted. Actually, this is not an alarming situation, because it is quite harmonious. Otherwise, I find it alarming when humans intimately embrace objects (laughs) (…) anything that assumes such a humanlike shape is alarming possibly dangerous." (female, 27, management assistant in real estate)

In summary, although touch was generally perceived as less alarming from mere observation, robot-initiated touch was perceived as more alarming than reciprocal touch forms and human-initiated touch. Intimate reciprocal touch (embrace) was slightly more alarming than the other reciprocal touch forms. Hence, different forms of touch can be regarded as differently alarming, in line with H1.2.

The additional comments by the interviewees revealed that intimate touch between a person and a robot was perceived as alarming since a close relationship to a robot could not be imagined by the interviewees, or was even seen as an abnormal sign of affection towards an inanimate object.

6.3.3.8 Robot Influence on perceived expectedness and harassment

The influence of the robot type on the perceived expectedness and harassment is again explored. As visible in Table 13, stimulus pictures that included the toy like robots Robosapien and Lego NXT were perceived as the least surprising, while pictures that showed Rhoni were medium surprising, and pictures with iCub and Nao were the most - but still moderately (mean value about 2.8 on a 5-point scale) – surprising. In the following, findings for each robot type are separately summarized.

Table 15. Mean values and standard deviations for surprise ratings per robot type and touch form (Is the situation surprising?).

	Robot Type									
	Rhoni		iCub		Nao		Robosapien		Lego NXT	
Touch Form	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
No touch	2.29	1.38	1.67	1.21	3.00	1.73	1.33	0.52	1.14	0.38
Handshake	2.00	1.53	2.67	1.21	3.29	1.70	2.00	1.10	1.71	0.76
Handhold	2.33	1.51	3.14	1.22	2.17	0.98	1.86	1.07	2.33	1.21
Touch to human's arm	3.33	1.63	3.14	1.35	2.67	1.37	2.43	1.27	3.33	1.37
Touch to robot's arm	3.14	1.77	1.83	0.98	2.29	1.25	1.33	0.82	2.43	1.62
Touch to robot's face	3.00	1.41	2.67	1.21	2.57	1.13	2.50	1.23	3.29	1.60
Touch to human's face	3.00	1.41	3.29	1.60	3.67	1.21	3.43	1.27	3.67	1.03
Embrace	2.50	1.23	3.71	1.38	3.00	1.41	4.29	1.11	2.50	1.38
Total	**2.69**	**0.96**	**2.81**	**1.16**	**2.83**	**0.95**	**2.44**	**0.99**	**2.52**	**0.83**

Rhoni. When Rhoni was presented, non-reciprocal touches to the arm of the robot and the human were rated as most surprising, while, reciprocal formal touch (here: handshake) was the least surprising with the huge humanoid robot (Table 15).

iCub. Intimate touches with the child like robot iCub were seen as most surprising, compared to other touch forms. Embrace and touch to the human’s face were rated as especially surprising. In contrast, handshake and touch to the robot’s arm were perceived as rather expected (Table 15).

Nao. For pictures of Nao, touch to the human’s face and handshake were perceived as most surprising, while touch to the arm of the robot and handholding were least surprising (Table 15).

Robosapien. As with iCub, the most surprising situations for Robosapien were those in which intimate touch happens between the human and the robot, namely: *embrace* and touch to the face of the human. Touch initiated by the human (*touch to robot’s arm*) and handholding were, however, not surprising (Table 15).

Lego NXT. Robot-initiated touch by Lego NXT was most surprising for this robot, while formal reciprocal touch (here: handshake) was on average not (Table 15).

In summary, intimate touch forms and touch initiated by the robot were the most surprising for all robots, whereas the handshake was the most anticipated touch, except for

Nao. For the smaller robots Nao and Robosapien, handholding was furthermore not surprising to the interviewees.

Given the potential influence that the robot type may have on the *perceived harassment*, mean ratings for the answers to the question *How alarming is the situation*? were also calculated per robot using a five-point Likert-type scale.

First, the ratings for each robot were considered, regardless of the touch form. The results show that pictures which portrayed the smaller robots Lego NXT, Nao, and Robosapien were perceived as not particularly alarming at all (mean below 2.0), while pictures of the taller robots iCub and Rhoni were more alarming (although all mean ratings are below the midpoint of the ratings scale which is 2.5) (Table 16).

Table 16. Mean values and standard deviations for harassment ratings per robot type and touch form (Is the situation alarming?).

	Rhoni		iCub		Nao		Robosapien		Lego NXT	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
No touch	1.86	1.46	1.67	1.21	2.29	1.38	1.67	1.03	1.29	0.49
Handshake	2.29	1.70	2.17	1.47	2.14	1.35	1.83	1.33	1.29	0.49
Handhold	2.17	1.47	2.57	1.27	1.67	0.82	1.29	0.49	1.50	0.55
Touch to human's arm	2.67	1.63	2.86	1.22	1.83	0.75	2.14	1.35	1.67	1.21
Touch to robot's arm	3.00	1.41	1.50	0.55	1.29	0.49	1.50	1.23	1.14	0.38
Touch to robot's face	2.00	1.29	1.67	0.82	1.29	0.49	1.33	0.52	1.86	0.90
Touch to human's face	3.00	1.41	2.43	1.51	2.33	0.82	2.29	1.38	2.83	1.60
Embrace	2.17	0.98	2.43	1.13	1.50	0.84	2.29	1.70	1.50	0.55
Total	**2.38**	**0.98**	**2.19**	**1.05**	**1.71**	**0.47**	**1.81**	**0.83**	**1.62**	**0.60**

Rhoni. When considering the combinations of robot type and touch form (Table 16), the most alarming combination based on the mean ratings are observed in the robot Rhoni in combination with robot-initiated touch (*touch to human's face, touch to human's arm)* and *touch to robot's arm*.

Interviewees stated that *touch to the human's face* by Rhoni appeared alarming to them, due to the robot's appearance and its clumsiness, which might cause injuries if the person and the robot got closer.

> “I can imagine, if you make a wrong move and get in between these steel fingers, then it could become problematic.” (male, 36, post doc researcher in computer science)

> “He seems to have gross motor skills.” (male, 29, job center employee)

However, reciprocal touches (handhold, handshake) were least alarming with the huge robot.

iCub. For iCub, harassment is perceived as highest when the robot touches the human’s arm, or when handholding is presented (Table 16). As additional comments on the ratings illustrate, touch with iCub is perceived as alarming mostly because of its appearance.

> “The handshake itself is not alarming, but since the robot looks so unlikely (…) No. If he were to walk around here (…) not for me.” (female, 27, industrial management assistant)

> “I think it rather depends on the robot’s appearance and less on the fact that robot and human embrace each other.” (male, 26, PhD candidate in psychology)

In contrast, touches from the human to the robot’s arm or face are not alarming.

Nao, Robosapien & Lego NXT. For pictures with the smaller robots Nao, Robosapien, and Lego NXT, *touch to human’s face* was the most alarming while *touch to robot’s face* was the least. Furthermore, handshake was absolutely not alarming for Robosapien and Lego NXT (Table 16).

Taking these findings into account, the perception of varying forms of touch as expected or alarming differs with the different robots, in line with H2.2. While the reciprocal embrace was the most surprising touch for pictures with iCub and Robosapien, robot-initiated touch to the human’s face was most surprising for cases in which Nao and Lego NXT were present. While human-initiated touch forms were less surprising for most robots, human- as well as robot-initiated non-reciprocal touches to the arm and face were perceived as surprising with the robot Rhoni. The formal handshake was not perceived as surprising for all robots except Nao (see Table 13). Overall, robot-initiated touch (arm and face) was perceived as most surprising for all robots.

6.4 Relational Interpretation of HRT

In order to answer the question of how HRT touch is interpreted in terms of relational interpretations (RQ3, cf. Burgoon, 1991), the relational interpretation units were coded in a number of iterations. Due to the number of interviewees (*N* = 13) and the number of stimuli per interviewee (*n* = 20) 260 coding units were identified. The final coding scheme consisted of four main categories with diverging subcategories (Table 17). The relational interpretations could predominantly be divided into *functional relationship* and *personal relationship*. Furthermore, a category *no relationship* was introduced for statements that describe the human and robot as unrelated, and a category *unclear relationship*, for statements that could not be assigned to one of the other categories. For clarification, each category is summarized with example statements in Table 17.

Table 17. Coding frame for relational interpretations.

Interview Question: How would you describe the relationship between the person and the robot in the picture?

Main category: Relational Interpretation

Sub-categories	Description	Example	Decision rules	Cohen's *K*
Functional relationship	Statements that described a relationship that is not personal in nature but based on instrumental reasons such as an examination, test, the handling of technology or mere curiosity, were categorized as *functional relationship*.	*Test/Examination* "The robot could be a nurse, who comes to the human's help or assists somehow." (female, 57, German teacher) "It seems as if something is being debugged. For example, how close the robot's arm could be operated through its sensors." (male, 68, engineer in automotive industry) *Handling of technology* "The human just helps the robot. It seems as if he's carrying him over the place (…) because the human has to, because the robot can't move on its own. So, not	-	***K*= 0.83**

		friendly but rather a nursing service for robots." (male, 27, IT specialist) "In my opinion it is the transportation of a technical device from A to B. I'm an engineer." (male, 68, engineer in automotive industry) *Curiosity/Interest* "That's difficult, the question about the relationship. I would be rather curious in such situation and would touch different parts of the robot just to see how it reacted." (male, 29, job center employee) "(laughs) I don't have any idea. They don't have a relationship. She is interested in the robot and makes him move. (…)"4 (female, 57, German teacher)		
Personal relationship*	Statements that described the relationship as more personal were coded as *personal relationship* respectively.	"They know each other and she likes him - I think. She looks at him quite affectionately." (female, 27, industrial management assistant) "Like a mother-child relationship." (female, 27, management assistant in real estate)	-	***K*= 0.93**
No relationship	If the statement suggests that the interviewee did not infer any relationship between the human and the robot, the unit was categorized as no *relationship*.	"I never see any kind of relationship there." (male, 29, job center employee) "No relationship. The human observes the robot, nothing else happens." (female, 57, German teacher)		***K*= 0.69**
Unclear relationship	Statements that could not be assigned to the other categories, and that contained vague and undefined statements about the relationship were categorized as *unclear relationship*.	"She touches him and the robot stretches out its hand. It seems as if they have a closer, better relationship." (male, 24, chemist) "A personal relationship? I don't know (laughs), but it seems as if the robot isn't looking at the woman." (female, 33, social worker)		***K*= 0.74**
			overall	***K*= 0.83**

*Statements that are categorized as personal relationships are further examined with regard to their relational meanings (see RQ3b: Relational themes within personal relationship interpretation)

So far, the categorization of the answers to the question, how interviewees would describe the relationship, into functional, personal and unclear relationships demonstrates that individuals are in fact able to make relational interpretations for human-robot relationships (RQ3a). Furthermore, frequencies were calculated for each main category (*no relation, unclear, functional,* and *personal relationship*) to examine the proportion of each category per touch form (H1.3).

6.4.1 Relational Interpretations according to touch form

In total, only 13 out of 260 statements were categorized as *no relation,* 41 as *unclear*, but 43 were categorized as *functional*, and 163 as *personal relationships* (see Table 18).

Table 18. Relational interpretation according to different kinds of touch (frequencies).

Kind of touch	No relation	Unclear relationship	Functional relationship	Personal relationship
No touch	3	7	5	18
Touch forms (cumulated)	10	34	38	145
Handshake	1	8	3	21
Handhold	2	8	4	18
Touch to human's arm	1	3	9	19
Touch to robot's arm	2	4	8	19
Touch to robot's face	1	6	3	23
Touch to human's face	3	3	5	21
Embrace	0	2	6	24
Total	**13**	**41**	**43**	**163**

No touch control stimuli: Most interpretations (n = 18/33) are categorized as personal relationship. Second most are unclear relationships. Several times, therefore, interviewees had difficulties inferring a relationship from a picture that showed an interaction without touch several times (n = 7/33). Five interpretations were categorized as functional and three as no relation (Table 18).

Touch stimuli cumulated: In comparison to no touch stimuli, touch stimuli were also most frequently categorized as *personal relationships* (n = 145/226), followed by *functional relationship* (n = 38), *unclear relationship* (n = 34), and finally *no relationship* at all (n = 10; Table 18).

In contrast to the few statements that show that interviewees did not see a concrete relationship between the human and the robot, the majority of the statements (206 out of 260) indeed represented relational interpretations. Furthermore, most of these statements (n=163) were categorized as *personal relationship*, while only 43 were categorized as a *functional relationship*.

The following paragraphs analyze the relational interpretations within the main functional and personal categories in more detail, comparing the different kinds of touch which were depicted in the pictures. The main aim of this step is to explore the interpretations according to the kinds of touch to enable later comparison of the results with findings from interpersonal literature (RQ3b).

The most *functional interpretations* were observable for arm touches (*touch to human's arm*: *n* = 9; *touch to robot's arm*: *n* = 8). Also, *embrace* (*n* = 6) and *touch to human's face* (n=5) were more frequently interpreted functionally than *handhold* (*n* = 4), *touch to robot's face* and *handshake* (*n* = 3, each; Table 18).

With regard to the relational interpretations, the relationship most frequently described as personal was for *embrace* pictures (*n* = 24), followed by *touch to the robot's face* (*n* = 23) and *touch to human's face* (*n* = 21). Reciprocal touches between the hands (*handshake, n* = 21; *handhold*, *n* = 18) and touches to the arm of the human and the robot (*n* = 19 each) were less frequently, but still often, described as a personal relationship (cf. Table 18). Further distinctions within personal interpretations are reported under relational themes (see Chapter 6.4.4).

6.4.2 Relational interpretations according to robot type

With respect to H2.3, the relational categorizations are also evaluated with regard to the different robot types. Overall, when considering the categories per robot, it becomes obvious that personal interpretations prevail for each robot. However, the most personal interpretations can be found for the childlike robot iCub (*n* = 38), followed by the smaller robots Nao and Lego NXT (*n* = 36, each) and Robosapien (*n* = 32). In contrast, only 21 relational interpretations were categorized as personal for pictures with the large robot

Rhoni (Table 19). The relationship to Rhoni was also interpreted more often as functional (*n* = 13), than the relationship to Nao and Robosapien (n=8, each), as well as iCub and Lego NXT (*n* = 7, each). Furthermore, unclear relational definitions prevailed for Rhoni (*n* = 13), followed by Nao and Robosapien (*n* = 8, each), Lego NXT (*n* = 7) with iCub having the fewest (*n* = 5). Difficulties in seeing any relationship between the human and the robot (*no relation) are observable* for pictures with Rhoni (*n* = 5) and Robosapien (*n* = 4). There were also some difficulties with regard to iCub and Lego NXT (*n* = 2, each), whereas interviewees never stated seeing *no relation* for stimuli on which Nao was presented (Table 19).

Table 19. Relational interpretation according to different robot types (frequencies).

Robot Type	No relation	Unclear relationship	Functional relationship	Personal relationship
Rhoni	5	13	13	21
iCub	2	5	7	38
Nao	0	8	8	36
Robosapien	4	8	8	32
Lego NXT	2	7	7	36
Total	**13**	**41**	**43**	**163**

In summary, differences between the varying robot types with respect to the relational interpretation are observable in line with H2.3. In particular, the huge mechanical looking robot evoked fewer personal but more functional and unclear relational interpretations than the other (smaller) humanoid robots.

6.4.3 Relational themes within personal relationship interpretation

In order to test whether the personal interpretations for the different touch forms resemble relational interpretations from interpersonal literature (RQ3b; Burgoon, 1991), the descriptions that were categorized as *personal relationship* were further analyzed with regard to the relational themes they cover (cf. Burgoon & Hale, 1984). Six themes were thereby inductively extracted from the material, namely: 1*) familiarity, 2) intimacy/closeness, 3) dominance, 4) formality, 5) composure, and 6) relational symmetry* (see Table 20).

Table 20. Coding Frame for relational themes within the category personal relationship.

Sub-categories	Description	Example	Cohen's *K*
Relational Themes			*K*= 0.93
Familiarity (n=55)			
Familiar	Statements included messages about how well the human and the robot know each other.	"One could assume that they know each other. The robot looks as if he's listening." (male, 59, technician) "… And it seems as if they know each other. Maybe work together or something." (female, 27, industrial management assistant)	
Unfamiliar		"It looks like a conversation between strangers." (male, 36, post doc researcher in computer science) "It resembles an ordinary greeting between strangers." (male, 27, IT specialist)	
New/Getting to know		"They shake hands. Perhaps the robot is able to talk and they say hello. In other words, they start to bond. Maybe they can talk to each other. They're getting to know each other." (female, 57, German teacher) "I would say [LH: the relationship] doesn't exist for long, but it's quite friendly. Or they are well-disposed, but are just getting to know each other." (female, 27, management assistant in real estate)	
Intimacy/closeness (n=97)	Statements about the perceived emotional closeness between the human and the robot.		
Close/intimate		"He's looking at her with his Lego-like head. That seems – since he's quite near her – seems quite intimate." (female, 33, social worker) "A close relationship with intimacy." (male, 59, technician)	
Impersonal		"The person is sitting opposite the robot, but is sitting there without an open posture. They don't seem very intimate." (female, 27, social education worker) "They shake hands, seem distant, like an initial contact." (female, 27, social education worker)	
Dominance (n=23)	Statements that point to the superiority of one interaction partner, either by declaring that one partner is in need of the other's help, or directly		

	by describing one partner as dominant.	
Human dominant	Statements that refer to the human as dominant.	"The person is dominant, despite her size she's superior – the robot is taller than the person." (male, 26, PhD candidate in psychology) "It seems as if the human is in charge of this relationship and could command the robot." (male, 27, IT specialist)
Robot dominant	Statements that refer to the robot as dominant.	"… the person seems to feel inferior towards the robot, I would say from that picture." (female, 27, social education worker) "The relationship appears less intimate, because the touch or the bodily posture of both signals something like 'I take you by your arm and lead you somewhere' – as if the robot is superior at the moment, or wants to be superior." (male, 26, PhD candidate in psychology)
Composure (n=6)	Statements that point to the serenity of the human in the situation.	**Relaxed** "As a human relationship. She strokes the cheek as if she's expecting a reaction, whether he's going to move or roll his eyes (…). She doesn't seem to have any scruples or fear of the robot." (female, 55, middle school teacher) **Tense** "The person seems stressed, because she's sitting a little bit stiffly." (male, 36, post doc researcher in computer science) "In my opinion the woman seems tense. I don't know why, but somehow… she might be surprised that the robot is touching her now." (female, 27, industrial management assistant)
Formality (n=5)	Statements that described the relationship as formal or businesslike.	"That's quite a polite gesture by the robot, hence I would describe them as businessmen among themselves." (male, 26, PhD candidate in psychology) "That could be something commercial. One gets to know someone in a professional context." (male, 36, post doc researcher in computer science)
Relational symmetry (n=49)	Statements that include a comparison to another (interpersonal) relationship.	
Asymmetrical relationship		**Parent-child** "It resembles mother and child walking together side by side." (male, 36, post doc researcher in computer science)

	"They are quite close, seem familiar almost like a mother and child." (female, 27, social education worker)
	Pet/toy-owner "The relationship between those two reminds me of a human and her pet (…) because the person is standing, the robot's strongly submissive role becomes apparent, such as typically exists with domestic animals." (male, 26, PhD candidate in psychology) "The robot has a cute posture, seems content. And the woman also makes a nice gesture (…) as with a pet that is patted." (female, 27, management assistant in real estate)
Symmetrical relationship	**Friends** "Although he has no humanlike traits, it seems rather amicable from the pictures, as if they know each other." (male, 29, job center employee) "Looks quite pleasant, and friendly, too." (male, 24, chemist)
	Miscellaneous "Similar to office co-workers, …" (female, 27, management assistant in real estate)
	K= 0.93

Note. The relational themes are not mutually exclusive. This means that more than one theme (category) can be assigned to the same coding unit (e.g. familiarity and closeness).

Most relational interpretations were related to the theme *intimacy/closeness* (n = 97), followed by *familiarity* (n = 55) and *dominance* (n = 23). Composure was addressed seven, and formality only five times. A comparison to another (a-)symmetrical relationship was made 49 times. The following paragraphs summarize the distribution of the themes across the different touch forms (H1.3) that were presented.

6.4.4 Relational themes according to touch form

With regard to the theme *familiarity*, the relationship is most often interpreted as familiar if touch to the arm (*touch to human's arm*, n = 6; *touch to robot's arm*, n = 5), *touch to human's face*, *embrace,* or *handshake* is depicted (n = 5, each). Pictures of *handshake* (n = 4) or *touch to human's face* (n = 2) are sometimes described as if the human and the robot are just *getting to know* each other. Pictures that show the *handshake* are, however, interpreted as *unfamiliar six times*. T*ouch to the robot's arm* and *touch to the human's face* were also interpreted once as unfamiliar (*n* = 1, each).

The theme *closeness/intimacy* was the most frequently (*n* = 97) addressed among the personal relationship interpretations. Overall, the intimacy of all forms of touch noted were more frequently interpreted as *close/intimate* (*n* = 73) than *impersonal* (*n* = 15). No touch stimuli, in contrast, were categorized as close (*n* = 4) and impersonal (*n* = 5) almost equally often.

The statements that addressed the theme *intimacy/closeness* frequently described the relationship between the human and the robot as *close/intimate* when an intimate form of touch was presented, namely if they *embraced* each other (n= 18), or if touch to the face (*touch to robot's face, n* = 16; *touch to human's face*, *n* = 15) was depicted. Touches to the arm (*touch to robot's arm*, n= 9; *touch to human's arm*, *n* = 6), and hand to hand touches (*handhold*, *n* = 8; *handshake*, *n* = 2) were less often described as *close/intimate*.

In contrast, less intimate touches such as the *handshake* (*n* = 8), and touches to the arm (*touch to human's arm*, *n* = 4; *touch to robot's arm*, *n* = 2) were repeatedly described as *impersonal*, while the intimate touch forms were not (*n* = 0, except *touch to human's face*, *n* = 1). In summary, all touch forms were more frequently described as *close/intimate* than *impersonal*, except for the handshake which was more often described as distant.

Relational statements that referred to the theme *dominance* (*n* = 23 in total) described the human as superior 17 times, and the robot six times. No reference to dominance was visible for the *no touch* stimuli.

After consideration of the different touch forms, dominance was most frequently addressed for *handhold* and *touch to robot's arm*. The human was interpreted as superior to the robot when *handhold* (*n* = 8), *touch to robot's arm* (*n* = 5), *embrace* (*n* = 3), and *touch to robot's face* (*n* = 1) were presented. In pictures where the robot touching the human was shown (*touch to human's arm*, *n* = 2; *touch to human's face*, *n* = 1), and *handshake* (*n* = 2), the robot was described as dominant.

The relational interpretations that referred to *composure* can be divided into statements that describe the interaction partners as *relaxed* or *tense*. Composure was mentioned twice for no touch stimuli, wherein one comment was categorized as relaxed and the other as tense. For touch stimuli, four statements were identified that referenced composure. Relaxation was interpreted for *handhold, touch to robot's face* and *touch to human's face* (*n* = 1 each). One reference to tension was observed for *touch to human's arm*. Composure was never discussed for *touch to robot's arm*, *handshake* and *embrace*.

The relational theme *formality* was mentioned five times in total within the relational interpretations. Once for the *no touch* control stimuli, and four times for *handshake* stimuli.

> "The handshake looks quite formal. Also, the distance. Friends would greet each other differently, even if they were to shake hands, this would be closer to the body, or an embrace. This is rather a commercial handshake." (male, 36, post doc researcher in computer science)

Finally, many relational statements referred to *relational symmetry* when comparing the human-robot relationship with a (humanlike) relationship (*n* = 49 in total). The descriptions of the relationships either described a *symmetrical relationship* (e.g., co-workers), or an *asymmetrical* one (e.g., parent-child relationship). Asymmetrical descriptions were more frequently assigned (*n* = 19) than symmetrical interpretations (*n* = 30).

Most asymmetrical relational interpretations were observed in reciprocal touch, namely: *embrace* and *handhold* (*n* = 5, each). Furthermore, *touch to human's arm* was interpreted in terms of an asymmetrical relationship four times. Touches to the face of the human and the robot were each described as asymmetrical relations twice.

For intimate reciprocal touch, comparisons to an asymmetrical relationship were most frequently made (*handhold*: *n* = 5, *embrace*: *n* = 5). Comparisons to asymmetrical relationships were also noted for non-reciprocal touches, robot-initiated touch (*touch to human's arm*: *n* = 4, *touch to human's face*: n= 2) and human-initiated touch (*touch to robots' face*: *n* = 2). *Handshake* and *touch to robot's arm*, were never compared to an asymmetrical relationship.

Comparisons to a symmetrical relationship were often made when touch to the face of the robot (*n* = 6) or the human (*n* = 5) was depicted on the stimulus. Also, several references to a symmetrical relationship were made for *touch to human's arm* and *embrace* (*n* = 4, each), as well as for reciprocal hand touches (*handshake, handhold*), and touch to the arm of the robot (*n* = 3 each).

The findings are in line with hypothesis H1.3 that different touch forms lead to different relational interpretations. On the one hand, different touch forms are differently categorized as functional or personal relationships. On the other hand, relational themes within personal relationship interpretations show that different forms of HRT are perceived in a similar way as interpersonal touch forms, which points to the existence or application of a social meaning model of touch to interpretations of HRT (RQ3b). The themes resemble those known from interpersonal research, rather than the functional category.

6.4.5 Self-Assessment of Anticipated Emotional State

The question of how HRT is evaluated (RQ4) was addressed by means of interviewees' estimations of their personal feelings. As mentioned earlier, interviewees were asked to imagine being the person in the picture in order to assess their anticipated emotional state. They then rated their imagined valence, arousal and dominance by means of the Self-Assessment Manikin. Mean ratings for each dimension were first calculated (Table 21) and then analyzed per touch form (H1.4), and afterwards per robot type (H2.4).

Table 21. Descriptive statistics for the anticipated valence, arousal and dominance.

	SAM valence		SAM arousal		SAM dominance	
	M	*SD*	*M*	*SD*	*M*	*SD*
No touch	3.74	0.53	2.17	1.13	3.50	0.92
Handshake	3.46	0.66	2.58	0.91	3.53	0.69
Handhold	3.44	0.75	2.33	0.92	3.90	0.78
Touch to robot's arm	3.72	0.64	2.27	1.05	3.83	0.71
Touch to human's arm	3.21	0.74	2.76	0.84	3.31	0.73
Touch to robot's face	3.51	0.71	2.47	0.86	3.83	0.77
Touch to human's face	2.99	0.78	3.10	0.73	2.95	0.79
Embrace	3.37	0.92	2.53	0.90	3.85	0.80

6.4.5.1 Anticipated emotional state according to touch form

Anticipated valence. Overall, all forms of touch were generally evaluated as rather positive from the imagined participant perspective (mean ratings from 2.99 to 3.74 on a scale from 1 to 5, see Table 21). However, interviewees anticipated feeling best in *no touch* control situations. The next most pleasant were touches initiated by the human (*touch to robot's arm*, and *touch to robot's face*, Table 21). Interviewees mentioned that they would actually feel lucky (male, 24, chemist) if they were to touch the robot's arm, or face (female, 33, social worker).

Reciprocal touches were the second most pleasant forms of touch. The less intimate they were, the more pleasant they were perceived. Consequently, a formal *handshake* was anticipated as more pleasant than a more intimate *handhold*, and finally the most intimate touch, the *embrace* was anticipated as being the least pleasant among the reciprocal touch forms (Table 21).

The least pleasant forms of touch according to the mean ratings were the touches that were initiated by the robot (Table 21). With regard to touch to human's face, for example, interviewees explained that they would be afraid (male, 27, IT specialist) and feel uncomfortable (male, 24, chemist) if a robot were to touch their face. In contrast, another interviewee remarked that she would feel more involved in the interaction if the robot were to touch her arm.

> "Actually quite nice, because the robot directly involves itself in this situation. He seems to be able to sense, because otherwise he wouldn't grasp there. He wants to share something. This is quite nice." (female, 27, management assistant in real estate)

Anticipated Arousal. Regarding interviewees' *anticipated arousal* level, the lowest means were seen for the *no touch* control stimuli (Table 21). Among the different forms of touch, the highest levels of arousal emerged in situations where the robot is the initiator of touch: *touch to human's face*, and *touch to human's arm*, whereof the touch to the face was the more arousing (Table 21).

Reasons that were given for a higher arousal level in situations where robot-initiated touch was displayed, show that higher arousal was regarded positively as well as negatively. In some cases, high arousal was anticipated due to excitement caused by the novelty of the situation.

> "Since I haven't been interacting with robots that confront me as a physical entity that often, I guess I would be excited." (male, 26, PhD candidate in psychology)

In other cases, however, negative arousal was observed because of a lack of trust caused by the unpredictability of the robot's behavior.

> "Because you never know what the robot is going to do next." (male, 27, IT specialist)

> "I would probably not trust a robot if I didn´t know him and he touched my face for the first time." (female, 27, social education worker)

Anticipated arousal was lowest for the situations in which the human touched the robot. In comparison with the robot-initiated touches, it is still apparent that more intimate touches to the face were more peculiar than less intimate touches to the arm, and therefore caused higher levels of arousal (Table 12).

With regard to *touch to robot's face*, some interviewees explained that they would be aroused, because they did not know what reaction they could expect from a robot (male, 26, PhD candidate in psychology) or "…what these things do" (female, 57, German teacher).

Anticipated Dominance. The last dimension of the self-assessment was *anticipated dominance*. High ratings represent feelings of superiority towards the robot, and low ratings inferiority, respectively. The analyses of the mean ratings demonstrate that the interviewees generally did not anticipate feeling inferior to the robot across all touch conditions, just as in the *no touch* control condition. Actually, mean ratings above 3.5 on a 5-point scale indicate that they imagined being rather superior (21).

The mean rating for *no touch* (*M* = 3.50, cf. Table 21) pictures sets a baseline which is above the midpoint of the five-point scale. Hence, the interviewees felt on average superior to the robots regardless of touch (here: if touch was absent). In comparison to this baseline dominance value, superiority was anticipated in situations where the person touched the robot's arm or face (see Table 21). Comments by the interviewees further underlined that they would anticipate feeling superior if they were the toucher - especially in cases where the face was touched, since this particular form of touch offers power over the other.

> "…because at the head you can exert more power over a person." (male, 29, job center employee).

Besides, interviewees anticipated feeling most dominant in informal reciprocal touch situations (*handhold,* and *embrace,* Table 21). The interviewees explained that although both touch each other equally (reciprocal), humans will always be superior and in charge of the situation (e.g. male, 68, engineer in automotive industry).

In contrast, formal reciprocal touch (*handshake*), and touch from the robot to the human (*touch to human's* face, and touch *to human's arm*) led to lower anticipated dominance than *no touch* (Table 21). Consequently, imagining the robot to actively initiate touch reduced the anticipated dominance of the human because the perceived dominance of the robot was increased. However, mean ratings of 2.95 and 3.31 suggest that the interviewees still did not feel inferior, but rather equivalent to the robot when it touched the human.

The comments of the interviewees underline this assumption. Many interviewees mentioned that even if the robot was the active partner, they would feel superior, because they can always quit the interaction if they want to.

> "The movement looks more dominant, nonetheless I would feel superior because I could terminate the whole thing at any time." (male, 26, PhD candidate in psychology)

> "I can always escape. I'm not at his mercy." (male, 68, engineer in automotive industry)

Some also mentioned feeling uncertain about the abilities of the robot, and thus uncertain about their superiority or inferiority.

> "It's hard to judge such a robot. You may have the feeling that there are plenty of features in such a machine." (female, 57, German teacher)

With respect to H1.4, the findings for anticipated valence, arousal and dominance support the assumption that different touch forms lead to different anticipated emotional states.

6.4.5.2 Anticipated emotional state according to robot type

Valence. When analyzing the mean ratings per robot type for the anticipated valence, it becomes clear that the interviewees imagined feeling equally good in situations with different robots. Similar high mean ratings above 3.3 on a five-point scale demonstrate that they imagined feeling generally good across all robot types. However, they reported feeling best in situations with the smaller robots Robosapien and Lego NXT, and worst with Nao, iCub and Rhoni (Table 22).

In the following table, the order of the *anticipated valence* of each touch form is presented for each robot separately to examine potential preferences for combinations of robot type and touch form.

Table 22. Mean Ratings for *anticipated valence* according to touch form and robot type.

	Rhoni		iCub		Nao		Robosapien		Lego NXT	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
No touch	3.86	0.90	3.67	0.82	4.00	0.58	3.67	1.21	3.57	0.54
Handshake	3.00	0.82	3.17	1.17	3.71	0.49	3.17	0.75	4.43	0.79
Handhold	3.33	0.82	3.29	1.11	3.00	1.10	4.14	0.69	3.00	1.27
Touch to human's arm	3.50	1.23	2.86	0.90	3.00	0.89	3.71	1.25	2.83	1.47
Touch to robot's arm	3.57	0.79	3.67	1.21	4.00	0.82	3.50	0.84	3.86	0.90
Touch to robot's face	3.86	1.07	3.50	1.38	3.71	0.49	3.00	0.89	3.57	1.27
Touch to human's face	2.67	1.37	3.14	1.46	2.50	1.05	3.29	1.25	3.00	0.89
Embrace	3.00	1.27	3.71	1.11	2.83	1.17	3.57	1.27	3.33	1.21
Total	**3.37**	**0.58**	**3.37**	**0.71**	**3.38**	**0.81**	**3.48**	**0.87**	**3.48**	**0.87**

Rhoni. The anticipated valence ratings show that interviewees preferred touching the huge mechanical looking robot Rhoni themselves (human-initiated touch to robot's arm and face). In contrast, reciprocal touches (*handshake, embrace*) and robot-initiated touch to the face were less positively evaluated (Table 22).

iCub. For the partly mechanical looking, but also childlike robot, iCub, intimate reciprocal touch (*embrace*) as well as touch directed to the robot's arm were anticipated as favorable interactions while non-reciprocal robot-initiated touch was evaluated with lower valence (Table 22).

Nao. Pictures with the medium sized, plastic covered robot Nao, were positively anticipated if touch was initiated by the human (touch to robot's arm and face), or if it was reciprocal but formal (*handshake*). In contrast, intimate reciprocal touch (*embrace*) and robot-initiated touches were anticipated as less favorable (Table 22).

Robosapien. The small, toy like robot Robosapien in combination with intimate reciprocal touch (handhold) and touch to the human's arm evoked positive feelings (Table 22). The formal handshake and human-initiated touch to the face of the robot were, however, less positively perceived when presented with Robosapien.

Lego NXT. Finally, the smallest robot Lego NXT evoked positive reactions when presented as shaking hands (reciprocal formal touch) with the person, or when being touched at the arm by the person (human-initiated touch). In contrast, intimate reciprocal handholding was perceived as less desirable, as well as robot-initiated touch to the human's arm (Table 22).

The second dimension, *anticipated arousal*, was overall lowest for the smallest robot Lego NXT and the largest robot Rhoni, while medium high ratings were observable for Nao and Robosapien. Highest arousal was reported for the childlike iCub robot (Table 23).

Rhoni. In situations in which the large robot Rhoni was presented, *touch to human's face* and the reciprocal touches *handshake* and *handhold* evoked the highest arousal ratings (Table 23). For instance, interviewees mentioned that they would be aroused because of the superior size of the robot.

"High arousal, because of the robot's appearance. If I imagine being in this situation, I would be smaller than the robot and (...) based on the superiority in size you cannot easily anticipate the reaction or the consequences of the reaction." (male, 26, PhD candidate in psychology)

Table 23. Mean Ratings for *anticipated arousal* according to touch form and robot type.

	Rhoni		iCub		Nao		Robosapien		Lego NXT	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
No touch	1.86	0.90	2.50	1.38	2.00	1.16	2.33	1.75	2.00	1.00
Handshake	2.93	1.48	2.67	1.03	2.43	1.27	2.50	1.05	2.43	1.27
Handhold	2.50	1.05	2.71	1.38	2.33	1.51	2.14	1.07	1.83	1.17
Touch to human's arm	2.33	1.21	3.00	1.16	2.50	0.84	3.14	0.69	2.33	1.21
Touch to robot's arm	2.00	1.00	2.33	1.21	2.57	0.98	2.00	1.27	2.29	1.60
Touch to robot's face	2.14	1.22	2.67	1.03	2.43	1.13	2.33	0.82	2.71	1.11
Touch to human's face	3.00	0.89	3.14	1.07	3.00	0.89	3.43	0.98	2.67	0.82
Embrace	2.08	0.92	2.71	1.38	2.33	1.21	2.86	0.90	2.33	1.21
Total	**2.36**	**1.08**	**2.72**	**1.20**	**2.45**	**1.12**	**2.59**	**1.06**	**2.32**	**1.17**

In comparison, the lowest arousal ratings were observable for the picture in which the human touches the arm or face of the robot, and where both embrace each other (Table 23). Although the embrace was expected to be the most intimate form of touch, and should thus elicit high arousal, comments by the interviewees revealed that some interpreted the depicted situation as rather functional, e.g., as the transportation of an object.

"The human just helps the robot. It seems as if he's carrying him somewhere (...)" (male, 27, IT specialist)

"For me again the transportation of a technical device, a robot." (male, 68, engineer in automotive industry)

iCub. For iCub, robot-initiated touch to the human's face and arm caused the highest imagined arousal, followed by informal reciprocal touches (handhold, embrace). Lowest arousal was observed for the pictures in which the human touches the arm or face of the robot (Table 23).

Nao. Robot-initiated touch to the human's face was rated as the most arousing for Nao (Table 23). Less arousing, however, were those situations, in which intimate reciprocal touch (*handhold, embrace*) appeared between the human and the robot.

Robosapien. For Robosapien, highest arousal levels were observable for pictures that show robot-initiated touch to the face and arm. Reported arousal was in contrast low, if *handhold* or *touch to the robot's arm* was presented to the interviewees (Table 23).

Lego NXT. Finally, face touches initiated by the human as well as by the robot led to the highest imagined arousal in interactions with Lego NXT, whereas *handhold* did not evoke much arousal (Table 23).

Anticipated Dominance. Finally, the interviewees reported feeling most superior towards Robosapien, and least superior facing Rhoni. Summing up, superiority was high (mean above 3.5) for all robots except Rhoni (Table 24).

Additional comments on the ratings, moreover, demonstrate that the ratio between the human and the robot affected interviewees' anticipated feelings. For all robots except Rhoni, interviewees reported feeling superior because of their own bodily inferiority.

> "The robot is completely inferior due to its size." (male, 27, IT specialist)

> "I'm in charge and I'm relatively taller and play with it." (female, 57, German teacher)

On the other hand, when the robot Rhoni was presented, which is about 30 cm taller than the person in the picture, the superiority of the human was reduced because of the robot's size. However, interviewees still did not feel inferior, but more equal to the robot than in the other cases.

> "The robot is in fact taller, but I am still more intelligent." (male, 26, PhD candidate in psychology)

In order to clarify how the feeling of dominance in the imagined interaction with one robot is affected by the touch form, mean dominance ratings for each touch form per robot are presented in Table 24. Overall, interviewees felt most dominant when they imagined interacting with the smallest robot Lego NXT, followed by Robosapien, iCub, Nao and finally Rhoni.

Table 24. Mean ratings and standard deviations for anticipated dominance.

	Rhoni		iCub		Nao		Robosapien		Lego NXT	
Touch form	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
No touch	2.71	0.49	4.00	1.10	3.14	0.38	4.17	0.98	3.14	1.07
Handshake	2.71	0.76	3.67	0.82	3.43	0.79	4.17	0.98	3.43	0.54
Handhold	3.00	1.41	3.71	0.76	4.50	0.55	4.17	0.75	4.33	0.82
Touch to human's arm	2.83	1.47	3.29	0.76	3.50	0.84	3.29	0.76	3.67	1.03
Touch to robot's arm	3.00	1.00	4.50	0.55	3.57	0.54	4.33	0.82	3.43	0.54
Touch to robot's face	3.43	0.98	4.00	0.89	3.86	0.90	4.17	0.98	3.43	0.79
Touch to human's face	2.50	1.64	2.86	0.69	3.00	1.10	2.86	0.38	3.67	1.21
Embrace	3.67	1.03	3.57	0.79	4.17	0.75	3.57	0.98	4.67	0.52
Total	**2.95**	**0.87**	**3.67**	**0.74**	**3.63**	**0.61**	**3.69**	**0.74**	**3.81**	**0.74**

Rhoni. When interviewees imagined experiencing the different interactions as depicted in the pictures with Rhoni, they reported feeling most superior in the embrace situation and when the person touched the robot’s face. In contrast, when the robot touched the human’s face or a reciprocal but formal touch (handshake) was displayed, interviewees felt less superior to the robot (Table 24).

iCub. When iCub was presented to the interviewees, their perceived dominance was highest if human-initiated touch (arm and face) was visible on the stimulus, and least if the touch was robot-initiated (Table 24).

Nao. Nao in combination with intimate reciprocal touch (handhold, embrace) elicited high feelings of superiority in the interviewees. Lower superiority was observed when robot-initiated touch to the face of the human was shown.

Robosapien. For Robosapien, interviewees generally always felt strongly superior to the small robot. Only in situations where the touch was initiated by the robot, were dominance ratings a little lower than for the other forms of touch (Table 24).

Lego NXT. Pictures that depicted embrace and handhold with the Lego NXT led to strong feelings of superiority, in contrast to pictures in which the robot was touched by the human (arm and face), or both shake hands (Table 24).

In summary, the results regarding the anticipated emotional state of the interviewees under consideration of the robot type revealed that human-initiated touch was favorably evaluated (high valence, low arousal, and high dominance) for almost all robots.

Anticipated valence for Rhoni was rated best if human-initiated touches were presented, while reciprocal touch forms were even more favorably evaluated for all other robots. Among the other robots, formal reciprocal touch (handshake) was evaluated as more desirable than informal reciprocal touch (handhold, embrace) for Nao and Lego NXT, while informal reciprocal touch was preferred over handshake touch for iCub and Robosapien. Arousal was imagined to be highest in interaction with iCub, but lowest with Lego NXT and Rhoni, whereby the comments of the interviewees revealed that some interpreted the embrace touch in particular as functional (e.g., as in transportation), and thus less arousing, if Rhoni were present.

Finally, interviewees imagined being superior to all the robot types that were included. Although they anticipated feeling least superior towards the tall robot Rhoni and most superior towards the small Lego NXT robot, which suggests that dominance is strongly correlated to the robot's size: The taller the robot, the lower the individual's feeling of dominance.

6.5 Discussion of the Qualitative Interviews

The aim of this interview study was to explore HRT initially from an observer perspective. Therefore, a qualitative approach was chosen to gather insights into the acceptability, perception, interpretation, and evaluation of HRT based on stimulus pictures that portray a human person (actress) interacting with different humanoid robots. Touch was present or absent in these pictures. In addition, different forms of touch were included that have previously been investigated in research on interpersonal touch (Burgoon, 1991), namely: handshake, handhold, touch to the arm, touch to the face, and embrace.

Answers to the specific research questions and hypotheses are discussed in the review of the yielded results in the following paragraphs. Each paragraph refers to one research question, or hypothesis, respectively.

6.5.1 Summary of the results and interpretation with regard to the research questions

6.5.1.1 How acceptable is robot touch to humans?

The analysis of the body charts revealed that robot touch to many parts of the human body is generally considered acceptable (RQ1), and surprisingly, even more than human touch (RQ1a). Interviewees agreed that parts of the face, the chest and the private parts are accessible neither to robot touch, nor to touch by an unknown human. They further agreed that touch to the hands and arms is uncritical from both, humans and robots. In contrast, robot touch to most parts of the back, legs and shoulders are on average permitted by the interviewees, whereas human touch to these regions was only said to be acceptable under certain circumstances. As rationale, a lower inhibition threshold towards an inanimate object, and an assumed task-relatedness of robot touch were mentioned. Furthermore, trust in the technology was named as a prerequisite for allowing robot touch, which could help in reducing the worry of being hurt by an uncontrollable robot, a reason that was mentioned for the refusal of robot touch (RQ1b).

The high acceptability of robot touch to body regions that have a high potential to be touched by robots (e.g., hand or shoulder) constitutes a fruitful basis for the general allowance of robot touch, which is a prerequisite for the accomplishment of positive effects of robot touch. In addition, these body parts have already been demonstrated as areas to which touch results in positive effects in interpersonal interactions (e.g., hand touch leads to better evaluation: Fisher, Rytting, & Heslin, 1976; shoulder touch leads to higher tipping: Crusco & Wetzel, 1984).

In conclusion, robot touch might be a useful alternative to human touch, especially for tasks where a lower inhibition threshold is desirable, as in the transportation, bathing or cleaning of (old, sick) people. Negative effects that could occur with interpersonal touch that is associated with personal space invasions, dominance, undesired liking, or even sexual desire (Burgoon & Jones, 1976; Henley, 1977, 2012; Nguyen, Heslin, & Nguyen, 1975), might be reduced when the toucher is a robot.

Furthermore, it is possible that the acceptance of robot touch would further increase if robots become more ubiquitous in the future and humans are more used to them. The explanations that robot touch would be acceptable if the robot is familiar and one has trust in technology predicts this (RQ1b; see Study 1, Chapter 6.3).

Alternatively, it can be surmised that the acceptance might decrease if robots develop into socially interactive, and thus more humanlike entities (cf. Mori, MacDorman, & Kageki, 2012). If this were to be the case, the inhibition threshold might increase if robots were perceived as more and more animated, equipped with emotions, thoughts and intentions (cf. findings on lower self-disclosure towards humans than inanimate computers, e.g., Weisband & Kiesler, 1996). However, based on the other findings (see below), which suggest that individual differences might influence the acceptance as well as the perception, interpretation and evaluation of touch, it can be assumed that individual preference for or against humanlike robots, might further determine reactions towards such developments. Some individuals who easily anthropomorphize things and have positive attitudes towards the development of new technologies might prefer being in touch with robots which appear social and humanlike, while others may not (Nomura & Kanda, 2008; Nomura et al., 2004; Nomura, Suzuki, Kanda, & Kato, 2006a).

While the acceptability of touch was rather generally addressed in distinction to human touch (by means of the body charts), the remaining research questions and hypotheses focused on the stimulus pictures, and are revisited in the following.

6.5.1.2 How is HRT perceived from an observer perspective?

In order to gather an unbiased impression of the first perception of HRT, interviewees were asked to verbalize their thoughts during the observation of the pictures that include HRT (think aloud method). The categorization of the original descriptions of the stimulus pictures according to their valence showed that most comments were value neutral, demonstrating that valued opinions did not prevail when interviewees were confronted with HRT for the first time. Furthermore, those statements that were evaluative were predominantly positive and referred to the situation including the presented forms of touch. Different forms of touch between robots and humans were thus largely positively perceived from an observational point of view. Intimate touch forms, such as embrace and touches to the face of the human and the robot, evoked particularly positive comments. This is in line with the findings reported in Burgoon and Walther (1990) with regard to interpersonal touch. In their study, reciprocal touches (handholding and handshake) as well as touch to the face were the most favorably evaluated forms of touch from mere observation. Individuals therefore seem to associate reciprocal and intimate touch forms with positive and close relationships from an observational point of view. Furthermore, this tendency is observable for interpersonal touch as well as HRT interactions.

Negative valued descriptions occurred less often in the present study, and were more often caused by the appearance and size of the robot that was depicted than by the touch form that was included (see also touch form H1 & robot type H2 below).

Apart from the perceived valence, the perception of HRT was further explored by means of ratings on how surprising and alarming the different situations in the pictures appeared. The ratings suggest that overall, HRT was overall perceived as medium surprising and low alarming. With regard to the different touch forms, interviewees reported being surprised when touch to the face of the human or the robot, or an embrace were depicted, all of which are intimate forms of touch. Touches to the hands (handshake, handhold) and the arms were in contrast more expected and thus less surprising. These findings are, again, similar to those yielded in interpersonal contexts (Burgoon & Walther, 1990), where formal handshaking was rated as the most expectable form of touch, and touch non-reciprocal touches to the arm and face, as well as arm around the shoulder, were least expected by the observers.

With regard to harassment, touches from the robot to the face and arm of the human were rated as the most alarming touches. As a consequence, HRT in general does not seem to be alarming to humans from an observer perspective. However, intimate touch forms that are more surprising were also rated as more alarming, but as demonstrated earlier, overall mean ratings on harassment were below the midpoint of the scale, which indicates no to low perceived harassment.

In conclusion, the results demonstrate that the observation of HRT by means of photographs is similar to comparable findings from interpersonal touch research (Burgoon & Walther, 1990). The interviewees generally seemed open-minded towards the presented interactions that included HRT, what is reflected in the positively valued descriptions of the stimuli. Different touch forms further appeared to be equally expected as in interpersonal encounters. All findings lend support to the notion that individuals perceive HRT as equal to interpersonal touch. Hence, the media equation approach (Nass & Moon, 2000; Reeves & Nass, 1996) seems to hold for the perception of HRT, which can further be seen as a first prerequisite for the potentially beneficial effects of robot touch on human well-being.

6.5.1.3 How is HRT interpreted from an observer perspective?

The next question was, how individuals interpret HRT in terms of relational descriptions of the human-robot relationship. The main categorization of these descriptions demonstrated that on the whole, the interviewees interpreted the human-robot interactions that were presented in photographs in a relational way (RQ3a). It is noticeable that the majority of these interpretations were categorized as personal relationships, which means that the perceived relationship between the human and the robot was similar to an interpersonal relationship. Furthermore, the examination of these descriptions along different relational themes revealed that relational interpretations of HRT also resembled findings from interpersonal touch (Burgoon, 1991; Burgoon & Walther, 1992; RQ3a).

For one thing, the themes that emerged from the material (the relational descriptions of HRI), namely: familiarity, intimacy/closeness, dominance, formality, composure, and relational symmetry reproduced relational themes that were reported in earlier work on interpersonal relationships (Burgoon, 1991; Burgoon & Hale, 1984). Furthermore, the comparison of different touch forms with regard to the relational themes shows that a social meaning model that has been confirmed for the meanings of touch in interpersonal context (Burgoon, 1991), also applies to HRT (to some extent, RQ3b). For instance, embrace and touches to the face were interpreted as more intimate/close than touches to the arms or hands. Also, the theme formality emerged for pictures that show human and robot shaking hands. These findings support the hypothesis H1.3a and H1.3b (see also Chapter 6.5.1.5) that different forms of HRT are interpreted differently, comparable to interpersonal touch.

The theme relational symmetry further demonstrates that interviewees used familiar relational definitions to describe the human-robot relationship, because adequate relational definitions for human-robot relationships might be missing at the moment.

Alternatively, the frequent occurrence of personal interpretations of the human-robot relationship might also have resulted from demand characteristics of the interview. Interviewees might have suspected that the interviewer expected them to describe the relationship in terms of close interpersonal relationships and thus might have confirmed these expectations. To avoid such bias, interviewees were on purpose not directly asked about the touch that was included in the interaction. They were also not asked about the intimacy or closeness, but to describe the relationship with their own words ("How would you describe the relationship between the human and the robot on the photograph?") to avoid suspicion. Furthermore, in terms of social desirability it can be argued that personal interpretations of human-robot relationships can be regarded as inappropriate, and should therefore be denied towards a human interviewer (Nass & Moon, 2000).

As distinct from interpersonal interpretations of touch (e.g., relational themes cf. Burgoon & Hale, 1984), the human-robot relationship was also often categorized as a functional relationship. Although one could assume that this might resemble the "task-orientation" theme (Burgoon & Hale, 1984) from interpersonal contexts, the relational descriptions that were summarized under this category demonstrate that the descriptions were not comparable to typical personal relationships.

The division of the functional descriptions into handling technology, test/examination and curiosity/interest clarifies the boundaries of the comparability of HRT and human-robot relations to interpersonal touch and interpersonal relationships. Although similarities are visible within the personal relationship category, the functional relationship category points to the fact that robots are inanimate objects and thus the relationship with them can also be described in a similar way as the relationship with other things or objects. It seems as if the decision whether HRT was rather personally or functionally interpreted depended on individual differences, as for instance the description of the embrace as transportation of the robot by an engineer showed.

6.5.1.4 How is HRT evaluated based on personal feelings?

Based on the observational approach it was not possible to infer how individuals would actually react if they were to have physical contact with a robot. Consequently, with regard to the emotional reaction, interviewees were asked to imagine being the person presented in the picture and assess their anticipated feelings (valence, arousal and dominance) according to this point of view.

As regards the question of how HRT is evaluated (RQ4), the results for the anticipated ratings demonstrate that the interviewees generally expected to feel good and superior to the robot in almost all the presented interactions. Comparing the different forms of touch revealed that they are differently evaluated, which lends support to H1.4. A slight decrease in anticipated dominance was only visible in pictures that depicted robot-initiated touch. This is similar to earlier findings from Major and Heslin (1982) who showed that in interpersonal interactions, the initiators of touch are perceived as more dominant than the recipients of touch.

Remarkably, the order of touch forms with regard to valence and arousal was in direct contrast with one another. Therefore, a negative correlation between arousal and valence was revealed. In fact, touch from the robot to the human caused the highest arousal but lowest valence, while reciprocal touch was in the middle (for arousal as well as valence), and touch from the human to the robot elicited low arousal, but was evaluated most favorably. These results match the findings of Chen, King, Thomaz, and Kemp (2014, 2011) who demonstrated that affective intended touch from a robot was less desirable than instrumental robot touch, which in addition caused lower arousal than affective touch. Lower arousal thus seems to be favorable for positive evaluations of touch in HRI.

6.5.1.5 The form of touch alters the perception, interpretation and evaluation of HRT

The aforementioned results demonstrate that the form of touch is a crucial variable that affects the perception, interpretation, and evaluation of HRT, which supports hypothesis H1. Three major dimensions of touch, which repeatedly appeared as decisive for HRT based on the interviews, can be summarized: reciprocity, direction and formality/intimacy of touch (Table 25). These dimensions have also been discussed previously in the literature on interpersonal touch (e.g., Heslin & Alper, 1982; Thayer, 1986).

As can be read from the Table 25, the forms of HRT considered in this study can be categorized according to their reciprocity as reciprocal (handshake, handhold, embrace) or non-reciprocal (directional) touch. The non-reciprocal touch forms can further be distinguished according to their direction, i.e., whether the human touches the robot (human-initiated) or the robot touches the human (robot-initiated). In addition, each touch form can additionally be categorized as formal, which means impersonal and less intimate, or informal/intimate. Accordingly, embrace is for instance a reciprocal informal touch form, while touch to the human's arm is a non-reciprocal, robot-initiated touch form that is rather formal and less intimate.

Table 25. Categorization of the used touch forms on the dimensions: reciprocity, direction and formality/intimacy.

	Dimensions of touch forms		
Touch form	**Reciprocity**	**Direction**	**Formality/Intimacy**
Handshake	reciprocal	-	formal/less intimate
Handhold	reciprocal	-	informal/intimate
Touch to human's arm	non-reciprocal	robot-initiated	formal/less intimate
Touch to robot's arm	non-reciprocal	human-initiated	formal/less intimate
Touch to robot's face	non-reciprocal	human-initiated	informal/intimate
Touch to human's face	non-reciprocal	robot-initiated	informal/intimate
Embrace	reciprocal	-	informal/intimate

When reconsidering the results with respect to these dimensions, the following can be summarized:

H1.1 & H1.2: Perception. Positive perceptions of HRIs including touch are most frequently observed for informal/intimate reciprocal (embrace) or informal/intimate non-reciprocal touches directed to the face of the human or robot, wherein non-reciprocal, human-initiated, intimate touch (*touch to robot's face*) was again favored over robot-initiated ones (*touch to human's face*) (H1.1). With regard to the expectedness and harassment of the touch forms (H1.2), the informal/intimate touches were most surprising and alarming, but this time robot-initiated touch to the face was more surprising and alarming than human-initiated touch.

By contrast, negative perceptions were observable for formal reciprocal touch (*handshake*) and robot-initiated touch (non-reciprocal, formal: *touch to human's arm*, informal: *touch to human's face*), while less negative perceptions were observable for human-initiated touch (formal and informal), and intimate reciprocal touch (*embrace*). This perception contradicts the findings with regard to the harassment, where formal reciprocal touch (handshake) was less alarming than robot-initiated touch and informal embrace touch. It should, however, be noted that the negative comments with regard to the handshake gesture often referred to the robot instead of the touch form. Thus, general conclusions on the perception of human-robot handshake should be drawn cautiously.

H1.3: Interpretation. With regard to the relational categorization it can be summarized that functional relationships were more often interpreted for non-reciprocal touch forms (*touch to human's arm, touch to robot's arm, touch to human's face*), than for reciprocal ones. However, *embrace* was however sometimes functionally interpreted by interviewees who interpreted the situation as instrumental, e.g., transportation of the robot. Among non-reciprocal touch forms, formal touches to the arm were interpreted functionally more often than touches to the face, which are informal/intimate.

The relationship between the human and the robot was most frequently interpreted as personal when reciprocal intimate touch (*embrace*) was presented, followed by non-reciprocal but intimate touch to the face and more formal touch to the arms.

H1.4: Evaluation. With regard to the evaluation, it can be concluded that human-initiated touch is better evaluated and less arousing than reciprocal touch, which is even better evaluated and less arousing than robot-initiated touch. Dominance, in contrast, was rated highest for the intimate reciprocal touch forms (*handhold* and *embrace*), followed by human-initiated, formal reciprocal (*handshake*) and robot-initiated touch.

Finally, it can be summarized that reciprocal touch appeared favorable with regard to the perception and anticipated dominance. Regarding non-reciprocal touch, human-initiated touch forms are more favorably perceived, better evaluated, and associated with lower arousal than robot-initiated touches. Instead, the relational interpretations were more strongly influenced by the formality/intimacy of the touch form. Thereof, formal arm touch leads to more functional interpretations, and informal face touch to more personal ones.

When comparing these findings to previous work on robot touch, it becomes obvious that the mix of different forms of touch as in the work of Cramer and colleagues (e.g., tap to human's shoulder, high five, hug; Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, & Evers, 2009), might have affected the perception and evaluation of HRT. They reported that a proactive robot that touched a human user was evaluated as less machine like and more dependable than a reactive robot that touched the person in the video. Furthermore, no differences in the perceived closeness between the human and the robot were observable. But according to the knowledge gained from the present interview study, it can be surmised that the results might have been different had each touch form been regarded separately. For example, the perceived closeness might have differed between reciprocal HRT and no touch.

H2: The size and appearance of a humanoid robot alter the perception, interpretation, and evaluation of different forms of HRT.

The summary of the perception of the different robot types (Chapter 6.3.1) and the comparison of the different robots with respect to the perception, interpretation, and evaluation of HRT showed that the appearance and size of a humanoid robot alter these factors, in line with the literature on robot appearance (Syrdal, Dautenhahn, et al., 2008; Walters et al., 2009). This gives support to hypothesis H2.

The descriptions of the different robots revealed that the largest robot Rhoni was in general perceived as threatening because of its size as well as its mechanical appearance. Some interviewees even compared the robot to the "Terminator" or "bad guys from the movies." iCub, which is smaller was compared to a child, because of its size and appearance. The robot was mostly perceived as friendly, although some interviewees stated that the childlike appearance is eerie in their opinion.

The descriptions of Nao, Robosapien and Lego NXT share that all three are perceived as small, toy like robots. Nao and Lego NXT were further described as cute, friendly and likable, while Robosapien tended to be perceived as mechanical and modern according to its appearance.

The results that referred to the perception of HRT (H2.1) under consideration of the robot type demonstrated that 50% of the negative comments on the stimuli referenced the robot's size or appearance as a reason for the negative perception. If interviewees did not like something about the appearance, e.g., the kill-switch in the case of Rhoni, or the weapon like hand and the childlike appearance in the case of iCub, their general impression was negatively affected. Furthermore, smaller sized robots are more favorably perceived than taller ones. In particular, touch with the tallest robot Rhoni evoked fewest positive comments and was perceived as more alarming than touch with smaller toy like robots which have wear plastic covers (Nao, Robosapien, Lego NXT). The perception of iCub strongly depended on whether interviewees perceived the childlike appearance as favorable or creepy. However, mixed valence statements revealed that a pleasant perception of touch between a human and a robot (e.g., embrace) can compensate for a negative robot perception sometimes.

With regard to the interpretation of HRT (H2.3), primary differences were observed in the tallest robot Rhoni in contrast to all other robots. Among the relational interpretations the fewest personal interpretations were remarkable for Rhoni, whereas many unclear and functional categorizations were observable for the huge robot. It is further remarkable that the embrace with Rhoni was interpreted multiple times as a functional relationship, because the gesture was interpreted as the transportation of a technical device. For iCub, its childlike appearance often led to comparisons to an asymmetrical parent-child relationship.

Regarding the evaluation of HRT (H2.4), the robot's size appeared to be crucial. Interviewees anticipated better feelings when they imagined touch with a smaller robot, comparable to earlier work on distancing behavior (Walters et al., 2009). In fact, the smaller the robot the better the anticipated valence overall. One reason for this finding could be found in the perceived dominance ratings. According to the ratings, interviewees felt least dominant in contrast to the tallest robot. Hence, interviewees seem to prefer interactions with robots that are smaller than themselves so that they can still feel superior in comparison to the robot. Alternatively, it can also be suspected that the mechanical appearance of the robot Rhoni, instead of its size, negatively affected the desirability of touch with the robot. In comparison to Rhoni, all other robots that were included have at least partial linings. Although no other humanoid robot of this size was available for this study, future studies should use robots of different sizes with similar linings.

6.5.2 Conclusion

The results of this exploratory interview study revealed that HRT is generally neutral to positively perceived from mere observation. Furthermore, different forms of touch are differently perceived, interpreted, and evaluated. The interpretations interviewees made with regard to the relationship largely resemble personal relationship interpretations that resemble interpersonal relationships. Touch between humans and robots is thus relationally interpretable on the same terms as interpersonal touch. With regard to human-robot interactions that might include touch it is important to consider, that specific forms of touch may evoke relational meanings about the relationship between a human and a robot.

The reciprocity, direction and formality of touch have moreover been proven as important dimensions of HRT. Human-initiated touch was overall more positively perceived and evaluated, and further less surprising, alarming or arousing than robot-initiated touch. Interviewees anticipated better feelings when formal reciprocal touch (handshake) was included in the interaction compared to informal reciprocal touch (handhold and embrace), although the results with regard to the perception and interpretation from the observer perspective suggested that embrace touch leads to more positive descriptions in particular and more relational interpretations as personal, conveying intimacy and closeness.

An explanation for this deviation can be found in the assumptions about the congruency of touch and relational closeness as proposed by Heslin and Alper (1983). According to the authors, increased intimate touch only leads to positive reactions when the relationship is adequately close. In contrast, if the relationship is only moderately intimate or non-existing, increased intimacy of touch results in discomfort. Applied to the results, it is possible that interviewees assumed that the person and the robot have a close relationship based on the observation of touch presented in the pictures (e.g., embrace), which is in line with the findings of Burgoon (1991; intimate touch forms lead to intimate relational interpretations). However, when they imagined that they were in such a situation with a robot with whom they did not have a close relationship, or even no relationship at all, intimate touch forms such as embrace or touch to the face might be anticipated as discomforting due to an incongruence between the relational intimacy and the intimacy of touch.

Also, the appearance and size of a robot further influence the perception, interpretation and evaluation of HRT. Small sized robots which are less mechanical looking, e.g., covered in plastic, but also not too humanlike are favorable according to the findings. In conclusion, the appearance and size of robots should be considered when choosing robots to influence human well-being. For instance, findings for the medium sized, plastic covered and not too humanlike robot Nao revealed positive evaluations on most dimensions, so that using a robot that is at least smaller than the average human user and not threatening in its appearance (e.g., mechanical, uncovered, too humanlike) should be recommended.

6.5.3 Limitations and Outlook

In comparison to quantitative approaches, a comparable small sample of $N = 13$ was interviewed. Although no inferential statistics were calculated due to the sample size, the reported mean values should also be regarded with caution. Moreover, interviewees of different age groups were chosen to collect a broad variety of opinions, while the sample was small. Nonetheless, findings could be dependent on individual's difference (e.g., profession).

The categorization of interview answers can also be criticized. On the one hand categorizing the material helps to reduce the interviewees' answers to the core statements, but on the other hand the reduction poses the danger that relevant comments disappear in the analysis. In order to reduce the possibility of missing important aspects that are relevant to the acceptance, perception, interpretation and evaluation of HRT, quotes were additionally included in the analysis. In addition, quotes were used instead of paraphrases so that no textual deviations altered the answers of the interviewees (cf. Flick, 2002).

With regard to the think aloud method that was applied, it can be surmised that interviewees might have had difficulties verbalizing their thoughts, especially on such an intimate topic as touch. According to the media equation theory (Nass & Moon, 2000; Nass & Steuer, 1993; Nass, Steuer, Henriksen, & Dryer, 1994), individuals socially react to technologies automatically (mindlessly) but deny the behavior afterwards. Since interviewees did not react immediately to a robot, because they were confronted with photographed interactions, it is not possible to compare their reaction to a retrospective self-reported evaluation. In consequence, it can only be suspected that interviewees might have adjusted their answers to be socially desirable at once.

However, the findings (e.g., relational interpretations similar to interpersonal literature) did not lend support to the assumption that interviewees might have denied that experiencing HRT was similar to interpersonal touch. One factor that might have helped is the chosen observer perspective, which is similar to a third person perspective. Although HRT has been described as inappropriate and incomprehensible by some interviewees, it is possible for instance that the observer perspective allowed descriptions of the human-robot relationship as close and personal, while interviewees might thought that having a close relationship with a robot is inappropriate (comparable to a *third person effect*, Davison, 1983).

Otherwise, it is possible that interviewees interpreted the relationship personal due to demand characteristics of the interview situation, e.g., answer questions according to an anticipated goal of the study. However, the occurrence of both, personal and functional interpretations, rather indicates that the form of touch and individual differences were responsible for the varying perception and interpretation of HRT.

The mere observation of touch, which is regularly a dynamic act that includes physical contact that in turn leads to physiological arousal, could also be criticized because key elements of touch are missing during plain observation. Nevertheless, earlier studies on interpersonal touch used observational methods based on photographs and video-recordings, and revealed that at least relational interpretations of touch coincide between observers and participants (Burgoon, 1991; Burgoon & Newton, 1991). Beyond that, the observation of photographs has been said to be the simplest, fastest and most controlled way to present touch to observers (Burgoon, 1991).

Finally, it has been criticized by some interviewees that the context in which the interaction on the photographs happened was unknown. Hence, they had difficulties to make judgements about the desirability of touch, when they did not know e.g., why the robot should touch a human.

Based on the aforementioned shortcomings and open questions, challenges for future research and the realization in the follow up studies are outlined in the next section.

6.5.4 What remains open? **Conclusion for future studies**

The major shortcomings of this exploratory study will be addressed in the follow up studies. Since a qualitative approach has shortcomings as mentioned above, quantitative studies with broader samples were conducted subsequent to the interviews to quantify the gathered impressions about HRT.

The interview study has already considered touch characteristics (different forms of touch) as well as robot characteristics (different humanoid robots in different sizes). However, other factors are also crucial with regard to the perception, interpretation, and evaluation of touch, which could eventually affect human well-being. The analysis of the interviews implies that individual differences like profession and expertise influence the perception and interpretations of different touch forms (e.g., perception of embrace as the transportation of a technical device by an engineer). Therefore, person characteristics should be investigated more systematically with larger samples in the future studies (mainly Study 2 and 3).

Above all, the analysis revealed that different touch forms with different humanoid robots are diversely expected. Hence, individuals seem to have distinct expectations about how HRIs should look like. These expectations further seem to be influenced by individual characteristics as expertise, but also by the appearance and size of a robot. For instance, formal touch forms as the handshake were rated as less surprising than more intimate touch forms (e.g., touch to the face, embrace). Furthermore, touch initiated by the robot was more surprising, and hence less expected, than human-initiated and reciprocal touch. In order to address the potential shortcoming that the mere observation of HRT might have, this thesis incorporates a mixed methods approach that includes data from observation as well as from actual HRT (see Study 4).

Beyond, the context in which the interaction takes place might affect how expected HRT is, how it is interpreted, and finally how it is evaluated. Therefore, expectations, touch form (direction and intimacy), and different contexts are scrutinized in a consecutive experimental study (see Study 3).

7 Study 2: *Online Survey on the Acceptability of HRT*

Based on the interviews (Study 1) it is assumed that robot touch to some body regions is more acceptable than human touch, whereas the acceptability of robot touch is further determined by the person's characteristics, the characteristics of the robot and the characteristics of the touch form (direction of touch). The present study was therefore consecutively conducted to quantify the findings from the interview study using a larger sample.

7.1 Research Question and Hypotheses

The main question that was addressed with the online questionnaire was which factors influence the acceptability of HRT. Crucial variables which had already been revealed in the interviews (Study 1) were therefore translated into measureable scales/scale items, to see whether these impressions could be quantitatively replicated with a larger sample. Figure 7 depicts an amended version of the HRT evaluation process, which fits the variables that were under consideration in the present study.

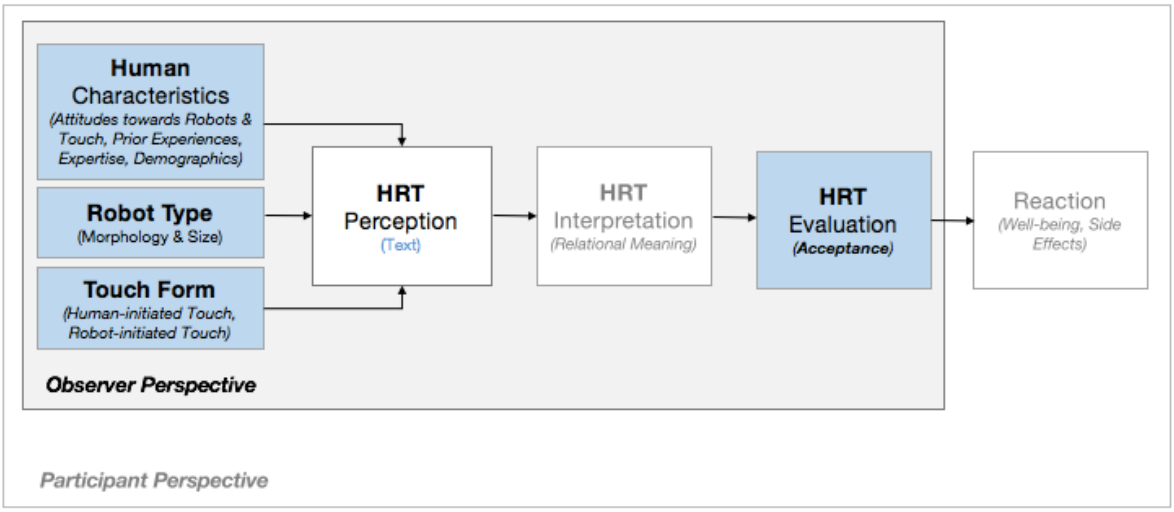


Figure 7. Systematical overview of the HRT evaluation process as regarded in the online survey (Study 2). Variables that are of special interest are highlighted in blue, while parts that have been neglected are gray.

The focus of the survey was on the acceptance of HRT. The influence of human characteristics, robot type (morphology and size), as well as the direction of HRT (human- and robot-initiated) were also deepened and quantified. Contextual factors, such as the intent of touch (cf. Chen, King, Thomaz, & Kemp, 2014, 2011), were also included to test whether participants reacted differently to descriptions of touch that were rather functionally or affectively motivated.

The following sections cover the hypotheses, which were built upon the knowledge that was gathered from the interviews, as well as from related work.

7.1.1 General Body Accessibility

Jourard (1966) reported that a human's body accessibility to touch varies according to who is the toucher. For instance, higher accessibility was revealed for friends than for strangers. When considering a robot as the initiator of touch it could thus be argued that peoples' acceptance of touch to their bodies by a robot would be even lower or at least comparable to touch from a human stranger. Instead, the results from Study 1 demonstrated that individuals have a lower inhibition threshold when the toucher is a robot. Hence they reported being more comfortable if an emotionless robot touched them than a human. With regard to the acceptance of robot-initiated touch, it is therefore assumed that individuals display a higher acceptance for robot-initiated touch than for touch from a human stranger. Based on the findings from the interviews (Study 1) it was specifically assumed that touch to the front and back of the legs, the shoulder and back is more accessible to robot touch than to human touch.

> H1: Touch from a robot to the leg(s), shoulder and back of a human is more acceptable than touch from a human to a human, while touch to other regions (feet, arm, hands etc.) is equally acceptable from robot and human touchers.

7.1.2 Rationale for Touch

Some comments from the interviewees (Study 1) further point to the context and reasoning of touch that might affect the perception, interpretation and evaluation. Functional purposes, for instance, were mentioned as a justification for making HRT more acceptable. In line with the findings of Chen, King, Thomaz and Kemp (2014, 2011), it is thus hypothesized that touch with a functional purpose, such as help or transportation, is more acceptable and desirable than touch that fulfills an emotional or affective purpose like comforting someone.

H2: Functional HRT touch is more acceptable than affective HRT.

7.1.3 Direction of Touch

With regard to the direction of touch, Major and Heslin (1982) demonstrated that it is better to give than to receive touch. In their study, observers of interpersonal touch evaluated initiators of non-reciprocal touch more favorably than recipients of. Accordingly, the findings from the interviews revealed that for different directions of HRT, touch directed from a human to a robot is more expected and positively evaluated from an observer perspective than robot-initiated touch to a human. Therefore, it is assumed, in line with Major and Heslin, that the initiation of touch to a robot is preferred over the reception of touch from a robot.

H3: Human-initiated touch to a robot is more acceptable than robot-initiated touch to a human.

7.1.4 Robot Characteristics

The morphology and size of a robot have further been demonstrated to affect the perception, interpretation and evaluation of HRT. The remarks from the interview study show that touch with smaller robots was favored over touch with taller robots, and that touch with pet like robots was favored over touch with humanlike robots. Also related work demonstrated that individuals allow closer distances from mechanical looking robots than from humanlike robots (e.g., Syrdal, Dautenhahn, & Walters, 2008). Therefore, the following hypotheses are formulated:

H4a: Touch with small robots is more acceptable than touch with tall robots.

H4b: Touch with pet like robots is more acceptable than touch with humanlike robots.

H4c: Touch with machinelike robots is more acceptable than touch with humanlike robots.

7.1.5 Person Characteristics

Individual characteristics that might alter the accessibility for, and acceptance of HRT, expertise with regard to new technologies, attitudes towards robots and touch, and participants' sex were identified from the literature and the interview study.

7.1.5.1 Expertise

The interviews indicated that individual differences in profession, expertise and general attitudes towards robots and touch can influence the personal acceptability of touch between a person and a robot. Based on the descriptions of the stimulus pictures from the interview study, it can be assumed that interviewees with higher expertise who work in technology-related industries (e.g., automotive industry) perceive HRT differently from naïve observers. For instance, the embrace touch was described as the transportation of an object by an IT specialist and an engineer, while the other interviewees interpreted the touch gesture as an embrace (as intended). Since functional (or instrumental) touch has been revealed as more desirable than affective touch in earlier work (Chen et al., 2014, 2011), it can be assumed that individuals with higher expertise accept robot touch more easily since they interpret it as functional rather than affective.

H5: The higher the individual's expertise, the higher their acceptance of HRT.

7.1.5.2 Attitudes towards robots

Moreover, insights were gained in the interviews that indicate that personal attitudes towards robots, and touch in general, also alter the perception and thus the acceptability of HRT. Negative attitudes towards robots have frequently been revealed as a decisive trait that influences human-robot interaction (e.g., Nomura & Kanda, 2008; Nomura, Kanda, &

Suzuki, 2006; Nomura, Suzuki, Kanda, & Kato, 2006). With regard to touch in human-robot interaction, Chen et al. (2014) and Cramer, Kemper, Amin, Wielinga and Evers (2009) demonstrated that negative attitudes towards robots affect opinions towards touch with robots. Participants with more negative attitudes (subscale emotions in interaction with robots) wished that the robot had not touched them in the study by Chen et al. (2014). Furthermore, the findings of Cramer et al. (2009) revealed an interactive effect between negative attitudes towards robots and the presence of touch in the perceived machine likeness of a robot: For individuals with negative attitudes, the inclusion of touch in the interaction led to higher perceived machine likeness, whereas for individuals with positive attitudes, touch reduced the perceived machine likeness compared to the absence of touch. In conclusion, it is hypothesized that negative attitudes towards robots reduce the acceptance of HRT.

H6: The more negative the individual's attitude towards robots, the lower their acceptance for HRT.

7.1.5.3 Attitudes towards touch

Finally, general tendencies for touch comfort have been shown in interpersonal contexts. For instance, Sorensen and Beatty (1988) demonstrated that individuals who have a general attitude against touch with others, respond more negatively to being touched on the shoulder after an interview session by evaluating the interviewer less positively, than individuals who have a tendency to endorse interpersonal touch. It can be concluded, therefore, that individuals have a general tendency to approach or avoid touch (cf. Andersen & Leibowitz, 1978) which affects their perception and reaction to touch. Furthermore, it can be supposed that the tendency to approach or avoid interpersonal touch might also spread to human-robot interactions, and thus influence the acceptance of HRT, so that touch avoiders have a lower acceptance for HRT touch than touch approachers.

H7: The more positive the individual's attitude towards interpersonal touch, the higher their acceptance of HRT.

7.1.5.4 Sex differences

The literature on interpersonal touch revealed that differences in the acceptance of touch exist between men and women. Since women receive more touch during their development, they are said to be more used to passive touch, and thus are more comfortable with receiving touch than men are (Sussman & Rosenfeld, 1978). However, men are more used to active touch (touching), since active touch is associated with status and dominance (Hall, 1996; Henley, 1973, 1977; Major & Heslin, 1982). In conclusion, it is hypothesized:

H8a: Women accept being touched by a robot more easily than men.

H8b: Men accept touching a robot more easily than women.

7.2 METHOD

In order to test these hypotheses, an online survey was built with the online software package SoSci Survey (https://soscisurvey.de). Unlike the interview study, no stimulus pictures were included to address the acceptability of HRT on a more global level. Instead, the findings from the interview study were translated into measureable scale items (text), to verify the impressions gathered about the determinants of HRT acceptability. A quantification of the findings with regard to stimulus pictures, however, follows in the online experiment (see Study 3).

7.2.1 Questionnaire

With respect to the hypotheses, the questionnaire consisted of questions concerning the acceptability of human and robot touch, the impact of the function and direction of the touch, as well as questions about robot and person characteristics, e.g., participants' general attitudes towards touch and robots (see Table 26 for an overview). The operationalization of each variable as listed in the left column in Table 26 is explained in detail in the following paragraphs. Five-point Likert-type scales ranging from 1 = "fully disagree" to 5 = "fully agree" were used unless otherwise mentioned. Cohen's d was calculated as effect size for mean comparisons (t-tests). According to Cohen (1988), effect size between 0.2 and 0.5 represent a small, from 0.5 to 0.8 a medium, and 0.8 and higher a large effect.

Table 26. Overview of the questions and their order in the online questionnaire.

Construct	Question/ Scale (Subscales)	Number of items & Scale Consistency (Cronbach's alpha)
Touch Acceptance for Human Touch	*How pleasant or unpleasant would you consider touch by a stranger to the following body regions?* (16 regions)	1= "unpleasant" to 5= "pleasant"
Attitude towards Touch	Need for Interpersonal Touch Scale (Nuszbaum, Voss, & Klauer, 2014)	20 items, α= .866
	Touch Avoidance Measure (Andersen & Leibowitz, 1978), two subscales: TAM1: Same-sex touch avoidance TAM2: Opposite-sex touch avoidance	TAM1: 10 items, α= .684 TAM2: 8 items, α= .795
Technological Expertise	Ad hoc items concerning the ability to deal with, and interest in, new technologies.	6 items, α= .817
Attitudes towards Robots	Negative Attitudes towards Robots Scale (Nomura & Kanda, 2004), three subscales: Negative attitudes towards… S1: … situations of interactions with robots S2: … social influence of robots S3: … emotions in interaction with robots	 S1, 6 items, α= .690 S2, 5 items, α= .688 S3, 3 items, α= .708
Touch Acceptance for Robot Touch	*How pleasant or unpleasant would you experience touch by a robot to the following body regions?* (16 regions)	scale: 1= "unpleasant" to 5= "pleasant"
Acceptability of Human-Initiated Touch	Human-initiated functional touch Human-initiated affective touch	3 items, α= .719 3 items, α= .823
Acceptability of Robot-Initiated Touch	Robot-initiated functional touch Robot-initiated affective touch	4 items, α= .701 2 items, α= .885
Acceptance of Touch according to Robot Appearance	Ad hoc items that cover the initiation and reception of touch with different robot types: Small robot Large robot Pet like robot Machinelike robot Humanlike robot	10 Items, separately regarded
Demography	Age, sex, graduation level, profession, industry/subject	

7.2.1.1 Touch Acceptance for Human and Robot Touch

Comparable to the interview study, acceptability of touch from a human stranger and a humanoid robot was assessed by means of body charts. In contrast to the interview study, participants this time had to rate how desirable touch to the respective body region was for them using a five point Likert-type scale, from 1 = "undesirable/unpleasant" to 5 = "desirable /pleasant", which was presented next to a reduced body chart (Figure 8). Based on the findings from the interview study, only 16 different regions were distinguished compared to the original differentiation into 24 areas (cf. Jourard, 1966). Primarily, the arm and face were no longer separated into individual parts (e.g., eyes, nose, mouth), but treated as a whole, because no strong variations between the parts were observed in study 1.

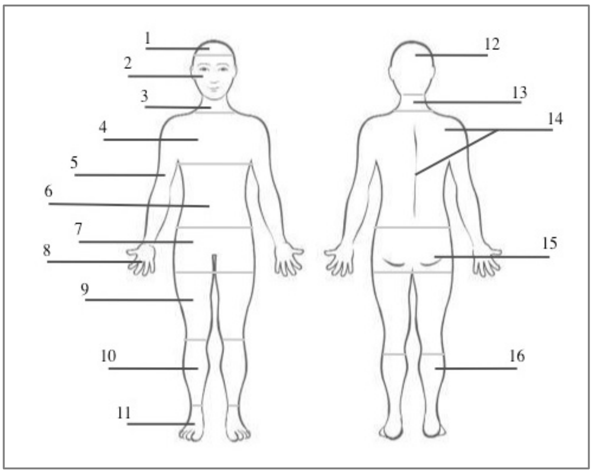


Figure 8. Self-created body chart with numbered regions.

The sixteen body regions were further labeled to ensure that participants understood which region was in question. The notations were: 1) forehead, 2) face, 3) neck/throat, 4) chest, 5) arm, 6) stomach, 7) genitals, 8) hand, 9) thigh/upper leg, 10) shank/lower leg, 11) foot, 12) occiput/back of the head, 13) nape/back of the neck, 14) shoulder/back, 15) buttocks, and 16) calf (cf. Figure 8).

With the aim of comparing touch from human strangers and humanoid robots, participants were asked to indicate how pleasant they rated touch, firstly from "a human stranger" and secondly (cf. order of questions Table 26), when imagining touch from "a humanoid robot".

7.2.1.2 Attitudes towards Touch

In order to assess the individuals' general attitudes towards interpersonal touch, scales which assess individual differences regarding touch approach and avoidance tendencies were considered. As these scales have yet to be applied in human-robot interactions, two different scales were chosen: the Touch Avoidance Measure (TAM; Andersen & Leibowitz, 1978) and the Need for Interpersonal Touch Scale (NFIPT; Nuszbaum, Voss, & Klauer, 2014). Although the titles of the scales sound different, the constituting items are quite similar.

The *Touch Avoidance Measure* consists of 18 items that are divided into two subscales: TAM 1 and TAM 2. TAM 1 measures same-sex touch avoidance and includes ten items, for instance "A hug from a same-sex friend is a true sign of friendship" or "I find it difficult to be touched by a member of my own sex" (reversed; *Cronbach's* α = .684). TAM 2 measures opposite-sex touch avoidance and consist of eight items, e.g., "I think it is vulgar when members of the opposite sex touch me" (reversed), or "I like it when members of the opposite sex touch me" (*Cronbach's* α = .795). The statements were rated on a five point Likert-type scale from 1= "fully disagree" to 5= "fully agree." Therefore, high ratings on both subscales resemble a touch approach tendency, while low ratings indicate a tendency to avoid interpersonal touch. Participants were on average touch approachers, with a slightly higher tendency to approach opposite-sex touch (TAM 2: M = 3.83, SD = 0.59) than same-sex touch (TAM 1: M = 3.49, SD = 0.56).

The *Need for Interpersonal Touch Scale* consists of 20 items that assess attitudes towards touch by means of descriptions of everyday situations that include touch between individuals such as "If someone shakes my hand in greeting, it is easier for me to judge the person" or "I generally avoid bodily contact with other individuals." The items are rated on a seven-point Likert-type scale from -3= "fully disagree" to +3= "fully agree" according to the original scale. However, for data analyses the ratings were transformed into positive scores from 1 to 7, whereby 1 represents -3 and 7 represents +3. Three negatively worded items were reversed-coded before a (mean) sum score was calculated for the overall scale (*Cronbach's* α = .866). Participants on average had a rather positive attitude towards interpersonal touch (high need, M = 4.95, SD = 0.75). Pearson product-moment correlations revealed that both scales are positively related to each other. Significant positive correlations between NFIPT and TAM 1 ($r(82) = .54$, $p < .001$), and NFIPT and TAM 2 ($r(82) = .41$, $p < .001$) were observed.

7.2.1.3 Technological Expertise

To measure the individuals' expertise with regard to dealing with technologies, additional self-created items were included which address the participants' knowledge, e.g., "I am computer literate", "I am robot literate", and their interest in technologies, e.g., "I am interested in new technologies", or "I can easily deal with new technologies (e.g., smartphones, tablet computers, etc.)." In total, six items were formulated, that were rated on a five-point Likert-type scale from 1= "fully disagree" to 5= "fully agree". The six items were collapsed into one sum score that demonstrated good reliability (*Cronbach's* α = .817). The average level of self-perceived expertise in dealing with technology was relatively high ($M = 3.30$, $SD = 0.66$).

7.2.1.4 Attitudes towards Robots

Attitudes towards robots were assessed by means of the 14-item version of the *Negative Attitudes toward Robots Scale* (NARS; Nomura & Kanda, 2004). The scale consists of three subscales that measure *negative attitudes towards situations of interactions with robots* (NARS S1, 6 items, *Cronbach's* α = .690), e.g., "I would feel very nervous just standing in front of a robot", *negative attitudes towards social influence of robots* (NARS S2, 5 items, *Cronbach's* α = .688) e.g., "I feel that in the future, society will be dominated by robots", and *negative attitudes towards emotions in interaction with robots* (NARS S3, 3 items, *Cronbach's* α = .708), for instance: "I feel comforted being with robots that have emotions (reversed)." Negative attitudes were on average moderately prevalent. The highest means are observable with regard to emotions in interactions with robots (NARS S3: $M = 3.23$, $SD = 0.91$) followed by lower mean ratings for the social influence of robots (NARS S2: $M = 2.91$, $SD = 0.78$) and the lowest means for negative attitudes with regard to interactions with robots (NARS S1: $M = 2.46$, $SD = 0.67$).

7.2.1.5 Acceptability of Human- and Robot-Initiated Touch

Since the interview study revealed differences in the desirability of HRT depending on who initiated the touch (human or robot), self-generated statements were built based on the comments from the interviews. As the reason or justification for touch was also solicited in the interviews, the statements further cover functional and affective reasons for human-initiated and robot-initiated touch. Participants were therefore asked to imagine owning a robot in the future with whom they might have physical contact.

For passive, human-initiated touch, six items were included, of which three resemble functional reasons ("I can imagine touching a robot out of curiosity or interest", "I can imagine touching a robot in order to transport it", and "I can imagine touching a robot in order to adjust something"), and three affective reasons ("I can imagine touching a robot in order to welcome it", "I can imagine stroking it", and "I can imagine touching a robot if it looks sad"). The single items were collapsed into a mean sum score for the acceptance of functional (*Cronbach's* α = .719) and affective human-initiated touch (*Cronbach's* α = .823). Two statements were also included that indicated difficulties in imagining HRT and the reasons for it: "In general, I cannot imagine touching a robot" (*M* = 1.39, *SD* = 0.73), "I cannot imagine a reason why I should touch a robot" (*M* = 2.40, *SD* = 1.35).

With regard to robot-initiated touch, participants were asked to imagine different situations in which they were touched by a robot. Therefore, six items were included, whereof four relate to functional reasons for touch ("A robot touches you after you have asked it to do so", "A robot touches you because you need its help", "A robot touches you to clean you", "A robot touches you to give you a massage"; *Cronbach's* α = .701), and two to rather personal/affective reasons ("A robot touches you to comfort you", "A robot touches you to cheer you up"; *Cronbach's* α = .885). The statements with regard to robot-initiated touch had to be rated on a five-point Likert-type scale that was labeled from 1= "unpleasant/unacceptable" to 5= "pleasant/acceptable." Finally, the item "A robot touches you for no identifiable reason" (*M* = 2.15, *SD* = 0.90) was included to allow for the acceptability of robot touch without a known reason.

7.2.1.6 Acceptance According to Robot Appearance

In order to validate the assumptions made about robot appearance, participants were asked to indicate how a robot which they would like to touch and be touched by, should look. Participants were therefore confronted with ten statements that related to the size (small, tall) and morphology (humanlike, machinelike, pet like) of the robot. Each appearance feature was included twice, once for human- and once for robot-initiated touch, e.g., “I would touch a small robot”, and “I would allow a small robot to touch me”, or “I would touch a humanlike robot”, and “I would allow a humanlike robot to touch me.” The items had to be rated on a five-point Likert-type scale from 1 = “disagree” to 5 = “fully agree”, and were regarded separately (see Results).

7.2.1.7 Demography

For demographical purposes, details of the participants’ age, sex, highest qualification, profession or subject of study, were collected.

Profession was assessed by means of the industry participants work in. They could choose between one of the following categories: society/law/education, media/journalism, medicine/health, economics, art/design/music, natural science/mathematics, engineering/technics, language/culture, IT/computer science, and other, with the option of typing in an additional industry. The industries and subjects were later categorized as technological-related (engineering/technics, IT/computer science, and natural science/mathematics) and non-related fields (society/law/education, economics, media/journalism, medicine/health, language/culture, and art/design/music).

7.2.2 Participants

Participants were recruited via social networking sites and advertisements on campus. In total $N = 84$ finished the survey, whereof $n = 51$ (61%) were female, and $n = 33$ (39%) male. They were aged between 18 and 58 years ($M = 22.44$, $SD = 6.21$). The majority of the participants (93%) were students. Most participants ($n = 77$) held a high-school diploma, while seven already had a university degree. Regarding the technology-relatedness of their field of study or profession, the majority (86%) reported working in a technology-related field (computer science, engineering), while the minority (14%) worked in a non-related sector such as the arts, journalism, or economy.

7.3 Results of the online survey

The collected data was analyzed with SPSS Statistics Version 22. Scales and subscales were calculated in advance of the analysis (see method section). Internal consistency of the summarized scales was adequate to good (.68 and higher, Clark & Watson, 1995). The following sections are dedicated to the hypotheses that were outlined at the beginning.

7.3.1 Touch Acceptance for Human and Robot Touch

With regard to the acceptance of touch to different body regions (H1), touch to the arm and hand were the most acceptable regions for touch by a human and robot toucher (Table 27). Least acceptable were touches to the genitals as well as touch to the buttocks by both human and robot touchers (Table 27).

Table 27. Mean ratings, standard deviations and test statistics for the comparison of human and robot touch.

Body Region	Human toucher		Robotic toucher		Paired-sample t-test		
	M	*SD*	*M*	*SD*	*t*	*df*	*p*
Forehead	1.95	0.98	2.32	1.04	-3.26	83	.002
Face	1.75	0.99	2.11	0.98	-2.83	83	.006
Neck/throat	1.74	1.13	1.85	0.93			n.s.
Chest	1.76	1.13	1.76	0.91			n.s.
Arm	3.26	0.91	3.13	0.99			n.s.
Stomach	2.02	1.08	1.93	0.97			n.s.
Genitals	1.40	0.88	1.20	0.53			n.s.
Hand	3.38	1.03	3.26	1.05			n.s.
Upper leg	1.98	1.03	2.01	0.96			n.s.
Lower leg	2.18	0.95	2.25	1.05			n.s.
Foot	1.86	0.91	2.19	1.14	-3.18	83	.002
Back of the head	2.44	1.28	2.29	1.09			n.s.
Back of the neck	2.02	1.25	1.87	1.11			n.s.
Shoulder/back	3.00	1.17	2.79	1.14			n.s.
Buttocks	1.46	0.80	1.49	0.78			n.s.
Calf	2.01	.912	2.10	.989			n.s.
Overall	2.14	0.71	2.16	0.70			n.s.

When comparing means for human and robot touchers to each body region separately (H1), significant differences for touch to the forehead, face and foot are visible (Table 27). The mean ratings for these body regions are in line with the direction of hypothesis H1, that touch from a robot was more acceptable than touch from a human stranger. However, the identified body regions did not resemble those named in H1 (legs, shoulder and back) according to the findings from the interview study (see Study 1), literary H1 was not supported. For the remaining body regions, no significant differences were remarkable.

7.3.2 HRT Acceptance According to the Function (Reason) of Touch

To test whether touch with a functional reason is more acceptable to human participants than affective touch, paired-sample t-tests were conducted for the statements that referred to human-initiated and robot-initiated touch. For touch by the human to the robot, a large effect was observable, which shows that touch with a functional purpose ($M = 4.70$, $SD = 0.49$) is significantly more acceptable to humans than emotional driven touch to a robot ($M = 3.32$, $SD = 1.23$); $t(83) = 10.63$, p < .001, $d = 1.41$. Also, with regard to robot-initiated touch to the human, functional justified touch was significantly more acceptable ($M = 3.35$, $SD = 0.74$) than affective touch ($M = 3.07$, $SD = 1.14$); $t(83) = 3.26$, p = .002. But this time, the effect was small according to Cohen (1988): $d = 0.27$. Overall, the results lend support to H2 that functional justified touch between humans and robots is more acceptable than affective touch.

7.3.3 HRT Acceptance According to the Direction of Touch

Besides the acceptance of varying touch intents (see H2), the direction of touch was further elaborated in the context of the same questions about the acceptance of HRT. A paired-samples t-test for human- and robot-initiated touch yielded significant differences within the functional as well as the affective touch dimension which supports hypothesis H3. Within the functional reasoned touches, human-initiated touch to the robot was rated as significantly more acceptable ($M = 4.70$, $SD = 0.49$) than robot-initiated touch ($M = 3.35$, $SD = 0.74$); $t(83) = 16.88$, $p < .001$, $d = 2.10$. The same pattern was observable for affective touch: human-initiated, affective touch was significantly more acceptable (*M* = 3.32, *SD* = 1.23) to the participants than robot-initiated, affective touch (*M* = 3.07, *SD* = 1.14); $t(83)$= 2.77, p = .007, *d* = 0.21. Both comparisons support hypothesis H3 that human-initiated touch is more acceptable than robot-initiated touch. Again, a large effect according to Cohen (1988) was observable within functional touch, whereas only a small effect was revealed for affective touch evaluations between human- and robot-initiated touch.

7.3.4 HRT Acceptance According to Robot Characteristics

In order to test the hypotheses concerning the size and appearance of a robot, questions about the acceptance of touch with a particular type of robot were asked twice, once for robot-initiated, and once for human-initiated touch.

With regard to the hypothesis that HRT with small robots is more acceptable than touch with tall robots (H4a), a paired-sample t-test was run for the acceptance of touch with small and tall robots, for robot-initiated as well as human-initiated touch. The results yielded a significant difference for both directions of touch (robot-initiated: $t(83) = 9.09$, $p < .001$, $d = 0.99$, and human-initiated: $t(83) = 6.95$, $p < .001$, $d = 0.81$), demonstrating that touch from (*M* = 4.07, *SD* = 0.88) and touch to a small robot (*M* = 4.21, *SD* = 0.81) is more acceptable than touch from (*M* = 2.93, *SD* = 1.22) and to a taller robot (*M* = 3.37, *SD* = 1.27). According to Cohen (1988), both comparisons represent large effects. The differences in the mean values further support hypothesis H4a which states that HRT with smaller robots is more easily accepted than touch with taller robots.

In order to compare pet like and humanlike appearances (H4b), a paired-sample t-test was conducted that contrasted the acceptability of touch (human- and robot-initiated) with pet like and humanlike robots. Agreeing with hypothesis H4b, a significant difference was observed for the acceptability of robot-initiated touch by pet like (*M* = 3.60, *SD* = 1.12) and humanlike robots (*M* = 3.27, *SD* = 1.26); $t(83) = 2.25$, $p = .027$, $d = 0.29$. The same was true for touch by the human of a pet like (*M* = 4.04, *SD* = 0.94) or humanlike robot (*M* = 3.71, *SD* = 1.13); $t(83) = 2.43$, $p = .017$, $d = 0.29$. In line with hypothesis H4b, touch with pet like robots was evaluated as more acceptable to human subjects than touch with humanlike robots. Both findings represent small effects.

Finally, the acceptance of touch with machinelike (mechanical) and humanlike robots (H4c) was compared by means of a paired-sample. Again, human- and robot-initiated touch was considered. The test revealed no significant differences in the acceptability of touch by mechanical (human-initiated: $M = 3.71$, $SD = 1.00$, robot-initiated: $M = 3.26$, $SD = 1.11$=) and humanlike (human-initiated: $M = 3.71$, $SD = 1.13$, robot-initiated: $M = 3.27$, $SD = 1.26$) appearing robots. Hence, H4c had to be rejected.

7.3.5 HRT Acceptance According to Person Characteristics

In order to test hypotheses H5, H6 and H7, hierarchical linear regression analyses were calculated to predict the acceptance of functional and emotional touch elicited by a human or a robot. In the first step, the participant's sex was entered to allow for its influence on touch acceptance. In the second step, general attitudes towards interpersonal touch (need for interpersonal touch: NFIPT, and touch avoidance: TAM1, TAM2) were entered as the relevant literature on interpersonal touch revealed that individual differences in touch comfort determine the desirability of touch. Finally, in the third step, technology related person characteristics as negative attitudes towards robots (NARS S1, S2, S3) and the individual's expertise regarding technologies were entered to see whether these characteristics were able to predict HRT acceptance. The procedure was repeated for all four dependent variables.

7.3.5.1 Acceptance of functional human-initiated touch

The first analysis should predict the acceptability of functional HRT that is directed from the human to a robot. The results of the multiple hierarchical regression (Table 28) revealed a significant positive relationship between opposite sex touch avoidance (TAM2) and the acceptance of functional human-initiated touch. As expected in H7, participants averse to opposite sex touch (low on TAM2) indicated a lower acceptance for functional touch of a robot, whereas touch approachers (high on TAM2) showed a higher acceptability.

Furthermore, the analysis yielded a significant negative relationship between negative attitudes towards the social influence of robots (NARS S2) and the acceptance of human-initiated touch with a functional purpose (Table 28). According to this, a higher negative attitude resulted in a lowered acceptance of functional human-initiated touch. As a consequence, support for H6 was visible for the subscale negative attitudes towards social influence with robots.

With regard to the influence of participants' expertise, no significant main effect was observable, contrary to H5.

Table 28. Multiple hierarchical regression analysis on the acceptance of functional human-initiated touch.

		Acceptance of functional human-initiated touch					
		B	*SE B*	*β*	*t*	*p*	*ANOVA*
Step 1	Constant	4.67	0.16		29.00	.000	$F(1, 82) = 0.05, p = .824$
	Sex	0.02	0.11	.03	0.22	.824	
Step 2	Constant	3.78	0.47		8.01	.000	$F(4, 79) = 1.97, p = .108$
	Sex	-0.03	0.12	-.03	-0.25	.806	
	NFIPT	-0.07	0.09	-.11	-0.77	.444	
	TAM1	0.12	0.11	.14	1.07	.290	
	TAM2	0.23	0.10	.29	2.27	.026	
Step 3	Constant	4.34	0.60		7.20	.000	$F(8, 75) = 2.95, p = .006$
	Sex	-0.07	0.12	-.08	-0.63	.532	
	NFIPT	-0.02	0.09	-.03	-0.24	.812	
	TAM1	0.10	0.11	.11	0.91	.367	
	TAM2	0.13	0.10	.16	1.32	.191	
	NARS S1	-0.19	0.09	-.25	-2.00	.049	
	NARS S2	0.00	0.08	.00	-0.03	.977	
	NARS S3	-0.06	0.07	-.12	-0.86	.393	
	Expertise	0.12	0.09	.16	1.34	.186	

Note: $R^2 = .00$ for Step 1, $\Delta R^2 = .09$ for Step 2 ($p = .059$), $\Delta R^2 = .15$ for Step 3 ($p = .009$)

7.3.5.2 Acceptance of functional robot-initiated touch

Next, a multiple hierarchical regression was conducted on the acceptance of functional HRT directed from a robot to a human. As depicted in Table 29, general attitudes towards touch (NFIPT, TAM1, TAM2) as well as negative attitudes (NARS S2) made it possible to predict the acceptance of functional touch initiated by a robot. A significant negative relationship between the participants' need for interpersonal touch (NFIPT) and the acceptance of functional robot-initiated touch, demonstrated that a higher need for interpersonal touch caused a lower acceptability for functional robot-initiated touch, contrary to H7. Instead, touch avoidance (TAM1, TAM2) was positively related to the acceptance of functional robot-initiated touch. The more the participants accepted same-and opposite-sex touch, the more likely they were to appreciate functional touch initiated by a robot. In conclusion, mixed support for H7 was found for functional robot-initiated touch acceptance.

Furthermore, a significant negative relationship between negative attitudes towards the social influence of robots (NARS S2) and the acceptance of functional robot-initiated touch indicated that higher negative attitudes resulted in lowered acceptance, as expected in H6.

Table 29. Multiple hierarchical regression analysis on the acceptance of functional robot-initiated touch.

		B	*SE B*	*β*	*t*	*p*	*ANOVA*
Step 1	Constant	3.07	0.24		12.58	.000	$F(1, 82) = 1.50, p = .224$
	Sex	0.20	0.17	.13	1.23	.224	
Step 2	Constant	1.80	0.69		2.62	.011	$F(4, 79) = 4.28, p = .003$
	Sex	0.11	0.17	.07	0.63	.528	
	NFIPT	-0.31	0.13	-.32	-2.40	.019	
	TAM1	0.43	0.16	.32	2.62	.010	
	TAM2	0.38	0.15	.31	2.59	.011	
Step 3	Constant	4.05	0.82		4.96	.000	$F(8, 75) = 6.37, p < .001$
	Sex	0.12	0.16	.08	0.78	.438	
	NFIPT	-0.29	0.12	-.30	-2.37	.021	
	TAM1	0.40	0.15	.30	2.76	.007	
	TAM2	0.27	0.14	.22	2.02	.047	
	NARS S1	-0.16	0.13	-.14	-1.28	.203	
	NARS S2	-0.23	0.10	-.24	-2.20	.031	
	NARS S3	-0.19	0.10	-.23	-1.87	.066	
	Expertise	-0.06	0.12	-.05	-0.51	.615	

Note: $R^2 = .02$ for Step 1, $\Delta R^2 = .16$ for Step 2 ($p = .003$), $\Delta R^2 = .23$ for Step 3 ($p < .001$)

7.3.5.3 Acceptance of affective human-initiated touch

Besides functional reasoned HRT, the analyses were also calculated with regard to affective reasoned touch initiated by a human (here) or robot (see next section). A multiple hierarchical regression analysis revealed that attitudes towards interpersonal touch did not significantly determine the acceptance of affective HRT as hypothesized in H7 (Table 30). However, a significant negative relationship was observable between participants' negative attitudes towards robots (NARS S1, NARS S3) and the acceptability of emotional touch initiated by a human (Table 30). High negative attitudes towards interactive situations with robots (NARS S1) and negative attitudes towards emotions in interaction with robots (NARS S3) diminished the acceptance for affective HRT, as hypothesized in H6.

Table 30. Multiple hierarchical regression analysis on the acceptance of affective human-initiated touch.

		B	*SE B*	*β*	*t*	*p*	*ANOVA*
Step 1	Constant	3.58	0.41		8.84	.000	$F(1, 82) = 0.48, p = .491$
	Sex	-0.19	0.28	-.08	-0.69	.491	
Step 2	Constant	1.48	1.22		1.21	.229	$F(4, 79) = 0.95, p = .438$
	Sex	-0.13	0.30	-.05	-0.42	.676	
	NFIPT	0.15	0.23	.09	0.64	.524	
	TAM1	0.22	0.29	.10	0.76	.448	
	TAM2	0.13	0.26	.06	0.50	.621	
Step 3	Constant	5.53	1.42		3.90	.000	$F(8, 75) = 4.83, p < .001$
	Sex	-0.10	0.28	-.04	-0.34	.733	
	NFIPT	0.16	0.22	.10	0.74	.463	
	TAM1	0.19	0.25	.09	0.77	.447	
	TAM2	-0.14	0.23	-.07	-0.60	.553	
	NARS S1	-0.51	0.22	-.28	-2.35	.021	
	NARS S2	-0.07	0.18	-.04	-0.36	.717	
	NARS S3	-0.47	0.17	-.34	-2.67	.009	
	Expertise	-0.02	0.21	-.01	-0.09	.926	

Note: $R^2 = .01$ for Step 1, $\Delta R^2 = .04$ for Step 2 ($p = .350$), $\Delta R^2 = .29$ for Step 3 ($p < .001$)

7.3.5.4 Acceptance of affective robot-initiated touch

Finally, a multiple hierarchical regression on the acceptance of emotional touch directed from a robot to a person was considered. As summarized in Table 31, only individual differences that were directly related to robots significantly predicted the acceptance of affective robot-initiated touch, namely negative attitudes to emotions on interacting with robots (NARS S3). The significant negative relationship between negative attitudes towards emotions on interacting with robots and the acceptance of emotion-driven touch from robots, revealed that high negative attitudes reduced the acceptance of affective robot-initiated touch. The finding supports H6.

Table 31. Multiple hierarchical regression analysis on the acceptance of affective robot-initiated touch.

		B	*SE B*	*β*	*t*	*p*	*ANOVA*
Step 1	Constant	3.01	0.38		7.93	.000	$F(1, 82) = 0.03, p = .871$
	Sex	0.04	0.26	.02	0.16	.871	
Step 2	Constant	-0.45	1.09		-0.42	.677	$F(4, 79) = 2.93, p = .026$
	Sex	0.15	0.27	.06	0.55	.585	
	NFIPT	0.17	0.21	.11	0.81	.420	
	TAM1	0.47	0.26	.23	1.81	.074	
	TAM2	0.22	0.23	.12	0.94	.349	
Step 3	Constant	3.88	1.19		3.26	.002	$F(8, 75) = 8.18, p < .001$
	Sex	0.13	0.23	.06	0.58	.565	
	NFIPT	0.13	0.18	.08	0.70	.489	
	TAM1	0.40	0.21	.19	1.86	.067	
	TAM2	-0.03	0.20	-.01	-0.14	.893	
	NARS S1	-0.20	0.18	-.12	-1.11	.269	
	NARS S2	-0.19	0.15	-.13	-1.27	.208	
	NARS S3	-0.57	0.15	-.46	-3.92	.000	
	Expertise	0.00	0.18	.00	0.01	.990	

Note: $R^2 = .00$ for Step 1, $\Delta R^2 = .13$ for Step 2 ($p = .012$), $\Delta R^2 = .34$ for Step 3 ($p < .001$).

In summary, the findings from the multiple hierarchical regression analyses demonstrated that knowledge of a person's attitude towards interpersonal touch (need for interpersonal touch, touch avoidance) enabled one to predict their acceptability of functional touch between a human and a robot (human- as well as robot-initiated). The relationship between touch avoidance and functional touch acceptability was positive as assumed in H7: a higher approach tendency for interpersonal touch also predicted more acceptance of functional HRT. But contrary to H7, a negative relationship between the participant's need for interpersonal touch and the acceptability of functional robot-initiated touch was revealed, showing that a higher need for touch evoked a lower acceptance of functional touch initiated by a robot.

With regard to the explanatory value of technology related person characteristics, the analyses showed that negative attitudes towards robots are a strong predictor for the acceptance of touch between humans and robots as hypothesized in H6. As previously reported, negative attitudes towards interactive situations with robots (NARS S1) had a significant influence on the acceptance of functional and affective touch from a human to a robot. Negative attitudes towards the social influence of robots (NARS S2) and negative attitudes towards emotions on interacting with robots (NARS S3), however, significantly predicted the acceptance of touch when initiated by a robot. In contrast, technological expertise in general did not affect the acceptance of HRT. Hence, H5 was rejected.

7.3.6 HRT acceptance and sex differences

As demonstrated in the multiple hierarchical regression analyses, the sex of the participant neither significantly predicted the acceptance of human-initiated touch (cf. Table 28 and 30), nor that of robot-initiated touch (Table 29 and 31), contrary to H8a and H8b. A further look at the means (Table 32) revealed that male participants' acceptance of functional robot-initiated touch was higher than females, whereas females showed a higher acceptance for affective human-initiated touch, which contradicts the hypothesized directions of H8a and H8b, although the differences were insignificant.

Table 32. Means and standard deviations for the acceptance of different directions and functions of HRT according to participant's sex.

	Human-initiated				Robot-initiated			
	Functional		Affective		Functional		Affective	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female (*n* = 51)	4.69	0.47	3.39	1.17	3.27	0.63	3.05	1.14
Male (*n* = 33)	4.72	0.52	3.20	1.31	3.48	0.89	3.09	1.16

7.4 Discussion of the findings from the acceptability questionnaire

7.4.1 Results summary and interpretation

The aim of the present study was the replication and validation of the findings from the qualitative interviews. Eight hypotheses were formulated concerning the acceptance of HRT. Knowledge of the general acceptability of HRT and the determinants which affect the acceptance is important, hence acceptability is a prerequisite for the emergence of positive effects. The following paragraphs summarize and interpret the results with respect to each hypothesis.

H1: Significant differences between human and robot touch to the forehead, face, and foot were revealed, whereby touch from a robot was evaluated as more acceptable than touch from a human. As was found in the interview study, individuals seem to have a lower threshold for robot touch compared to human touch, at least with regard to some body areas. No significant differences were observed where a body area was more accessible to human touch than to robot touch.

The findings again demonstrated that robot touch cannot be equated with touch from a human stranger (Jourard, 1966). The results showed that touch from a robot was preferable to touch from a human stranger. As revealed in Study 1, a lower inhibition threshold for robot touch can be explained by the fact that a robot is not a living creature with emotions or ulterior motives.

Although the direction of the finding is in line with the results from the interview study, the observed differences cover different body areas. While robot touch was rated as more acceptable than human touch to the forehead, face and foot in this study, the legs, shoulder and back were more accessible to robot touch in the interview study. In addition, robot touch to the forehead and foot was on average only acceptable under certain circumstances, indicated by the yellow coloring. With regard to the face, the findings from the interview study, however, demonstrated that touch from both humans and robots was rather unacceptable (average color red).

One reason for this difference could be the scaling. While interviewees were only able to choose one of three possible colors (red: not acceptable, yellow: under certain circumstances, green: acceptable) in the interview study, participants in the online survey were able to choose one out of five options from 1 = "unpleasant/unacceptable" to 5 = "pleasant/acceptable". In addition, interviewees colored 24 body regions, whereas participants in the survey could only evaluate 16 broader body parts.

H2: Significant differences for human- as well as robot-initiated touch demonstrated that functional touch is more acceptable to humans than affective touch with robots. This is in line with the findings of Chen et al. (2014, 2011) who reported higher enjoyment and understanding (the necessity of touch) after instrumental (functional) touch from a robot compared to affective touch, whereby the reason for touching was varied by using different verbal messages (instrumental: "I'm going to clean you", affective: "Everything will be ok"), while the touch gesture was the same.

Taken together, a clear preference for functional HRT can be recognized for human- as well as for robot-initiated touch. This preference could be a result of the expectations an individual might have with regard to robots and their purpose. According to the results, touch that serves a functional purpose seems to meet human expectations, whereas touch seen as an affective gesture by or to a robot does not. Future work should consider these expectations concerning touch in human-robot interaction in more detail, to clarify the link between expectation and the acceptance or evaluation of HRT (see Study 3). Furthermore, the results indicate that individuals are able to judge HRT based on textual statements and that the evaluations resemble findings from real human-robot interactions.

As regards the application of touch in human-robot interactions, it seems reasonable to recommend avoiding very affectionate forms of touch, especially if a human user is not yet familiar with a robot. By contrast, the present study, as well as the work of Chen and colleagues (Chen et al., 2014, 2011), demonstrated that humans are open to robot touch that serves a specific purpose. Hence, the application of HRT for functional reasons seems to be convertible without hesitation.

H3: Regarding the direction of HRT, the results clearly support hypothesis H3 that human-initiated touch is more acceptable than robot-initiated touch, which was also suggested by the findings from the interview study. Furthermore, the results are comparable with earlier findings from Major and Heslin (1982) which demonstrated that the initiation of touch is more favorably evaluated than the reception of touch. In addition, the present findings showed that the differences in the direction of touch are the same for functional as well as for affectively reasoned touch. For functional justified touch, especially, a large effect size gives support to the notion that touch from humans to robots is favored over touch from robots to humans. Nonetheless, mean values over 3.0 on a five-point scale indicate that participants did not refuse robot-initiated touch, but showed a medium to high acceptance, which is, however, lower than the acceptance of human-initiated touch.

Although the findings support the impressions that were gained from the interview study, to some extent they seem to conflict with earlier findings by Shiomi et al. (2016; see also Nakagawa et al., 2011), who reported a positive effect (higher motivation) of a robot's active touch (robot-initiated touch) compared to passive touch (human-initiated touch). If human-initiated touch is more acceptable than robot-initiated touch, and acceptability is a prerequisite for positive effects to emerge, a more positive reaction after passive rather than active touch should have been observable. Nevertheless, it should be remarked that the implementation of active and passive touch in the work of Nakagawa et al. (2011) was not equivalent to the differentiation into human- and robot-initiated touch as used in this thesis (and within this study). In the work of Nakagawa et al. (2011) participants first initiated touch to the robot (human-initiated touch) in all conditions, before the robot actively touched the participant (back) in the active touch condition. The authors also reacted to this "confusion" by renaming their experimental conditions "human-to-robot" and "robot-to-human after human touch" instead of passive and active touch in their recent publication (Shiomi et al., 2016).

Therefore, it seems as if the reciprocation of touch by the robot after a generally more accepted human-initiated touch to the robot, had a positive effect on the individual's motivation. Therefore, the comparison of reciprocal and non-reciprocal HRT should still be considered, as well as the comparison of different directions of HRT (see Study 3).

Alternatively, motivation, as a behavioral reaction to actual HRT in the work of Shiomi et al. (2016; see also Nakagawa et al., 2011), cannot automatically be compared to the general acceptability of HRT as collected in this study. Hence, it seems possible that the behavioral reaction to actual HRT (human- or robot-initiated) might differ from individuals' responses when generally asked about HRT.

H4 a-c: The findings concerning the robot's size and morphology support the conclusions from the interview study: Touch with small robots was more acceptable than touch with tall robots (H4a), and touch with pet like robots was more acceptable than touch with humanlike robots (H4b). In contrast to studies on robot approach distance (Syrdal, Dautenhahn, et al., 2008), no differences between machinelike and humanlike robots were observable in this questionnaire, which is why H4c was rejected. For the purpose of designing human-robot interactions that includes touch to increase human well-being, the size and morphology should be considered to elicit the most positive effects. According to the findings so far, small (at least smaller than the human partner) and pet like robots are favorably evaluated with regard to touch acceptance. As earlier work with pet like robots demonstrated, positive effects on human well-being can be elicited through physical interactions (human-initiated touch) with pet like robots (e.g., Shibata & Tanie, 2001; Wada

& Shibata, 2006; Wada, Shibata, Saito, Sakamoto, & Tanie, 2005). However, with regard to the question of whether humans might profit from touch that is actively initiated by a robot, the robot would need to have at least some humanlike body parts, such as arms and hands, to touch a human. When considering the mean values for the acceptance of touch with robots that differ in their morphology, it can be concluded that touch with humanlike and mechanical looking robots is also acceptable to humans because of the relative high means (values above 3.2).

Consequently, any future studies into the positive effects of robot touch should focus on smaller robots that can be humanoid to enable touch, but which should not look too humanlike.

H5-H8: With respect to the influence of human characteristics on the acceptability of HRT, the analyses revealed that attitudes towards interpersonal touch and negative attitudes towards robots were able to predict the acceptance of HRT, whereas the participants' sex and expertise did not. Hypotheses H5, H8a, and H8b were hence rejected.

As hypothesized in H6, individuals with higher negative attitudes towards robots showed a lower acceptance of HRT. To be precise, negative attitudes towards interactive situations with robots (NARS S1) predicted the acceptance of functional and affective human-initiated touch, while negative attitudes towards the social influence of robots (NARS S2) predicted the acceptance of functional robot-initiated touch, and negative attitudes towards emotions when interacting with robots (NARS S3) predicted the acceptance of affective touch initiated by a robot. This matches earlier findings on robot touch which showed that negative attitudes towards robots impact on the desirability of robot-initiated touch (Chen et al., 2014) as well as the evaluation of the robot as more or less machinelike after the touch has happened (Cramer et al., 2009).

Obviously, individuals with a negative attitude towards robots probably avoid close encounters with them, and thus avoid HRT. Since it can be assumed that robot touch to an individual who has a negative attitude towards robots, or who might even be afraid, could have more negative consequences than no touch at all, the inclusion of touch in human-robot interaction should be carefully considered. Knowledge about the user is of great importance to inform a robot about what is expected and accepted by a human. However, this information has not been easy to capture up to now, and hence is often missing in human-robot interaction.

Otherwise, earlier work on attitudes in human–robot interaction demonstrated that negative attitudes can be reduced through interaction with robots (Nomura, 2014). It seems possible that this might also be true with regard to robot touch. Individuals might become used to being exposed to robots and having physical contact with them. Although they might be surprised or afraid when they experience robot touch for the first time, their attitude might then change if the experience was not as bad as they expected it to be. Based on the knowledge that human-initiated touch and functional reasoned touch is more acceptable to human users, it is recommended integrating a familiarization phase for new users in which they first touch the robot, e.g., press a button to give tactile feedback.

Regarding H7, attitudes towards interpersonal touch (TAM and NFIPT) also had an impact on the acceptability of functional HRT. In line with hypothesis H7, individuals who avoid interpersonal touch are less likely to accept even functional reasoned touch with a robot, comparable with the results reported in Sorensen and Beatty (1988). Touch avoiders, therefore, show negative reactions to touch from humans and also consider robot touch undesirable.

In contrast, the need for interpersonal touch was negatively related to the acceptance of functional robot-initiated touch, which means that people with quite a positive attitude to interpersonal touch, are less accepting of functional robot-initiated touch, whereas individuals who do not appreciate interpersonal touch, welcome functional robot-initiated touch. Examination of the standardized beta values revealed that a negative relationship was observable for functional HRT, while a positive relationship was visible for affective HRT, although the effects were not significant. Thus, it seems reasonable to believe that a positive attitude towards touch facilitated the acceptance of touch with a robot, whereas functional reasoned touch is less desirable by people who appreciate interpersonal touch in a conversation, e.g., an embrace from a friend (Nuszbaum et al., 2014).

In conclusion, knowledge of an individual's attitudes towards robots and touch is of great importance with regard to human–robot interaction that may include touch, because it can be assumed that negative attitudes might cause a negative response if touch should occur, because of the lower acceptability of HRT which was revealed in the present survey. In addition, a touch that is undesirable to a human user might even cause more negative consequences than the absence of touch (Major & Heslin, 1982).

H8: In contradiction of hypotheses H8a and H8b, no significant differences in HRT acceptability between female and male participants were observable. This is contrary to earlier observations on interpersonal sex differences that showed that females have a more positive attitude towards same-sex touch, while males have a more positive attitude towards opposite-sex touch (Andersen & Leibowitz, 1978), and that females are in general more positive towards social touch than males are (e.g., Fisher, Rytting, & Heslin, 1976; Major & Heslin, 1982; Nguyen, Heslin, & Nguyen, 1975; Whitcher & Fisher, 1979).

On the one hand, this finding might suggest that sex differences from interpersonal literature cannot be transferred to touch in human-robot interactions. On the other hand, it is also possible that sex differences are irrelevant in interactions with robots, if robots are imagined as sexless (neuter) in contrast to interpersonal encounters where others are identified as of the same or opposite sex. In this case, sex would not be decisive in the acceptance of HRT at all.

In summary, the results of this online survey support the assumptions that were gathered from the qualitative interviews. Apart from specific body areas (H1) and sex differences (H8), all hypotheses that were based on the findings from the interview study found at least partial support:

- Although H1 was not supported in respect of the same body areas as in the interview study, findings from the survey also supported the view that robot touch to some body areas (here: the forehead, face and foot region) is more acceptable than human touch to the same areas.
- Functional HRT is more acceptable than affective HRT, regardless of the touch direction (H2).

- Human-initiated touch of a robot is accepted more easily than robot-initiated touch (H3), although high mean ratings indicated a generally moderate acceptance for both forms of HRT.
- Touch with smaller robots was favored over larger robots (H4a), and pet like robots are more acceptable for touching than humanlike robots (H4b), but no difference between machinelike and humanlike robots was observed, contradicting H4c.
- Person characteristics influence the acceptability of HRT: the lower the negative feelings towards robots (H6) and interpersonal touch (H7), the higher the acceptance for HRT. Against H5, general technological expertise did not significantly predict HRT acceptance.
- Sex differences with regard to the acceptance of HRT were not observed as expected (contradicting H8).

Consequently, the replication and validation of the findings from the interview study can be regarded as successful with minor exceptions.

7.4.2 Limitations and Outlook

Nonetheless, some limitations of this empirical study should be noted. Firstly, there was no control over the circumstances under which participants completed the survey as it was done online. Secondly, the sample size could have been larger and the ratio of male and female participants could have been more balanced.

Also, the fact that the participants were merely invited to imagine touch with robots is open to criticism. Individuals might have quite differing ideas when thinking of a robot, although they were instructed to think of humanoid robots (except when they were asked about different kinds of robots). No picture or video of a robot was included in this study to gain an insight into the acceptability irrespective of the robot's specifics. In order to receive information about the kind of robot participants imagined, open questions like "Please describe the robot you imagine in as much detail as possible. What does it look like? What abilities does it have?" could be included in future survey studies.

However, the results from the survey resemble those from Study 1, where the interviewees were confronted with pictures of different robots.

Moreover, the knowledge gained through a purely text based survey exploring peoples' acceptance of a sensitive topic such as touch with robots can be called into question. Besides the missing information about a specific robot type, it could be suggested that participants do not have informed opinions about HRT. Hence they might have answered the questions according to their stereotypical views on robots, or else they might have answered in a socially desirable manner, e.g., indicating that affective contact with an inanimate object such as a robot is inappropriate. Social desirability should, therefore, be lower in the anonymous online survey environment compared to the face-to-face interviews. In addition, a stereotypical answer could also reveal information about the abstract ideas humans might have about HRT.

To conclude, the present study revealed that the acceptance of HRT varies according to the context, or reason for touch (here: functional and affective reasons), the direction of touch (here: human-initiated and robot-initiated), as well as the characteristics of the robot (morphology and size) and the human (attitudes towards robots and touch). The participants' sex and expertise, on the other hand, did not play a role in the acceptance of HRT.

Next, it should be examined how these factors influence the perception, interpretation and evaluation of HRT presented in photographs as in the interview study. Therefore, an online experiment was implemented that combined stimulus pictures from the interview study with vignettes that predetermined the context in which HRT happened.

8 Study 3: *Online Experiment on the Influence of Touch Expectancies and Context on the Interpretation and Evaluation of HRT*

The question of how observers perceive, interpret, and evaluate HRT has already been qualitatively approached in Study 1. However, inferential conclusions about the interpretation and evaluation were not possible on the basis of the data. A further criticism is that contextual information required to judge the touch forms depicted in photographs was missing. Hence, a question arises as to whether contextual factors influence the perception, interpretation, and evaluation of HRT. For this purpose, an online experiment was planned to ensure a controlled comparison of the perception, interpretation, and evaluation of different forms of HRT, based on photographs in different contexts, and with a larger sample.

Since Study 1 revealed that the forms of HRT can be distinguished with regard to their dimensions: the direction and intimacy of touch (where the direction could either be human- or robot-initiated or reciprocal, and the degree of intimacy could be either formal or intimate), the impact of touch direction and intimacy is the focus of the present study.

The most reliable method for a controlled variation in forms of HRT with varying directions and degrees of intimacy, in combination with diverse contextual information, was (again) considered to be a choice of photographs requiring evaluation from an observer perspective. Moreover, the major aim of the present study was the clarification of the underlying process operating when individuals are confronted with HRT from an observational perspective. Finally, the present study aimed to test whether related theories on interpersonal touch apply to touch in HRI.

The following sections thus address the impact of contextual variables (8.1), the influence of different touch forms according to their direction and degree of intimacy (8.2), and the explanatory value of expectancies in the HRT evaluation process (8.3).

8.1 Context and Functions of Touch

Depending on the interaction context, touch serves different functions. For instance, a doctor may touch a patient to examine a specific part of the body, a hairdresser touches a customer to cut her or his hair, and parents may touch their children to calm them. A major distinction into functional and affective contexts and functions can be drawn here, where touch serves either a task-related function, or is used to convey affection and understanding. This distinction is further transferable to earlier categorizations of touch, according to its meanings and functions from interpersonal literature. For example, Heslin's functions of touch (see Heslin & Alper, 1983) can be regarded as rather affective (social/polite, friendship/warmth, love/intimacy, sexual arousal), or functional (functional/professional). Also, the forms and meanings of touch revealed by Jones and Yarbrough (1985) can be separated into affective forms of touch (positive affect, playful, ritualistic, and hybrid touches) that carry affective meanings (e.g., support, appreciation, inclusion, affection, and sexual desire), and functional touches (control and task-related touches) with instrumental meanings (e.g., compliance, attention-getting, or task accomplishment).

The impact of contextual variables on the effects of interpersonal touch was studied by Nilsen and Vrana (1998). In their experiment, they tested the effect of functional and affective reasoned touch on cardiovascular responses. Participants were touched a first time to take their pulse, and a second time without a functional reason, but together with an apology from the experimenter for being late (social/affective touch). Their findings revealed that a decrease in the cardiovascular response was observable after the functional touch, as has been suggested in other related studies on the positive impact of touch on cardiovascular response. However, after the social touch, an increase in blood pressure and larger changes in heart rate were measured, which indicated a negative physiological reaction in comparison with the functional touch. The authors concluded that social touch might have been inappropriate in a professional laboratory setting, as it conveys intimacy and social control. Hence, in a professional context, functional touch seems to be preferable over social touch. Furthermore, the findings suggest that a matching between touch form and context is reasonable.

Sussmann and Rosenfeld (1978) supposed that touch from a stranger could generally be perceived as intrusive if no justification is given. To test this assumption, they compared justified and unjustified touch in an experimental study. The findings revealed that touch that was justified in advance resulted in higher participant performance (i.e., decrements in performance in a digit symbol substitution test) and likability ratings for the toucher, than unjustified touch (in this example males were touched by females during task performance). The addition of a justification for touch may therefore help to overcome a general tendency to reject touch from strangers.

In HRI, the influence of the function of touch has so far only been investigated by Chen, King, Thomaz, and Kemp (2011; Chen et al., 2014). They manipulated the reason for a robot-initiated touch to the arm of a (human) participant in a clinical environment. Their findings suggest that instrumentally reasoned touch was perceived as significantly more necessary, enjoyable, and less arousing, than affective touch. Furthermore, when asked afterwards, participants in the affective touch condition indicated significantly more often that they had preferred the robot not to touch them at all. However, the evaluation of the robot touch was not affected by the given reason for touch.

In summary, in professional settings (e.g., a laboratory or clinical environment), a preference for functional touch over affective touch was demonstrated in interpersonal as well as human–robot interaction research. The denial of affective touch in professional settings suggests that meanings such as affection, intimacy, or sexual desire, which are related to affective touch (cf. Jones & Yarbrough, 1985), are undesirable in these contexts (cf. Nilsen & Vrana, 1998). However, it remains unclear whether affective touch between a human and a robot would be appreciated in non-professional circumstances.

The functions of touch and the contexts in which touch occurs can be subdivided into functional and affective ones on a meta-level. It was assumed that contextual information alters how observers define and interpret the relationship. Functional relationship definitions of the human-robot relationship were revealed as being unique to HRI (cf. Study 1). For example, interviewees described the relationship based on functional reasons as a test of functions, or as being driven by the curiosity of the human. As no contextual information was given in Study 1, it remained unclear whether a more concrete scenario would impact on how observers define the relationship between humans and robots touching each other. It seemed obvious to hypothesize that functional relationship definitions will be more pronounced if the interaction context is functional, whereas less functional definitions will be visible in an affective context.

H1: Observers of HRT assign more functional relationship definitions to a human-robot relationship if touch happens in a functional, rather than in an affective context.

Since it has been demonstrated that affective touch is accompanied by meanings of affection and inclusion (Jones & Yarbrough, 1985), it is furthermore hypothesized that more intimate interpretations are assigned to touch that happens in an affective context of HRT in comparison with a functional context.

H2: Observers of HRT perceive (a) more intimacy and (b) less formality between a human and a robot if touch happens in an affective rather than in a functional context.

Moreover, empirical studies on interpersonal interactions (Nilsen & Vrana, 1998) and HRI (Chen, King, Thomaz, & Kemp, 2014, 2011), as well as the findings from the survey (Study 2), have revealed that functional touch is more desirable than affective touch, even with robots. This is potentially because affective touch is unjustified and undesirable in professional settings with strangers. As robots can be assumed to be strangers to humans at an initial encounter, and affective exchange with a machine might be less expected and less desired than interpersonal touch, it is assumed that functional HRT is preferred over affective HRT.

H3: Observers of HRT evaluate the overall interaction more favorably if touch happens in a functional rather than in an affective context.

8.2 The Influence of the Direction and Intimacy of HRT

How the form of HRT influences its interpretation and evaluation is of interest, aside from the influence of contextual circumstances.

The findings from Study 1 indicated that different forms of human-robot touch are perceived, interpreted, and evaluated by observers in diverse ways, comparable to earlier findings on interpersonal contexts that revealed that touch forms elicited different relational interpretations in observers (Burgoon, 1991; Burgoon & Walther, 1990). Particularly, distinctions between different directions of touch (human-initiated, robot-initiated, and reciprocal touch) and varying degrees of intimacy (formal versus intimate) were observed. However, although the descriptive results (mean values) depicted differences, significance testing was not possible because of the small sample size in Study 1.

For this reason, both reciprocal and non-reciprocal touch forms were included in the present experiment, which was designed to replicate and quantify the findings from the interview study.

Against the background of Study 1, the statements from the interviewees revealed that the human-robot relationship could be differentiated into functional and personal relational definitions. Furthermore, it has been revealed that personal interpretations of touch are more strongly affected by the intimacy of the touch form, than by its direction: intimate touch forms were more often described as personal relationships than formal touch forms. In contrast, functional interpretations were more often affected by the direction: non-reciprocal touch was more frequently categorized as a functional relationship than reciprocal touch. In accordance, it is hypothesized that:

> H4: Observers of HRT assign more functional relationship definitions to the human-robot relationship if human-initiated or robot-initiated touch (non-reciprocal touch) is presented, rather than reciprocal touch.

Relational closeness can be further affected by the form of touch. As Heslin and Alper (1983) pointed out, relational closeness is crucial for the desirability and perceived pleasantness of intimate touch in interpersonal interactions. The higher the intimacy of a relationship, the more pleasant and desired is intimate touch, but if the relationship is not close or intimate, intimate touch is discomforting. For HRT, the perceived relational closeness may therefore also be an important factor that should be considered with respect to affective HRT. Furthermore, Kleinke, Meeker, and Fong, (1974) demonstrated that observers of touch between couples came to the assumption that they were more loving, i.e., more close, than couples that did not touch each other. Hence, it is assumed that the presence of touch in HRI leads to higher perceived closeness between a human and a robot.

Besides relational closeness, the meanings that are perceived to be conveyed by touch have been addressed in interpersonal touch research. For example, Burgoon (1991; see also Burgoon & Walther, 1990) demonstrated that different touch forms were perceived to convey distinct relational meanings, like intimacy, dominance, and formality. Their investigations revealed that reciprocal and highly intimate forms of touch, such as handholding and touches to the face, were perceived to convey more affection and composure than less intimate non-reciprocal forms of touch (like arm touch), while least affection but most formality was perceived to be conveyed through a handshake. With regard to HRT, the relational descriptions of the human-robot relationship from Study 1 demonstrated that intimate forms of HRT (embrace, touch to the face) were also perceived as conveying more intimacy (close/intimate) than formal forms of HRT (handshake, touch to the arm). The relational formality theme was instead only addressed for pictures that showed a formal handshake touch. According to this background it was hypothesized that:

> H5: Observers of HRT perceive (a) more intimacy, and (b) less formality between a human and a robot if the form of touch is intimate rather than formal.

With regard to the direction of touch, Henley (Henley, 1973, 1977, 2012) assumed that reciprocal touches are associated with closeness and solidarity, whereas non-reciprocal touches convey status and power. Correspondingly, when robot-initiated touch was presented in Study 1, dominance on the side of the robot was reported to be more than when human-initiated or reciprocal touch was depicted. Thus, it is further hypothesized for HRT that non-reciprocal touch conveys more dominance than reciprocal touch, and that robot-initiated touch conveys greater superiority of the robot than human-initiated touch.

> H6: Observers of HRT perceive (a) more intimacy and (b) less formality between a human and a robot if the form of touch is reciprocal rather than human- or robot-initiated (non-reciprocal).
>
> H6c: Observers of HRT perceive more dominance of the robot if robot-initiated touch is presented, rather than human-initiated or reciprocal touch.

Finally, the appraisal of HRT had already been revealed as being influenced by the reciprocity of touch. For instance, the findings of Burgoon and Walther (1990) suggest that reciprocal touch forms (handholding, handshake) are more favorably evaluated by observers than non-reciprocal touch forms (face touch, arm touch). Furthermore, Major and Heslin (1982) demonstrated that observers of touch evaluate the initiator of a touch more favorably with respect to status, assertiveness, expressiveness, and warmth, than the recipient of the touch. Consequently, it can be supposed that situations/pictures that depict a person as the initiator of touch are more favorably evaluated than situations in which a person is the recipient of touch from a robot. The findings from Study 1 support this assumption: interviewees' rated the stimulus pictures more favorably if human-initiated touch was depicted followed by reciprocal and robot-initiated touch. In accord, it is hypothesized for the impact of touch direction on the evaluation that:

> H7: Observers of HRT evaluate the human–robot interaction more favorably when human-initiated touch is presented than when reciprocal touch is presented, which is still more favorably evaluated than robot-initiated touch.

Beyond this, it is of interest as to whether combinations of the direction and intimacy of HRT (e.g., formal versus intimate reciprocal HRT) affect the interpretation and evaluation of HRT. Thus, a research question with regard to interaction effects was formulated:

> RQ1: Does the interpretation and evaluation of HRT vary systematically according to the combinations of touch direction and intimacy?

8.3 Evaluation of different touch forms according to the context of HRT

Earlier work on touch in HRI demonstrated that contextual factors influence the desirability of touch from a robot (Chen et al., 2014, 2011). The work of Chen and colleagues revealed that affectively judged touch from a robot in a professional HRI scenario was less desirable than functionally motivated robot-initiated touch. On this basis, it can be derived that in a professional context (functional, non-affective context) intimate HRT is less desirable than non-intimate HRT. Hence, it can be assumed that:

> H8: Observers of HRT will evaluate formal forms of touch more favorably than intimate forms of touch if the context is functional.

However, since HRT has not been systematically investigated in affective interaction contexts, it remains open as to whether the evaluation turns out differently if the interaction context is non-professional. Therefore, a research question was formulated for non-professional HRT contexts.

> RQ2: Is intimate HRT in a non-professional context more desirable than formal HRT?

8.4 The Explanatory Value of Touch Expectations

Building on the results of the prior studies (Study 1 and 2), it is assumed that the acceptability and evaluation of HRT depend on the touch form, robot appearance, individual differences, and contextual factors (see above). All the factors together form the human users' expectations, which can further impact the evaluation of HRT.

According to Heslin and Alper (1983), a violation of one's touch expectancies can result in negative relational consequences. Hence, an unexpected touch from a robot might cause rejection and reduce the acceptance of the robot. However, Burgoon and Hale (1988) demonstrated that violations of expectation can also cause positive outcomes, particularly when a behavior exceeds one's expectations, and is thus positively evaluated.

As HRT has already been revealed as unexpected in comparison with touchless interactions, it seems reasonable to test how expectations and violations of them might predict individual reactions to HRT. This process was formalized in the *Nonverbal Expectancy Violations Model* by Burgoon and Hale (1988) for interpersonal interactions. For a broader understanding, the model and related work on touch expectations are outlined in the following section.

8.4.1 Expectancy Violations Theory

Expectancy violations theory was first developed by Judee Burgoon and colleagues when investigating the influence of distancing expectations (Burgoon, 1978, 1983; Burgoon & Jones, 1976). The theory assumes that individuals hold expectations about the distance between themselves and other people, and that violations of these expectations induce arousal, which in turn leads to a positive or negative evaluation of the behavior, depending on the characteristics of the violator (e.g., attractive versus unattractive), the direction and extremity of the violation (e.g., closer or further than expected), and the context in which the violation takes place (e.g., crowded concert hall versus empty waiting room; Burgoon, 1983; Hale & Burgoon, 1984). Later on, the model was broadened to a variety of nonverbal behaviors, including touch (e.g., Burgoon, Newton, Walther, & Baesler, 1989; Burgoon et al., 1992; Burgoon & Walther, 1990), and was formalized as the *nonverbal expectancy violations model* in Burgoon and Hale (1988).

Theoretical assumptions

According to the *expectancy violations theory* (Burgoon & Hale, 1988, see also Burgoon & Jones, 1976; Burgoon, 1978; Burgoon, 1983), individuals have designated expectations about their interaction partners and their behaviors. These expectations are influenced by social norms (e.g., how to behave in church; you are not free to hug higher status persons such as your professor), earlier experiences with a person (repeated exposure in a television series to the actor David Hasselhoff eating a burger while lying on the floor makes the behavior less unexpected; repeated exposure to the Hoff talking to his car K.I.T.T. makes the behavior expectable, although talking to cars was not normal behavior in the nineties), and idiosyncrasies of a person (e.g., a person who initially embraces everyone). Expectations about strangers are generally based on social norms, while expectations about friends are rather determined by experience and idiosyncratic knowledge.

The model further distinguishes factors that determine expectations, namely: characteristics of the communicator, the relationship, and the context.

Communicator characteristics. Expectations about a specific other are influenced by characteristics of that person, such as age, sex, personality, appearance, and reputation.

For instance, one would be more likely to expect a formal handshake from an adult than from a child, or expect touch from a higher status partner rather than a lower status one (cf. Henley, 1973, 1977).

Relational Characteristics. The relationship between the recipient of touch and the communicator is also important. Earlier joint experiences (*prior history*), the degree of acquaintance, differences in status (*status inequality*), liking, and attraction, all influence expectancies (Burgoon & Hale, 1988).

Context. Lastly, the interaction context is also included in the model as an influential factor. Comparable to the above discussion on functional and affective contexts for touch (see Chapter 8.1), Burgoon and Hale (1988) mentioned communicative functions of a nonverbal behavior (e.g., touch to get attention), the formality of the situation (e.g., professional meeting), task-relatedness of a behavior (e.g., instrumental touch by a doctor to examine the patient), and environmental constraints (e.g., reduced proximity due to restricted space at a concert) as context variables.

All variables together form expectations about nonverbal behaviors that could emerge during interpersonal communication. How a nonverbal behavior of the opponent is evaluated in *expectancy violation theory* depends on an appraisal process that is outlined in the next section.

8.4.2 Appraisal process

According to the expectancy violation theory, an interaction outcome can be determined by an appraisal process, as depicted in Figure 9. If an enacted behavior violates the expectations of the perceiver, arousal emerges, which then guides the attention away from the content of the conversation (or interaction), and towards the relational level (Hale & Burgoon, 1984). In such cases, whether the behavior is positively or negatively evaluated depends mainly on the interpretation of the violation. For instance, if a fan meets his/her favorite actor and the actor embraces her or him, the gesture may be evaluated exceedingly positively, because an embrace from a famous film star, whom one has never met in person before, is an unexpected behavior. In this example, the expectations would be exceeded and a **positive violation of expectations** would occur, which in turn would lead to a positive evaluation and outcome. Otherwise, negative violations happen when a behavior that is expected (e.g., an embrace from a friend) is absent. Here the expectations are unsatisfied, and a **negative violation of expectations** happens, which results in a negative evaluation of the behavior.

However, if expectations are confirmed, no change in arousal happens, and the evaluation should therefore be less pronounced than after a violation (see below). A variable that was named *communicator reward valence* by Burgoon and Hale (1988) has an effect on the evaluation above the conformity or violation of expected behavior and its interpretation.

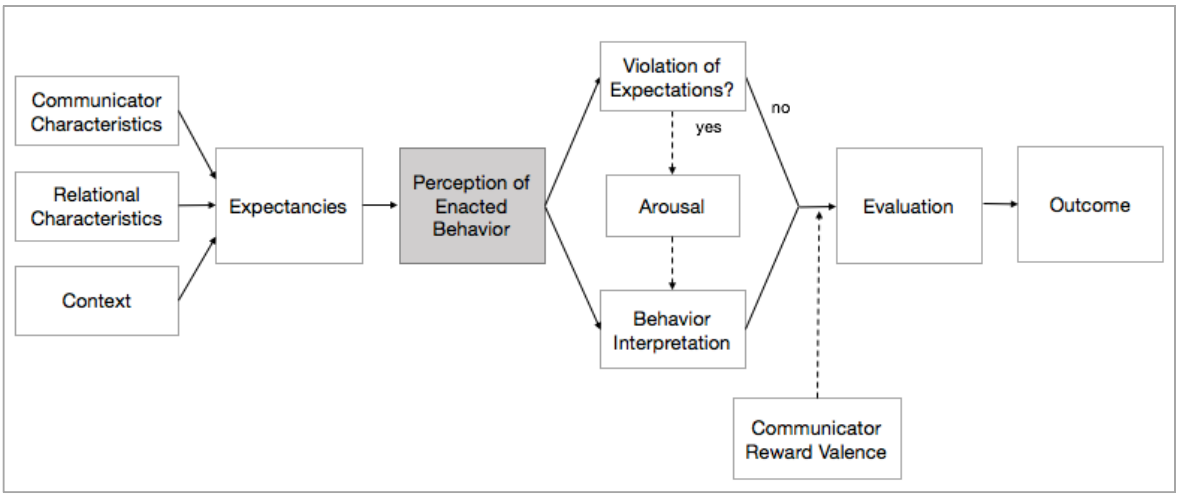


Figure 9. Graphical representation of the appraisal process based on Expectancy Violations Theory. (The model was self-crafted as a simplified version of the visualization depicted in Burgoon and Hale, 1988).

The *communicator reward valence* is a function of all the static characteristics of the communicator and the relationship (see above, e.g., physical attractiveness, status, reputation, anticipated future interaction), and the dynamic (spontaneous) behaviors that emerge during an interaction (e.g., giving constructive feedback, making compliments, or facilitating access to resources), which make the other an interaction partner worth interacting with (Burgoon & Hale, 1988; Burgoon & Jones, 1976). For example, the evaluation of a touch to the forearm could vary depending on the attractiveness of the communicating partner. Touch from an attractive partner might be interpreted as a sign of affection, which is desirable, while touch from an unattractive communicator might be interpreted as intrusive, and thus less favorable. However, if the communicator of touch is physically unattractive, but has access to specific resources, the communicator reward would still be high, and the evaluation would hence be more positive.

Burgoon and colleagues experimentally varied the communicator reward in several studies to demonstrate its impact on the appraisal process. Overall, mixed support for the role of the communicator reward has been reported in earlier work. In one study (Burgoon & Hale, 1988), reward was operationalized by means of the degree of the acquaintanceship between two interaction partners (friend = high reward versus stranger = low reward). In the experiment, it was revealed that friends that increased immediacy (e.g., increased proximity) were rated as more attractive than strangers that did the same, but no differences between high- and low-rewarding interaction partners were observed with regard to the perceived credibility, which was always higher when immediacy was increased as opposed to decreased.

Another manipulation of communicator reward was reported in Burgoon and Walther (1990) as well as in Burgoon et al. (1992). In both studies, reward was manipulated through the physical attractiveness and status of a confederate. The results revealed that intimate forms of touch from a high-rewarding communicator (highly attractive and high in status) were more expected and better evaluated according to observer ratings, whereas formal touches (e.g., handshake) were more expected and more favorably evaluated from a low-rewarding communicator (Burgoon & Walther, 1990). Furthermore, in an actual interaction, Burgoon et al. (1992) revealed that touches to the shoulder and forearm from a high-rewarding communicator conveyed more affection, and were more positively evaluated than touches from a low-rewarding communicator, although they were less expected. This supports the assumption that a violation from a high-rewarding communicator could even result in a favorable evaluation, inasmuch as the interpretation of the behavior is positively valenced.

In the appraisal process, the evaluation of the observed behavior leads to the decision on the final reaction (outcome, Figure 9). If the evaluation is positive, the outcome will also be positive (e.g., reciprocity). In turn, if the evaluation of a behavior is negative, it will result in a negative interaction outcome (e.g., rejection). The model further assumes that violations lead to more pronounced evaluations and outcomes (see above) than conformity to expectations. Hence, because of exceeded expectations, a positive violation of expectations should evoke a more positive evaluation and outcome than conformity to expectations, while a negative violation causes more negative evaluations and outcomes than conformity to expectations (Burgoon & Hale, 1988).

8.4.2 Touch Expectations in Human–Robot Interaction

In the realm of human–robot interaction, it is somewhat unclear whether touch constitutes an expected behavior or a violation of expectations. On the one hand, it can be suspected that the physical body of a robot might provoke expectations about a physical or tactile interaction and afford the need to touch the robot as an object of interest (cf. Jung & Lee, 2004; Lee, Jung, Kim, & Kim, 2006), which would be fulfilled in an interaction that includes touch. On the other hand, intimate forms of touch between a human and robot, and touch that is initiated by a robot, are currently rather unexpected, as the findings from Studies 1 and 2 demonstrated. With regard to the question as to whether robot touch can contribute to human well-being, it is thus of particular interest to know if robot touch can elicit positive reactions, even though some forms of HRT are unexpected. Thus, expectancy violations theory seems to be a promising framework for the prediction of reactions to a behavior (here: robot touch) that is unexpected, but that can still cause positive reactions.

When reconsidering the touch evaluation process (Figure 9) for human–robot interaction, it can be assumed that similar variables to those found in interpersonal interactions are decisive. First of all, it is presumed that individuals also have expectancies regarding robots and their behaviors. Therefore, research on expectations regarding robots is examined in the next paragraph.

8.4.3 Expectations with regard to robots' appearance and application fields

Independent to touch expectancies, Ray, Mondada, and Siegwart (2008) found that individuals have expectations about designated tasks that robots should execute in the future. Their analysis revealed that most individuals expect robots for domestic use to do ordinary cleaning tasks, and less creative and social tasks such as cooking or baby-sitting. Furthermore, they found that domestic robots are expected to look like big or small machines, and less like creatures, humans, or animals, whereof a small machine-like appearance was said to be the most preferred form for a domestic robot.

Similarly, Dautenhahn, Woods, and Kaouri (2005) studied the preferred roles and tasks for robot companions. Their data indicated that humans expect future robot companions to fulfill the role of an assistant, machine, or servant, but not that of a mate or friend (below 20%). In line with Ray et al. (2008), participants preferred robot companions for practical applications such as vacuuming, security, entertainment, and gardening. Childcare, however, was the least preferred task for a robot companion at home (10%).

Taken together, earlier work on humans' expectations on the applications for domestic and companion robots demonstrated that individuals expect robots to fulfill functional, rather than socio-emotional tasks. These findings lend further support to the notion that humans will expect HRT in a functional, rather than in an affective context (cf. H4), if they expect touch in human–robot interaction at all.

8.4.4 Expectations with regard to the interaction with robots

Spence, Westerman, Edwards, and Edwards (2014) investigated expectations on communication with a robot in comparison with human–human communication. They instructed participants to anticipate a conversation with another human or a robot, and then asked the participants what they expected the communication to be like. Their findings demonstrated that individuals have distinct expectations: less predictability, liking, and social presence was expected for a robot interaction than for one with a human partner. Thus, if general expectations on social capabilities in interactions with a robot are lower than those for interacting human partners, it can be assumed that humans do not expect a robot to perform an affective touch. However, even if the inclusion of touch in human–robot interaction constitutes a violation of expectations, it remains unclear whether the behavior is desirable or not; in the terms of EVT, whether it is a positive or negative violation. This is crucial, because although a violation has the potential to evoke a more positive reaction to touch than conformity to expectations, it could also evoke an even more pronounced negative effect if the violation is negatively evaluated (negative expectancy violation; Burgoon & Hale, 1988).

Violated expectations in uman–robot interaction

Prior work has already addressed the problem of unmet expectations in interactions with robots. Violations of expectations were denoted as a gap between expectations and the actual interaction, e.g., the 'adaptation gap' (Komatsu, Kurosawa, & Yamada, 2012), or 'expectations gap' (Kwon, Jung, & Knepper, 2016).

In a similar manner to EVT, Komatsu et al. (2012) distinguish between positive and negative adaptation gaps: a positive adaptation gap emerges if the actual functions of a robot exceed the expected ones, but a negative adaptation gap evolves if the expected functions are higher than the actual ones (cf. positive and negative expectancy violation in EVT). The authors assume that a negative adaptation gap causes disappointment and reduces trust in a robot (or agent), while a positive adaptation gap leads to satisfaction and increases trust in a robot.

To test their assumptions, Komatsu et al. (2012) conducted an experiment in which participants had to play a coin game with a Lego Mindstorm robot (not humanoid). In one experimental group, expectations of the robot's capabilities were set low by telling the participants that the accuracy of the robot's detection of coins was only 10%. In the other condition, expectations were set high by telling participants that the detection was successful in 90% of cases. Compliance with the robot's suggestions was then considered as a dependent measure. The results showed that participants accepted the robot's suggestions more often in the low expectancy group than in the high expectancy one, supporting the assumption that adaptation gaps in HRI affect participants' behavior towards a robot. The theoretical assumptions are quite similar to those of EVT. When transferring their findings to the terms of EVT, a positive violation of expectations happens in the low expectation group, which is positively evaluated (exceeded expectations), and thus causes a positive outcome (here: acceptance of the robot's suggestions). The finding lends support to the notion that a positive expectancy violation might cause a (strong) positive reaction due to exceeded expectations in human–robot interaction. Furthermore, it can be assumed that robot-initiated touch might exceed the expected functions of a robot, and thus evoke favorable reactions and evaluations if the robot is perceived as rewarding (see below).

Going beyond this, Kwon et al. (2016) compared expectations for robots in different contexts. The authors posited that humans have different theory-of-mind models for humans and robots. Moreover, they assumed that human-like mental models are likely to be attributed to more anthropomorphic robots, and that the mental models can be altered through interaction and observation. To test their assumptions, they conducted two experimental studies. In their first study, participants viewed a picture of a human, a humanoid robot, or an industrial robot working with a human in an industrial or domestic context. Participants were then asked to indicate how much they trust the robot or person to accomplish different tasks. The results demonstrated that trust to accomplish most tasks was significantly higher for a human than for a robot, regardless of the context. However, a difference between the robot types was observed in the domestic context: more trust in the robot's abilities to understand a request, take turn, empathize, and recognize a need, were attributed to the humanoid than to the industrial robot. The authors therefore concluded that individuals generalize the capabilities of a humanoid robot in a domestic scenario as having more unobservable abilities (e.g., to empathize), than they would do for less anthropomorphic industrial robots. In other words, individuals' expectations for humanoid robots in a domestic context are higher than their expectations for industrial robots, while expectations of the capabilities of both robots did not differ in an industrial context.

To examine whether expectations can be altered through either interaction or observation, participants evaluated a still picture and an accompanying video of a (humanoid) robot-human or human-human team working on a block stacking task (Kwon et al., 2016). With the aim of challenging pre-existing expectations that were based only on the appearance of the robot (still picture), the robot (and one human teammate) was shown to be incapable of stacking the blocks, and needed help from the partner. The comparison of the ratings demonstrated that the assigned block stacking capabilities of both human and robot diminished over time. Instead, with regard to verbal abilities (speaking English), the findings showed an increase in the expected ability of the robot over time. Hence, initial expectations on the robots speaking abilities might have been low based on the robot's appearance (still picture), but increased over time when participants observed the robot talking in the video. In summary, the findings suggest that humans' expectations of robots are affected by the robot's appearance and the interaction context. Furthermore, a second study by Kwon et al. (2016) revealed that expectations can be altered through observation or interaction.

With regard to EVT, the results of Kwon et al. (2016) support the role of dynamic aspects that emerge during interaction (see robot reward valence below) and further influence the interpretation of an observed behavior. Initially, static characteristics of the situation (context, robot appearance) determine expectations, but during interaction other dynamic variables (speaking/language abilities) alter the initial expectations, and affect the evaluation.

8.4.5 Application of the EVT Model to HRT & Open Questions

The preceding paragraphs have summarized the work on humans' expectations regarding the potential applications and abilities of robots, as well as the consequences of unmet expectations on the evaluation of robots and human–robot interaction. Nevertheless, to the present, no effort has been made to investigate touch expectancies in human–robot interaction. As a consequence, it remains unclear what expectations with regard to HRT prevail among humans.

To explore these expectancies and their impact on HRT evaluations, the original EVT process (see Chapter 8.4, Figure 9) was adapted to the context of HRI (see Figure 10). As robots have not yet entered the everyday life of the majority of people, norms regarding touch with robots are hitherto not established, and are so far unknown. Consequently, aspects that form expectations, as hypothesized in EVT (see Chapter 8.4), are of particular interest in studies designed to acquire a broader understanding of the HRT evaluation process.

The following paragraphs therefore cover the variables that may, according to EVT, determine HRT expectancies, interpretations, and evaluations, namely: human characteristics, robot characteristics (communicator characteristics), the human-robot relationship, contextual factors, and robot reward valence (see Figure 10).

Firstly, important components of the newly applied model are explained, then hypotheses and research questions regarding the expectedness of HRT and the appraisal process are formulated.

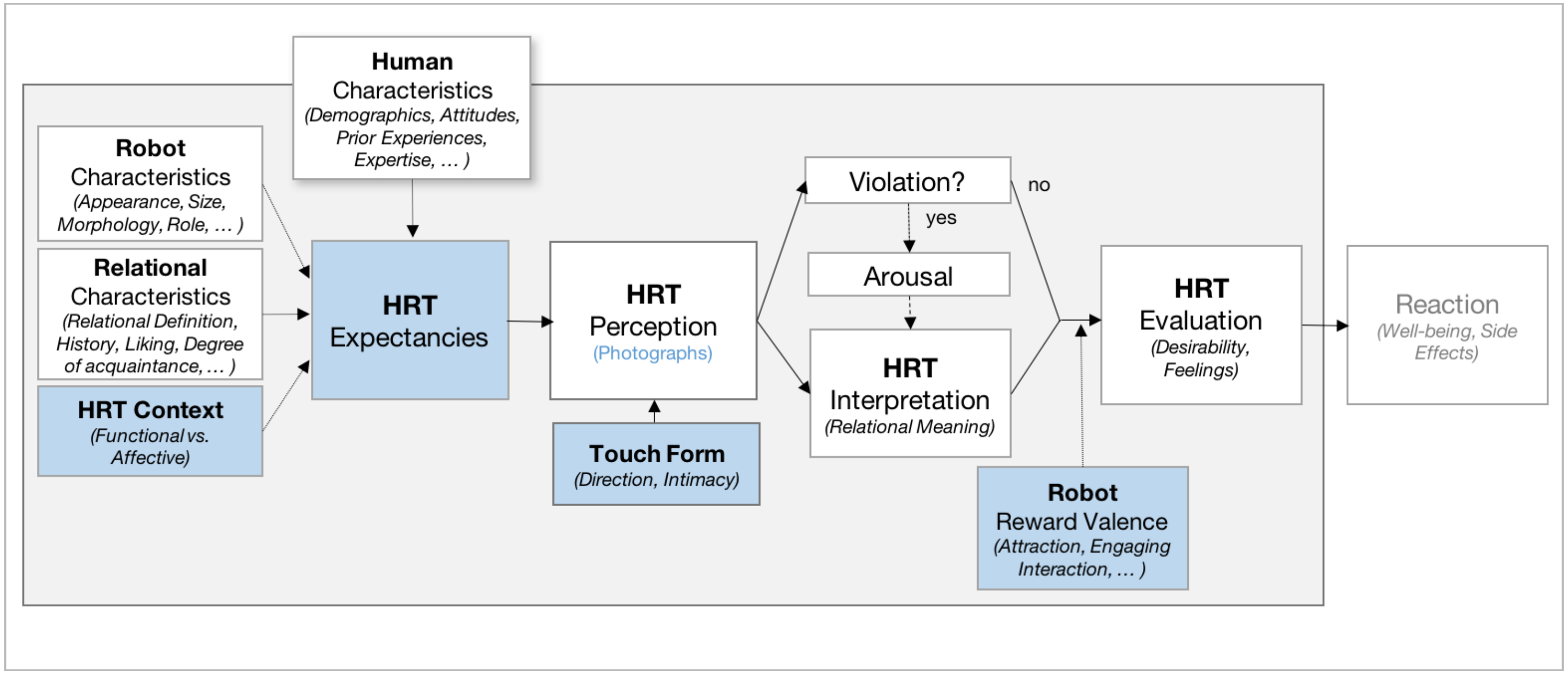


Figure 10. Expectancy Violations Model applied to HRT. (The model was self-crafted based on the model for interpersonal touch, which followed Burgoon and Hale, 1988; see above)

Robot Characteristics. When thinking of a robot as a communicator using touch, characteristics of the robot can be assumed to influence HRT expectancies (see Figure 10). As already revealed in the interview study, the appearance and size of a robot influence the perception, interpretation, and evaluation of HRT. Moreover, it is supposed that these factors, as well as a robot's morphology and role (e.g., tutor, assistant, domestic aid, companion), might further shape expectations. For example, as Kwon, Jung, and Knepper (2016) demonstrated, different robot abilities are expected depending on their appearance: higher expectations were observed for a humanoid robot's ability to accomplish a team cooking task than they were for an industrial robot. With regard to HRT, it can additionally be expected that a zoomorphic robot appearance might invite a different interaction (e.g., patting the robot like an animal, see Yohanan & MacLean, 2012) to a humanoid or android appearance (e.g., shake the hand; Haring, Watanabe, Silvera-Tawil, Velonaki, & Matsumoto, 2015).

Relational Characteristics in Human–Robot Interactions. As the interview study revealed, human observers assign relational meanings to human–robot interactions that include touch. Hence, expectations with respect to a robotic interaction partner might likewise be influenced by characteristics of the perceived human-robot relationship. For example, whether the relationship is personal or functional, whether they are acquainted or unfamiliar, or whether they are attracted to each other or not.

Context. As already mentioned above, the context of HRT is expected to influence the perception, interpretation, and evaluation of touch, and may thus also influence touch expectancies (see Chapter 8.1). With similarities to the assumptions made by Burgoon and Hale (1988), environmental constraints (e.g., restricted interaction space), the formality of the situation (depending on the human–robot interaction scenario, e.g., a formal job interview or a playful interaction), and the task-relatedness (functional or affective purpose) of touch, may determine HRT expectancies. With regard to task-relatedness, Syrdal, Walters, Koay, and Dautenhahn (2008) demonstrated that the approaching behavior of a robot was evaluated as more comforting when a clear purpose was discernible (e.g., carrying cups), than when no reason for the reduced distance was discernible (verbal interaction, or no interaction at all).

Robot Reward Valence. Above the characteristics that directly shape expectations, the reward valence of a robot (cf. communicator reward valence in the original theory) is likewise an important variable that moderates the interpretation, and hence the evaluation, of HRT (see Figure 10; Burgoon et al., 1992). As in the interpersonal case, reward valence is defined as a function of the static characteristics of a toucher (here: the robot) and the dynamic characteristics that evolve during interactions that make the robot rewarding, i.e., worth interacting with. A robot might for instance be perceived as rewarding for tangible reasons, e.g., if it assists a human in accomplishing a task, or due to its static characteristics, e.g., if it is cute looking or nice to touch. It may also be perceived as rewarding because of interaction dynamics that make communication with the robot enjoyable, e.g., if the robot talks politely or has a funny communication style. The likelihood that HRT is positively interpreted and concurrently evaluated is higher if the perceived reward valence of the robot is high, i.e., positive.

Especially when HRT violates the expectations of a touched individual; the reward valence of the robot should become more meaningful, because unexpected touch from an unrewarding robot (e.g., a robot with an eerie appearance) could easily cause discomfort. Following EVT, robot reward valence should then moderate the effect of touch interpretation on the evaluation if a violation takes place (see Figure 10).

Consequentially, if touch between humans and robots is unexpected, an increase in arousal should emerge, which directs the attention to the relational level (Figure 10, see also Burgoon & Hale, 1988). Afterwards, how the violation is interpreted depends on the robot reward valence, and whether it is positively or negatively evaluated. If the robot is perceived as highly rewarding, a positive interpretation is probable, due to a positive expectancy violation that causes a positive evaluation and an outcome that is even more positive than that conforming to expectations (here: an interaction without touch). However, if the perceived reward of the robot is low (e.g., the robot is perceived as eerie), a negative expectancy violation takes place, which should result in an undesirable evaluation and outcome.

Instead, if HRT does not represent a violation of individuals' expectations, the perceived behavior will be interpreted and evaluated without an attentional shift towards the relational level. The interpretation then determines how HRT is evaluated: if the behavior is desirably interpreted, its evaluation will be positive, but if the interpretation is undesirable, then the evaluation will be less positive or negative. Characteristics of a robot that make the interaction rewarding (or not) also play a role in the evaluation of HRT if expectations are confirmed, i.e., touch with a rewarding robot will still be better evaluated when it is expected. However, the evaluation should be even more pronounced if the behavior was unexpected (see 8.4.1).

8.4.6 The expectedness of HRT

Since touch expectancies for HRI have currently not been investigated, it should be questioned if individuals expect touch in HRI at all, whether they expect reciprocal, human- or robot-initiated touch, and whether contextual information alters the expectations. Hence the following research question was formulated:

> RQ3: Do individuals expect different forms of HRT depending on the interaction context?

According to earlier investigations that showed that individuals expect robots to fulfill more functional (e.g., cleaning) than affective tasks (e.g., playing) in the future, it can be anticipated that touch with robots is also more likely to be expected to happen for instrumental reasons in functional interaction contexts. Hence, it is assumed:

> H9: Observers of HRT are more likely to expect touch in a functional than in an affective context.

According to earlier findings on touch expectancies in the interpersonal context, it can be assumed that the expectedness of touch varies according to the form of touch. For instance, Burgoon and Walther (1990) and Burgoon et al. (1992) assessed the expectedness of different touch forms by asking participants to what extent they expected the presented form of touch between two individuals appeared to them. Their analyses revealed that a formal reciprocal handshake was the most expected form of touch, followed by more handholding, which was still reciprocal but less formal. In contrast, non-reciprocal touch forms, such as arm around waist, face touch, and arm touches, were less expected.

In HRI, no work has currently considered the expectedness of HRT, with the interview study (Study 1) yielding the first insights into the expectedness of different forms of HRT presented on photographs. According to the findings, the direction of touch predicted how expected touch between a human and a robot was perceived. In detail, the results suggested that touch from a human to a robot was most expected, followed by mutual touch, whereas touch from a robot to a human was least expected by observers. In line with this finding, the following hypothesis is posed:

> H10: Observers of HRT are more likely to expect human-initiated touch than reciprocal touch, which is in turn more expected than robot-initiated touch.

Regarding the degree of intimacy of HRT, it can further be assumed that formal forms of touch, such as handshake and a touch to the arm, are more likely to be expected than intimate forms, such as an embrace or a touch to the face region (cf. Burgoon & Walther, 1990; Burgoon et al., 1992). In accordance, the findings from Study 1 showed that intimate robot-initiated and reciprocal touches were the most surprising, and thus the least expected forms of HRT. Hence, it is hypothesized:

> H11: Observers of HRT are more likely to expect formal forms of touch than intimate forms of touch.

8.4.7 The interplay of varying factors in the HRT appraisal process

With regard to the evaluation of HRT, it can be derived from EVT and its application to HRI (Figure 10), that expectations as well as the interpretation of HRT, determine the evaluation of HRT. According to the theory, conformity to expectations is in general positively related to a favorable evaluation. Interpretations of touch as affective have also been shown to be positively related to the evaluation (Burgoon et al., 1992). Hence, the following hypotheses are proposed:

> H12a) The more observers expect HRT, the better their evaluation of touch.

H12b) The more affective observers interpret HRT, the better their evaluation of touch.

As outlined above, expectedness and interpretation are assumed to mediate the effect of touch form on the evaluation (Burgoon et al., 1989). Moreover, if HRT is interpreted as a sign of affection (conveying intimacy, attachment), it depends on the robot's reward valence whether this interpretation causes a positive or negative evaluation. Hence, if a robot is favorably evaluated due to its appearance or behavior (speech, gesture), touch from this robot is more likely to be favorably evaluated. It was hypothesized that better evaluations of HRT will occur if HRT represents an expected behavior (conformity), or if touch is unexpected but reward is high. Furthermore, according to the model it can be assumed (Figure 10) that more attention is payed to the relational meaning (i.e., interpretation) if the expectedness of HRT is low (i.e., a violation takes place) and heightens arousal. If HRT is interpreted as affection, the evaluation will be favorable if reward (attractive robot) is high, but will in turn result in an unfavorable evaluation if reward is low (unattractive robot). Therefore, it is hypothesized that the perceived reward of a robot moderates the effect of touch expectedness and touch interpretation on the evaluation of HRT.

H13: The effect of touch direction (human- or robot-initiated) on the evaluation of touch is mediated by (a) the expectedness and (b) the relational interpretation of HRT.

H14: Robot reward valence moderates the effect of (a) the expectedness and (b) the relational interpretation of HRT on the evaluation of HRT, in the sense that low expectedness and an affective interpretation of touch only have a positive impact on the evaluation if the robot was perceived as highly rewarding.

In order to make the structure of the hypotheses more transparent with regard to the independent and dependent variables, an overview of all hypotheses is given in Table 33.

Table 33. Overview of the posed hypotheses, included independent and dependent variables and the proposed direction of the hypotheses.

Hypothesis	IV	DV	Hypothesized direction
Influence of the context manipulation			
H1	Context for HRT (affective versus functional)	**Relational Definition** functional relationship definition	functional > affective
H2	Context for HRT	**Relational Interpretation** a) intimacy b) formality	a) affective > functional b) functional > affective
H3	Context for HRT	**Evaluation** general evaluation	functional > affective
Influence of touch form (direction and intimacy)			
H4	Direction of HRT (human, robot, reciprocal)	**Relational Definition** functional relationship definition	non-reciprocal (human- or robot-initiated) > reciprocal
H5	Intimacy of HRT (intimate versus formal)	**Relational Interpretation** a) intimacy b) formality	a) intimate touch > formal touch b) formal touch > intimate touch
H6	Direction of HRT	**Relational Interpretation** a) intimacy b) formality c) dominance	a) reciprocal > non-reciprocal b) Non-reciprocal > reciprocal c) robot-initiated > human-initiated and reciprocal
H7	Direction of HRT	**Evaluation** general evaluation	human-initiated > reciprocal > robot-initiated
H8	Intimacy of HRT (exclusively in functional context)	**Evaluation** general evaluation	formal > intimate
Expectedness of HRT according to the manipulations			
H9	Context of HRT	**Conformity to expectations**	functional > affective
H10	Direction of HRT	expectedness	human-initiated > reciprocal > robot-initiated
H11	Intimacy of HRT		formal > intimate
HRT appraisal process			
H12	a) The more observers expect HRT, the better their evaluation of touch. b) The more affective observers interpret HRT, the better their evaluation of touch.		
H13	The effect of touch direction (human- or robot-initiated) on the evaluation of touch is mediated by (a) the expectedness and (b) the relational interpretation of HRT.		
H14	Robot reward valence moderates the effect of (a) the expectedness and (b) the relational interpretation of HRT on the evaluation of HRT (…)		

With the objective of testing the aforementioned hypotheses and answering the research questions, an online experiment was conducted that was intended to replicate the findings from Study 1 and Study 2 with a broader sample, under consideration of HRT expectancies in different contexts.

8.5 METHOD – ONLINE EXPERIMENT

8.5.1 Design

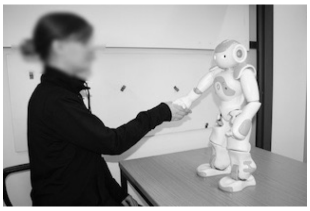
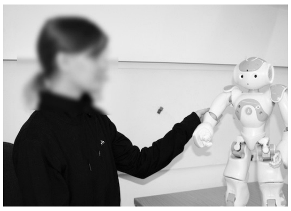
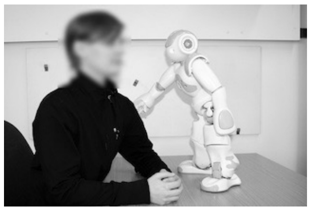
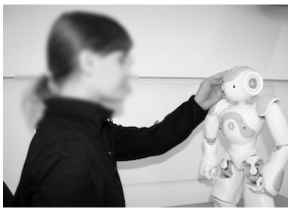
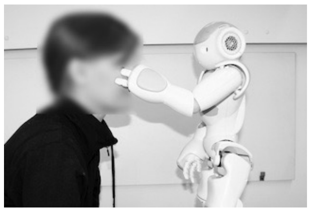
As the present study was designed to quantify the findings from the interview study with regard to different touch forms in different contexts, a selection of stimulus pictures from the interview study was re-used and presented in different HRT contexts, resulting in a 4 (direction of touch: human-initiated vs. robot-initiated vs. reciprocal vs. no touch control) × 2 (intimacy of touch: intimate vs. formal) × 3 (context: functional vs. affective vs. no context control) factorial between-subjects design. The between-subjects design was chosen to avoid demanding characteristics and to prevent participants from fatigue due to repetitive questions.

8.5.2 Independent Variables

8.5.2.1 Direction and Intimacy of HRT Forms

Pictures from Study 1 were re-used as stimulus material to present different forms of HRT by means of photographs. Robots that were described as eerie or dangerous in the interview study (Rhoni and iCub) were excluded, as it is assumed that favorable perception and evaluation of a robot are a basic prerequisite for the acceptance of robot touch. Among the remaining pictures, pictures of the robot Nao were chosen, because this robot was evaluated favorably by most participants in Study 1. For the purpose of the online experiment, digital versions of the pictures that depict Nao in different touch situations were included in the survey. The pictures differed in the presented direction of touch (reciprocal, human-initiated, robot-initiated) and in the degree of touch intimacy (formal, intimate, see Table 34 for an overview).

Table 34. Stimulus pictures according to the direction and intimacy of HRT.

	Direction of HRT		
Intimacy of HRT	Reciprocal HRT	Human-initiated touch	Robot-initiated touch
Formal HRT			
	Handshake	*Touch to robot's arm*	*Touch to human's arm*
Intimate HRT			
	Embrace	*Touch to robot's face*	*Touch to human's face*

For reciprocal HRT, pictures that show a handshake and an embrace were included. For human-initiated touch, a touch to the robot's arm and a touch to the robot's face were chosen to represent a formal and an informal directional form of touch respectively. Finally, the same touch forms were chosen for robot-initiated touch, namely: touch to a human's arm and touch to a human's face (cf. Table 34).

8.5.2.2 Given Context

Since the interview study revealed that the circumstances under which touch occurs between a human and a robot seems to be important for individuals to interpret and evaluate HRT, different contexts were included in this experimental study. According to the general differentiation made on the basis of theory and previous evidence (see Chapter 8.1), the context was manipulated to be either functional or affective. A no context control condition was also included to test whether no information equals one of the aforementioned contexts. The context manipulation was realized with textual vignettes that were displayed as plain text. For the functional condition the vignette description was: *"The person and the robot work together, and are just trying to solve a given task*." For the affective condition the text of the vignette was: *"The person and the robot are just getting to know each other and try* *to bond.”* In the control condition, no text was displayed at all (see Figure 11 for an example of the presentation).

In both conditions, no reference to touch was made in the vignettes, neither in advance, nor in retrospect, to avoid a priming effect. The vignettes only framed the interaction into a functional working context or an affective scenario in which the human and the robot are getting to know each other. Because of this it was possible to test whether the differentiation between a functional and an affective context for touch already affects touch expectancies.

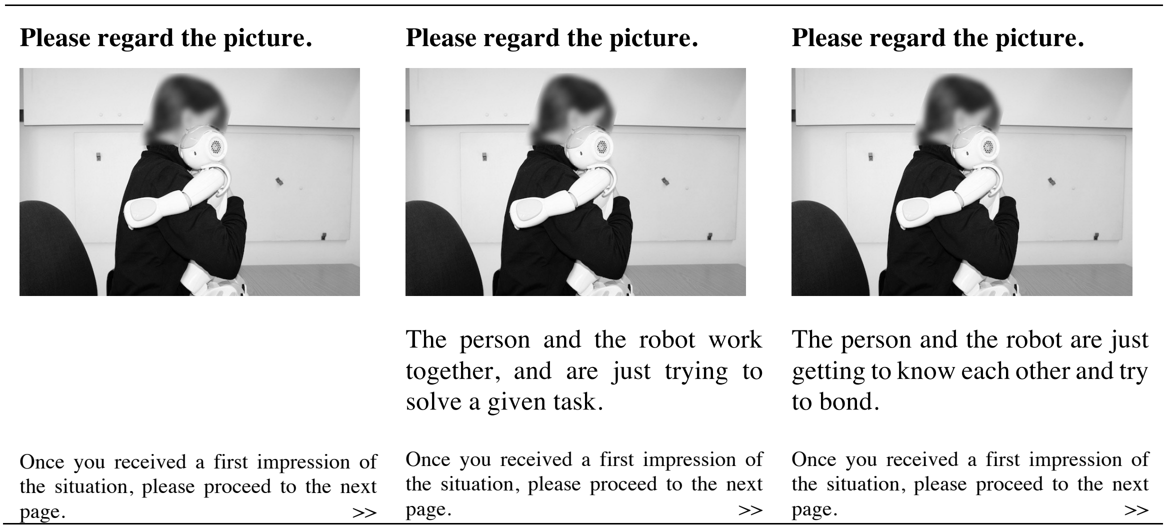


Figure 11. Examples of the stimulus presentation for intimate reciprocal touch (embrace) in combination with no given context, functional context, and affective context vignette (from left to right).

8.5.3 Dependent Variables

All dependent measures were assessed with a self-reported questionnaire. If not further stated, the items were rated on five-point Likert type scales ranging from 1 = “fully disagree” to 5 = “fully agree.” The number of items was reduced by means of sum scores per (sub-) scale in advance of the statistical analyses (see results).

8.5.3.1 Touch expectancies and expectancy violations (expectedness)

Touch expectancies were measured before and after the stimulus presentation. Firstly, to test whether humans expect touch in HRI at all, and whether these expectations are altered by contextual information, six expectations were formulated that started with “I expect that…", and referred to touch expectations regarding different directions of touch ("… the human and the robot touch each other", "…the human touches the robot", "…the robot touches the human"), in addition, statements that referred to the interaction in general were included to prevent a focus on the touch statements ("… the human and the robot look at each other", "…talk to each other", "… work together"). These statements were presented immediately after the first presentation of the vignette, but before the first presentation of the stimulus picture. Since the items covered expectations regarding different directions of touch, they were regarded separately in following analyses.

Secondly, after the stimulus presentation, violations of expectancies were assessed by means of the expectedness of the presented behavior. Expectedness was measured with four statements that were adapted from the work of Burgoon and Walther (1990) to fit the purpose of this study, and two further self-generated items. Since the pictures demonstrated non-reciprocal as well as reciprocal touches, the items which originally focused on one person (e.g., "Person A's behavior is appropriate") were modulated to focus on the interaction between the human and the robot: "The behavior of the human and the robot is appropriate," "The behavior of the human and the robot is what I would typically expect," "The human and the robot are engaging in normal conversational behavior," and "The human's and robot's behavior is unusual" (reversed). Two self-generated items were also added, namely: "The behavior totally confirms my expectations" and "I did not expect the interaction to look like this" (reversed). The negatively worded items were reverse-coded before all items were collapsed into one scale (mean sum score; 6 items, *Cronbach's* α = .851).

8.5.3.2 Interpretation of the pictures

With regard to the interpretation of the stimulus picture, different questions were asked to assess the relational definition and meaning, as in Study 1, as well as the perceived attachment from the person to the robot.

Relational meaning was measured with the Relational Communication Scale (Burgoon & Hale, 1987). Fourteen modified items that fitted with an observer perspective were adapted from the work of Burgoon (Burgoon, 1991). The items addressed relational themes such as affection, immediacy, dominance, composure, and formality. Again, 'person A' was replaced with 'robot' in the item formulations. Example items are: "The robot is showing affection for the person," "The robot acts like it is more powerful than the person," "The robot is trying to make the conversation informal," and "The person seems relaxed and composed." The items that refer to one relational theme (cf. Burgoon, 1991) were summarized into scales: *dominance* (2 items, *Cronbach's* α = .711), and *composure* (2 items, Cronbach's α = .685). As Burgoon and Hale (1987) demonstrated that the themes affection, immediacy, receptivity/trust, and similarity/depth/equality all relate to the overall topic of intimacy, the items concerned with these topics were summarized as *intimacy*/*affection* (8 items, Cronbach's α = .855). Finally, the items dealing with formality ("The robot is keeping the interaction very formal" and "The robot is trying to make the conversation informal") were separately treated, since their internal consistency when collapsed into one scale was weak (Cronbach's α = .207). They are further referred to as *formality* and *informality*.

Since the items of the relational communication scale focused on the relational meaning that was assigned to the behavior of the robot, attachment from the human to the robot was further assessed with three items that measured attachment as a facet of material possession, as in Kemper (2009). The items originally stem from the work of Sivadas and Machleit (1994) in the area of marketing research. For the purpose of this study, the items were adjusted to an observer perspective, and are thus phrased as 'the person' instead of 'I'. The resulting items were: "The person is emotionally attached to the robot", "The person has no feelings for the robot" (reversed), and "The person is sentimental about the robot." The items were mixed with the questions concerning the relational interpretation, and hence also rated on the same five-point scale. For further analyses the items were summed into one reliable score (3 items, *Cronbach's* α = .748).

Based on the *relational definitions* of the human-robot relationship from the interview study (cf. results from Study 1), ten additional items were constructed that represented either a *functional relationship* (e.g., "The person seems curious about the robot's skills", "The person tries out the robot's functionalities", 4 items, *Cronbach's* α = .652), or a *personal relationship* (e.g., "The person and the robot appear friendly", "The robot seems like a pet of the person", 6 Items, *Cronbach's* α = .774). The items were collapsed into sum scores for both relationship definitions. Furthermore, to check whether participants assigned a relational meaning at all, they had to evaluate the statement "I would never see any relationship between a robot and a human" (M = 2.73, SD = 1.33).

Finally, *relational closeness* was assessed by means of the Inclusion of Other in the Self scale (IOS; Aron, Aron, & Smollan, 1992), which is a seven-point pictorial scale that illustrates interpersonal relationships by means of circles that differ in the degree to which they overlap (see Appendix: Study 3 - Questionnaire). In the original version, one circle represents the 'self' and the other is labeled 'other'. In order to adapt the scale to the context of the present study, the labels were replaced with 'person' and 'robot' for the observer evaluation. Additionally, to act as a Self-Assessment Manikin, the IOS was collected a second time with circles for 'I' and 'robot', to allow an evaluation from an anticipated participant perspective. The pictures were coded from 1 (non-overlapping circles) = "not close" to 7 (almost totally overlapping) = "really close". The reliability and validity of this short pictorial measurement was demonstrated in Aron, Aron, and Smollan (1992).

8.5.3.3 Evaluation

A general evaluation of the desirability of the observed interaction between the human and the robot was assessed by means of four items adapted from Burgoon and Walther (1990). For the purpose of this study 'person A' was substituted with 'robot' and 'person B' was shortened to 'person'. The items were: "Most people would like to interact with the robot", "The robot's behavior is likely to please the person", "The robot's behavior is undesirable" (reversed), "The person is probably enjoying the interaction with the robot". The items were summed into one (mean) score (*Cronbach's* α = .585).

Besides the general evaluation, the participants' *emotional response* to the stimulus pictures was measured from two perspectives. Contrary to the interview procedure, participants were first asked to tell from an observer perspective how they think the person in the picture feels, and secondly how they would feel if they were the person in the picture. Again, emotional response was operationalized as valence, arousal, and dominance, measured by means of the SAM (Bradley & Lang, 1994; see Appendix Study 3 - Questionnaire). The pictorial scales were coded as five-point scales. Valence and arousal were reversed so that a high rating represents positive valence and high arousal. High ratings on the dominance scale resemble superiority, while lower ratings stand for inferiority. It was assumed that high valence, low arousal, and high dominance signify a positive emotional response, whereas, low valence, high arousal, and feelings of inferiority (low dominance) indicate a negative response.

8.5.3.4 Moderator variable: Robot reward valence

The perceived reward of the robot was operationalized by means of the perceived attractiveness of the robot for social and task-related purposes. As Burgoon and Hale (1988) showed that highly rewarding partners were rated higher on dimensions of interpersonal attraction, the social and task subscales of the *Interpersonal Attraction Scale* (McCroskey & McCain, 1974) were used in the present study. Each subscale was assessed with five items, which were adapted to the context of interacting with a robot, e.g., "I think the robot could be a friend of mine" or "I would like to have a friendly chat with the robot" for *Social Attraction*, and "I have confidence in the robot's ability to get a job done" or "The robot would be a poor problem solver" (reversed) for *Task Attraction*. Sum scores for each subscale were calculated for further analyses (*Social attraction*, Cronbach's α = .778; *Task attraction*, Cronbach's α = .731).

Additionally, the predictability of the robot's behavior was assessed by means of the *Attributional Confidence Scale (*CL-7, Clatterbuck, 1979), but this is not of interest for testing the present research questions and hypotheses.

8.5.4 Control Variables

Personal characteristics that were revealed to influence the acceptability of HRT in the preceding studies (see Study 1 & 2) were collected in order to control their influence on the dependent measures. Demographical information, prior experiences, and attitudes towards robots and touch were assessed.

With regard to *demographical information*, participants were asked about their age, sex, education, current occupation, and profession. Profession was assessed according to the industry in which participants worked (technology-related and non-related, cf. Study 2).

Prior experience with robots and touch were investigated with questions on whether participants already knew the robot on the picture, if they had already touched a robot, and if a robot had touched them (yes/no). If the participants replied 'yes', they were asked to elaborate further on the context in which they were touched by a robot, and to say which robot had touched them (open question).

Moreover, participants' general *exposure to robots* was assessed by asking how often they use robots and other technologies at work and during their spare time. In total, six items were built that covered three different technologies: "I use a computer/machine/robot at work" and "I devote myself to computers/machines/robots in my spare time." The items were rated on a five-point Likert type scale from 1= "never" to 5= "often."

Technological expertise was measured as in the online survey, by means of six self-generated items concerned with the participants' knowledge and interest in technology (cf. 7.2). The items were collapsed into one sum score that demonstrated good reliability (Cronbach's α = .843).

8.5.4.1 Attitudes towards robots

As in the online survey (Study 2), attitudes towards robots were assessed by means of the following subscales of the Negative Attitudes toward Robots Scale (Nomura et al., 2004): *Negative Attitudes toward Situations of Interactions with Robots* (NARS S1, 6 items, *Cronbach's* α = .747), *Negative Attitudes toward Social Influence of Robots (*NARS S2, 5 items, *Cronbach's* α = .633), and *Negative Attitudes toward Emotions in Interaction with Robots* (NARS S3, 3 items, *Cronbach's* α = .688).

8.5.4.2 Attitude towards interpersonal touch

General attitudes towards interpersonal touch were measured by means of the NFIPT scale. As in Study 2, the negatively worded items were reverse-coded, and all 20 items were then collapsed into one mean score (*Cronbach's* α = .875).

Participants' feelings of loneliness were also collected to control for the potential effect that loneliness might have on the anthropomorphization of robots (cf. Eyssel & Reich, 2013), which might in turn evoke stronger personal relational interpretations and thus distinct evaluations. A revised German version of the UCLA Loneliness scale (Döring & Bortz, 1993) was used that assesses loneliness without directly asking how lonely a person feels. Example items are *"I feel ostracized"* or *"No one really knows me."* The scale consists of 20 positively and negatively formulated items. Negatively worded items were reverse-coded before all items were summed into one reliable score (*Cronbach's* α = .930).

8.5.5 Stimulus Recall

A free recall and forced choice recall procedure was used to check whether the manipulation was successful. It was of interest to know whether participants recognized differences between different directions of HRT (stimulus picture), and further, if they perceived and remembered the given context in which the interaction was said to have taken place (vignette). Therefore, participants were primarily asked to describe what they saw on the picture (free recall), and afterwards descriptions of the stimulus pictures were presented that were rated according to their fit (cued recall). The descriptions covered the occurrence and reciprocity of touch ("The human and the robot touched each other"), the direction of touch ("The human touched the robot", "The robot touched the human"), and reference to the functional ("The human and the robot solved a task together", 2 items, *Cronbach's* α = .832) and affective context ("The human and the robot tried to establish a bond", 2 items, *Cronbach's* α = .708).

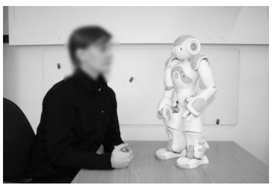
8.5.6 Procedure

The experiment was conducted as an online experiment using a German web platform for scientific surveys (www.soscisurvey.de). The experimental design was approved by the local IRB. The survey was available online from the beginning of April 2015 until the end of July 2015. Participants were recruited via social networking sites, forums, and the university campus.

On the first page of the survey, participants were welcomed and informed about the questionnaire. Afterwards, they were asked to answer general questions about themselves as their prior experiences with technology. Thereafter, the stimulus was announced and immediately followed by the vignette:

"In the following, you are going to evaluate an encounter between a human and a robot. Therefore, you will see a picture of an interaction between a human and a robot on the next page. The human and the robot… [vignette]"

Table 35. Structure and order of the variables in the online questionnaire

Questionnaire Parts and Scales/Measurements	Items, Reliability (Cronbach's alpha)
Part I: Pre Questionnaire - Control Variables	
Exposure to technologies (ad hoc)	6 items, α = .851
Technological expertise (ad hoc)	6 items, α = .843
Attitudes towards robots (NARS)	S1: 6 items, α = .747 S2: 5 items, α = .633 S3: 3 items, α = .688
Attitudes towards interpersonal touch (NFIPT)	20 items, α = .875
Loneliness (UCLA)	20 items, α = .930
Part II: Introduction to stimulus presentation + Vignette (none, functional, affective)	
"In the following, you are going to evaluate an encounter between a human and a robot. *Therefore, you will see a picture of an interaction between a human and a robot on the next page.* *The human and the robot…* [vignette]"	
Expectancies (self-generated/ad hoc items)	Single items
Part III: **Stimulus presentation** *(picture: reciprocal, human-initiated, robot-initiated,* or *no touch)*	
 *(no touch example)*	
Part IV: Post Questionnaire - Dependent Variables & Final Control Questions	

Dependent Measures	
Expectedness	6 items, α = .851
Evaluation	
General Evaluation	4 items, α = .585
Emotional State (SAM-Observer)	Pictorial scales
Relational Definition	
Functional relationship	4 items, α = .652
Personal relationship	6 items, α = .774
Relational Interpretation (RCS)	
Intimacy/affection	8 items, α = .855
Composure	2 items, α = .685
Dominance	2 items, α = .711
Formality/Informality	Single items
Attachment	3 items, α = .748
Closeness (IOS-Observer)	Pictorial single item
1st person evaluation	
Emotional response (SAM - 1st person)	Pictorial scales
Relational closeness (IOS - 1st person)	Pictorial single item
Robot Evaluation (Interpersonal Attraction Scale)	
Task Attraction	5 items, α = .731
Social Attraction	5 items, α = .778
Control Questions	
Prior exposure to robots and robot touch (ad hoc)	
Manipulation check questions (ad hoc)	
Demographics	

To gather information about the expectations participants had in advance, and how they might be influenced by the context manipulation (vignette), primary expectations were collected before the stimulus picture was presented. Subsequently, the stimulus was presented on a separate page along with the vignette text (see Figure 11). To ensure that participants did not forget about the context and the picture, both were continuously presented on the left, along with the questions on the right (see Appendix). The questions mainly focused on the expectedness, interpretation, and evaluation of the stimulus picture (for a detailed overview of the order of the dependent variables see Table 35). The evaluation was initially demanded from an observer perspective (cf. Burgoon, 1991; Burgoon & Walther, 1990; Burgoon et al., 1992), and later also partially from a first-person perspective. Therefore, participants were instructed to imagine being the person in the picture and were then asked to report their imagined affective state (SAM-1st person) and anticipated relational closeness to the robot (IOS-1st person). Thereafter, an evaluation of the rewarding nature of the robot was asked for, and questions concerning earlier experiences with robotic touch were posed. Finally, a manipulation check was performed with recall questions about the stimulus and the vignettes, and demographic information were collected. Participants were fully debriefed at the last page of the questionnaire and were offered the option to leave their email address in order to participate in the gift card tombola.

8.5.7 Sample

Participants were mainly recruited via online advertisements on social networking sites (mainly Facebook and Xing), different forums, and on campus. Course credits or the possibility to participate in a raffle for gift cards for between ten and 50 Euro for an online shop, were offered as incentives. In total, 12 gift cards with a total value of 200 Euro were raffled between all participants after the data collection was terminated.

Altogether, data were collected from 497 participants. Data form three participants that finished the survey particularly fast (faster than 300 seconds), were excluded from the analysis. Cases from participants with an age below 18 (6, 11, 16 and 17, n = 8) or above 90 (n = 1) were also excluded before the analyses. Afterwards, outliers that were identified by means of explorative analysis (Boxplot diagrams) for all dependent variables were individually checked for uncommon data patterns. According to this analysis, three more cases were deleted, which were identified as outliers in more than five dependent measures, and attracted attention by repeated ratings ("11111, 55555"). After data cleaning, 482 participants between the age of 18 and 65 years (M = 26.04, SD = 8.16) remained in the sample, of which 302 (63%) were female and 180 (37%) were male. The final distribution of the participants to the experimental conditions can be found in Table 36.

The majority of the participants were highly educated. More than half of the participants (53%) held a high-school diploma (n = 256) and a third (36%) reported a university degree (n = 172). Eleven percent (n = 51) graduated from school with different degrees or finished an apprenticeship, while only three participants were still school students. The majority of the participants were undergraduate, graduate, and PhD students (n = 308; 64%). The second largest group were employees (n = 124, 26%), and the remaining ten percent were unemployed (n = 12), civil servants (n = 13), self-employed (n

= 10), apprentices (n = 7), school students (n = 3), or otherwise occupied (e.g., interns, retirees, or volunteers; n = 5).

Table 36. Final distribution of participants to experimental conditions.

Direction	Intimacy	Touch Form	Context			total per touch stimuli	per direction
			Functional	Affective	None (control)		
Reciprocal touch	Formal	handshake	21	21	25	**67**	**135**
	Intimate	embrace	22	26	20	**68**	
Human-initiated	Formal	touch to robot's arm	23	22	25	**70**	**137**
	Intimate	touch to robot's face	23	22	22	**67**	
Robot-initiated	Formal	touch to human's arm	21	21	28	**70**	**133**
	Intimate	touch to human's face	21	21	21	**63**	
No touch control	-	no touch (control)	28	28	21	**77**	**77**
total per context			**159**	**161**	**162**		**482**

8.6 Results of the Online Experiment

Data analyses were conducted with SPSS Statistics Version 22 and version 2.16 of the PROCESS Macro (released 5 July 2016; Hayes, 2012, 2015). Parametric tests were used, even though normality cannot be assumed for Likert-scaled data. This decision was based on the knowledge that parametric tests are generally more robust than criticism of them often implies (Norman, 2010), and normality can be neglected for large sample sizes (here: N = 482) according to the central limit theorem (see Field, 2013). Errors were further minimized by means of random assignment to experimental groups, and almost equal group sizes.

8.6.1 Descriptive Overview

8.6.1.1 Profession and expertise

The participants' profession was again assessed according to the fields in which they worked. The list of fields was reduced to technical-related and non-technical industries (cf. Study 2). In contrast to the preceding online survey, the ratio in the sample was balanced: approximately half the participants (56%, n = 268) reported that they worked in non-technical industries, while the other half that they worked in technical-related industries (44%, n = 214). The participants' expertise with regard to newer technologies was on average moderate-to-high (M = 3.16, SD = 0.75, on a five-point scale).

8.6.1.2 Prior experiences

With regard to participants' exposure to robots, participants reported to use them only rarely at work (M = 1.30, SD = 0.69) and during leisure time (M = 1.39, SD = 0.81). When asked whether participants knew the robot in the picture (Nao) before, the majority (72%, n = 345) did not recognize it, while a minority (28%, n = 137) stated that they already knew it.

With regard to HRT experiences, nearly two thirds (62%, n = 299) reported that they had never yet touched a robot, while a little more than one third (38%, i = 183) had already touched one. Participants were also asked if a robot had touched them in the past. Here, the minority (8%, n = 40) answered 'yes', while the majority (92%, n = 442) answered with 'no'. When asked to further describe in what context they got into physical contact with a robot, most participants referred to experiences in university or school, for instance during experiments in which they had to interact with a physically present robot (n = 27). Others mentioned that they were touched by robots in public places like exhibition halls, museums, or at the supermarket (n = 6), and still others reported physical contact with robots at work (n = 3), or in private places (n = 1). The remaining did not mention an interaction context. When asked with which robots they experienced touch, the majority mentioned robots that are typically used in research, such as Aldebaran's Nao, Paro (Shibata & Tanie, 2001; Shibata et al., 1999), or Lego NXT robots (n = 21). Likewise, robot toys such as Ugobe's Pleo were mentioned three times, and industrial robots were also named three times. In the remaining 12 cases, the name or type of robot was not remembered.

8.6.1.3 Attitudes towards robots and touch

Participants negative attitudes towards robots, as collected by the NARS questionnaire (Nomura et al., 2004), were moderately pronounced for *Negative attitudes toward situations of interactions with robots* (NARS S1, M = 2.55, SD = 0.75) and the *social influence of robots* (NARS S2, M = 3.05, SD = 0.70), but were distinctly observable for *Negative attitudes towards emotions in interaction with robots* (NARS S3, M = 3.43, SD = 0.84). Hence, emotions in interactions with robots were on average estimated as undesirable.

Participants' interpersonal touch acceptability, measured by the NFIPT scale, was on average, high (M = 4.62, SD = 0.83) within the sample. Hence, participants generally perceived touch positively, and were not avoidant of bodily contact with other humans. Loneliness, however, was quite low within the sample (M = 1.82, SD = 0.57).

8.6.2 Manipulation Check

To test whether the manipulation was successful, participants were asked to indicate whether they observed touch between the human and the robot, and further, whether the touch was initiated by the human or the robot.

A one-factorial MANOVA was conducted with touch direction as the independent variable and the statements that checked whether the touch form was correctly remembered as the dependent variable. The results demonstrate that the manipulation was successful.

The multivariate effect of touch direction was significant (Pillai's Trace = 1.69, $F(9, 476) = 206.25$, $p < .001$, $\eta_{part.}^2 = .564$), and univariate main effects on all statements were observed (see Table 37). Post hoc tests (Bonferroni corrected) revealed that for the recalled presence of touch ("The human and the robot touched each other"), no touch ratings were significantly lower than robot-initiated, reciprocal, and human-initiated touch ratings ($p < .001$). Hence, participants correctly recalled whether touch was included or not. Furthermore, post hoc comparisons (with Bonferroni correction) demonstrated that participants also correctly remembered the direction of touch that was presented. Human-initiated touch (The human touched the robot) was recalled significantly more when human-initiated touch was presented on the picture as opposed to robot-initiated touch or no touch being presented ($p < .001$). No significant difference to reciprocal touch was observed. In contrast, robot-initiated touch ("The robot touched the human") was recalled significantly more after robot-initiated touch than after all other forms of touch ($p < .001$).

Table 37. Means, standard deviation and main effects of touch form on the manipulation check variables.

Touch Form				MANOVA Univariate effects			
	M	*SD*	*H*	*F*	*df*	*p*	$\eta_{part.}^2$
The human and the robot touched each other.				165.77	3	< .001	0.51
no touch control	1.12	0.49	77				
robot-initiated	3.65	1.47	133				
reciprocal touch	4.81	0.48	135				
human-initiated	3.71	1.52	137				
The human touched the robot.							
no touch control	1.12	0.56	77	1013.49	3	< .001	0.86
robot-initiated	1.3	0.81	133				
reciprocal touch	4.64	0.63	135				
human-initiated	4.77	0.68	137				
The robot touched the human.							
no touch control	1.09	0.44	77	608.39	3	< .001	0.79
robot-initiated	4.68	0.79	133				
reciprocal touch	4.27	1.04	135				
human-initiated	1.39	0.77	137				

In the next step, the context manipulation was checked by means of a one-factorial MANOVA with context as the independent variable and the recall statements as dependent variables. The MANOVA revealed a significant multivariate effect of context, Pillai's Trace = 0.09, $F(8, 476) = 5.89$, $p < .001$, $\eta_{part.}^2 = .047$. Furthermore, univariate effects were observable for three out of four statements, which demonstrates that the manipulation was successful (Table 38). The mean values reveal that affective descriptions were mostly recalled in the affective context, whereas functional descriptions were mostly recalled in the functional context. Post hoc analyses with Bonferroni correction further demonstrated that the difference between affective and functional touch was significant ($p = .037$) for the recall statement "The human and the robot were getting to know each other." With regard to the functional recall statements, significant differences between the functional and affective context were observed (*ps* < .001 both).

Table 38. Means, standard deviations, and main effects of context on the recall questions.

				Univariate test statistics			
HRT context	*M*	*SD*	*H*	*F*	*df*	*p*	$\eta_{part.}^2$
The human and the robot were getting to know each other.				3.91	2	.021	.016
none	3.31	1.03	162				
functional	3.28	1.07	159				
affective	3.58	1.11	161				
The human and the robot tried to bond.				1.96	2	.142	.008
none	2.90	1.06	162				
functional	3.02	1.17	159				
affective	3.15	1.15	161				
The human and the robot worked together.				12.27	2	< .001	.049
none	2.44	1.11	162				
functional	2.86	1.21	159				
affective	2.24	1.13	161				
The human and the robot solved a task together.				16.20	2	< .001	.063
none	2.41	1.19	162				
functional	2.80	1.20	159				
affective	2.06	1.08	161				

8.6.2.1 Influence of Control Variables

To gain an understanding of the collected variables and their relationships, bivariate correlations were calculated for the dependent variables and control variables that were identified as influential in Study 2 (also Study 1, see Table 39).

Table 39. Pearson Product Moment Correlations for the person variables and dependent variables (*N* = 482).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Person Variables:															
1. Expertise	1	.044	-.420**	-.171**	-.266**	.056	-.028	.029	.084	-.059	.024	-.009	-.008	-.073	.085
2. NFIPT	.044	1	.046	.047	-.043	.055	.069	.010	.038	-.035	.037	.077	.099*	.080	-.005
3. NARS S1	-.420**	.046	1	.539**	.468**	-.110*	-.013	-.108*	-.065	.154**	-.018	-.131**	-.093*	.163**	-.153**
4. NARS S2	-.171**	.047	.539**	1	.399**	-.138**	-.080	-.136**	.033	.082	-.073	-.177**	-.115*	.150**	-.136**
5. NARS S3	-.266**	-.043	.468**	.399**	1	-.110*	-.158**	-.097*	-.099*	.047	-.145**	-.204**	-.110*	.075	-.033
Dependent Variables:															
6.Expectedness	.056	.055	-.110*	-.138**	-.110*	1	-.093*	.241**	.231**	-.251**	-.053	.425**	.315**	-.159**	.215**
7. Affection	-.028	.069	-.013	-.080	-.158**	-.093*	1	.044	-.350**	.281**	.337**	.111*	.116*	.040	-.196**
8. Composure	.029	.010	-.108*	-.136**	-.097*	.241**	.044	1	-.048	-.348**	.262**	.400**	.430**	-.506**	.281**
9. Formality	.084	.038	-.065	.033	-.099*	.231**	-.350**	-.048	1	-.063	-.119**	.084	.010	.092*	.066
10. Dominance	-.059	-.035	.154**	.082	.047	-.251**	.281**	-.348**	-.063	1	.012	-.269**	-.164**	.228**	-.416**
11. Attachment	.024	.037	-.018	-.073	-.145**	-.053	.337**	.262**	-.119**	.012	1	.356**	.365**	-.087	-.038
12. Evaluation	-.009	.077	-.131**	-.177**	-.204**	.425**	.111*	.400**	.084	-.269**	.356**	1	.546**	-.176**	.192**
13. Valence	-.008	.099*	-.093*	-.115*	-.110*	.315**	.116*	.430**	.010	-.164**	.365**	.546**	1	-.257**	.182**
14. Arousal	-.073	.080	.163**	.150**	.075	-.159**	.040	-.506**	.092*	.228**	-.087	-.176**	-.257**	1	-.250**
15. Dominance	.085	-.005	-.153**	-.136**	-.033	.215**	-.196**	.281**	.066	-.416**	-.038	.192**	.182**	-.250**	1

According to the results of the correlation analysis (Table 39), expertise was unrelated to the dependent measures. Individuals' attitudes towards interpersonal touch (NFIPT) only showed a significant positive correlation with the perceived valence: the higher the need for interpersonal touch, the better the perceived valence. Instead, the subscales of the Negative Attitude Toward Robots Scale (NARS S1, S2, S3) correlated negatively with all dependent measures except arousal (positive correlation). Because of this, they were entered as covariates into the ANCOVAs to control their influence on the dependent variables. Since no difference in the main and interaction effects caused by the experimental manipulation were noticeable when the results with and without the covariates were compared, the ANOVAs are reported in the following sections without covariates.

8.6.2.2 Hypotheses Testing

The following paragraphs present the results with regard to the hypotheses. The analyses are presented along with the dependent measures, as they were assumed to appear in the evaluation process, starting with the relational definition and interpretation followed by the evaluation of HRT. Following this, hypotheses on the expectedness of HRT were examined before the hypotheses concerning the appraisal process were finally tested.

Relational Definition of the Human-Robot Relationship

With regard to the relational definition that was assigned to the human-robot relationship depicted in the photograph (H1, H4), an ANOVA was conducted with functional relational definition as dependent variable and context, direction, and intimacy as fixed factors.

The ANOVA revealed no significant main effect of context (H1), but a main effect of touch direction was significant ($F[2, 461] = 49.74$, $p < .001$, $\eta_{part.}^2 = .177$) as well as a significant interaction effect between touch direction and intimacy, $F(2, 461) = 49.42$, $p < .001$, $\eta_{part.}^2 = .177$. Hypothesis H1 therefore had to be rejected.

With regard to the main effect of touch direction, the mean values (Table 40) revealed that most functional definitions of the relationship were assigned if human-initiated touch was presented, followed by no touch, and reciprocal touch. The least functional interpretations of the relationship were applied to robot-initiated touch. This finding lends mixed support to H4, which assumed that non-reciprocal touch is interpreted more as a functional relationship than reciprocal touch, which is what was supported for human-initiated touch in comparison to reciprocal touch (significant difference according to post hoc comparison with Bonferroni correction, $p < .001$). However, robot-initiated touch was interpreted less as a functional relationship then reciprocal touch (difference also significant according to post hoc test, $p = .004$). This finding was relativized through the interaction of touch direction and intimacy.

Table 40. Means and standard deviations for the definition of the relationship as functional.

	Total per direction		Formal HRT		Intimate HRT		
	M	*SD*	*M*	*SD*	*M*	*SD*	*H*
no touch control	3.52	0.75					77
robot-initiated	2.87	0.88	2.49	0.88	3.29	0.66	133
reciprocal touch	3.15	0.76	3.59	0.54	2.72	0.70	135
human-initiated	3.71	0.59	3.69	0.61	3.73	0.58	137

When considering the means for the interaction effect of touch direction and intimacy, it appears that in line with H4, intimate non-reciprocal touch forms (human- and robot-initiated touch to the face) were more likely to be interpreted as a functional relationship than intimate reciprocal touch (embrace), whereas formal human-initiated touch led to more functional definitions than reciprocal touch, which further led to more functional definitions than robot-initiated touch. Accordingly, H4 was supported within intimate touch forms.

Relational Messages Conveyed through HRT

With respect to the relational meaning conveyed through HRT (H2, H5, H6), ANOVAs were calculated with context, direction, and intimacy of HRT as fixed factors and the relational themes affection, composure, formality, dominance, and attachment as dependent variables.

Affection

No main effect due to the context of HRT was observable (H2a), but main effects of touch direction ($F[2, 461] = 61.27$, $p < .001$, $\eta_{part.}^2 = .210$), and intimacy of touch ($F[1, 461] = 13.70$, $p < .001$, $\eta_{part.}^2 = .029$), emerged for the perceived affection that participants recognized from the robot to the human. Hypothesis H2a was therefore rejected for affection.

The observed main effect of touch intimacy was in line with hypothesis H5a. More affection was perceived when intimate HRT was presented ($M = 3.51$, $SD = 0.84$) than when formal HRT ($M = 3.25$, $SD = 0.81$) or the no-touch condition ($M = 2.98$, $SD = 0.65$) were presented. According to post hoc analyses (Bonferroni), the difference between intimate and formal HRT was significant ($p = .001$), supporting H5a.

Contrary to H6a, the mean ratings for affection according to touch direction demonstrated that most affection was conveyed through robot-initiated touch ($M = 3.86$, $SD = 0.68$). When reciprocal touches were presented, perceived affection was still high ($M = 3.39$, $SD = 0.83$), but it was lower when no touch ($M = 2.98$, $SD = 0.65$) or human-initiated touch were presented ($M = 3.31$, $SD = 0.82$). Post hoc comparisons with Bonferroni correction demonstrated that all pairwise comparisons differed significantly ($ps < .001$), except for human-initiated and no touch. The results demonstrate that reciprocal touch conveyed more affection than non-reciprocal touch initiated by the human, as hypothesized in H6a, although most affection from the robot to the human was perceived when the robot initiated touch to the human. In conclusion, partial support for H6a was observed.

Finally, no interaction effects between the independent variables were observed with regard to the conveyed affection (RQ1).

Composure

For the relational dimension composure, a three-factorial ANOVA yielded a significant main effect of touch intimacy ($F[1, 461] = 9.77$, $p = .002$, $\eta_{part.}^2 = .021$), as well as touch direction ($F(2, 461) = 15.50$, $p < .001$, $\eta_{part.}^2 = .063$), and a significant interaction effect between the intimacy and direction of HRT ($F[2, 461] = 4.70$, $p = .010$, $\eta_{part.}^2 = .020$). Contrary to H2, no effect of context occurred, which is why H2 was rejected for composure.

Mean ratings for composure showed that observers perceived the person on the picture to be more relaxed when intimate HRT was presented ($M = 3.60$, $SD = 0.84$) in comparison with no touch (M = 3.31, SD = 1.08) and formal HRT (M = 3.31, SD = 0.96). In line with H5a, the difference between intimate and formal HRT was significant, as was shown by a Bonferroni corrected post hoc test (p = .004).

A significant impact of touch direction also occurred, revealing that most composure was conveyed through human-initiated touch (M = 3.70, SD = 0.87), followed by reciprocal touch (M = 3.56, SD = 0.76) and no touch (M = 3.31, SD = 1.08), with robot-initiated touch conveying the least composure (M = 3.10, SD = 1.00). According to post hoc analysis with Bonferroni correction, the difference between reciprocal and robot-initiated touch was significant (p < .001), in line with H6a, but that between human-initiated touch and reciprocal touch was not.

The interaction effect between intimacy and direction further demonstrated that, in general, more composure was conveyed through intimate HRT when the direction was non-reciprocal. However, if there was reciprocal touch, no difference between intimate (embrace) and formal (handshake) touch was observable with regard to composure (Table 41).

Table 41. Means and standard deviations for the interaction effect between touch intimacy and direction.

	Total per direction		formal		intimate	
	M	*SD*	*M*	*SD*	*M*	*SD*
no touch control	3.31	1.08	-	-	-	-
robot-initiated	3.10	1.00	2.79	1.03	3.44	0.83
reciprocal touch	3.56	0.76	3.56	0.73	3.57	0.80
human-initiated	3.70	0.87	3.61	0.86	3.79	0.88
Total per intimacy	-	-	**3.31**	**0.96**	**3.60**	**0.84**

Attachment

With respect to the perceived attachment the person showed towards the robot(H5a), an ANOVA revealed main effects of touch intimacy ($F[1, 461] = 61.46$, $p <$ .001, $\eta_{part.}^2 = .118$), and touch direction (H6a; $F[2, 461] = 10.45$, $p < .001$, $\eta_{part.}^2 = .118$), as well as a significant interaction effect between them ($F[2, 461]) = 10.98$, $p < .001$, $\eta_{part.}^2$ =

.045). With regard to the context of HRT, no significant effect was observed, so therefore H2a was rejected for attachment.

Higher attachment was observed when intimate touch was included than when formal touch was included, yet formal touch in turn conveyed more attachment than no touch (Table 42). According to post hoc comparisons (Bonferroni), the differences between intimate touch and formal touch, and intimate touch and no touch, were significant (*ps* < .001). Hence, the results support H5a with regard to attachment.

Table 42. Means and standard deviations for perceived attachment according to touch intimacy, direction, and the interaction of both.

	Total per direction		formal		intimate	
	M	*SD*	*M*	*SD*	*M*	*SD*
No touch control	2.29	0.86	-	-	-	-
Robot-initiated	2.52	0.84	2.14	0.71	2.94	0.78
Reciprocal touch	2.99	0.88	2.49	0.72	3.49	0.74
Human-initiated	2.82	0.92	2.76	0.93	2.87	0.92
Total per intimacy	-	-	2.46	0.83	3.10	0.86

With regard to the direction of touch, reciprocal touch conveyed overall more attachment than human-initiated and robot-initiated touch, which in turn conveyed more attachment than no touch (Table 42). According to post hoc comparisons with Bonferroni correction, reciprocal touch was significantly higher than robot-initiated touch and no touch (*ps* < .001), and human-initiated touch differed significantly from robot-initiated touch (*p* = .015) and no touch (*p* < .001). In conclusion, H6a was supported for attachment.

The interaction between intimacy and direction of HRT (RQ1, Table 42) further demonstrated that most attachment was conveyed through intimate reciprocal touch (embrace). Within the intimate touch forms, reciprocal touch conveyed more attachment than robot-initiated and human-initiated touch, whereas within formal HRT forms, human-initiated touch conveyed more attachment than formal reciprocal touch (handshake) and robot-initiated touch (Table 42).

Relational Closeness

An ANOVA with perceived closeness as the dependent variable revealed no significant differences related to the context of HRT (H2). However, a significant main effect emerged for touch intimacy (H5a; $F[1, 461] = 55.49$, $p < .001$, $\eta_{part.}^2 = .107$), and touch direction (H6a; $F[2, 461] = 3.45$, $p = .032$, $\eta_{part.}^2 = .015$). The main effects were accompanied by a significant interaction of intimacy and direction (RQ1; $F[2, 461] = 4.72$, $p = .009$, $\eta_{part.}^2 = .020$). Because of the missing main effect of touch context, H2a was rejected for relational closeness.

Table 43. Means and standard deviations for the relational closeness per touch direction and degree of intimacy, and the interaction between them.

	Total per direction		formal		intimate	
	M	*SD*	*M*	*SD*	*M*	*SD*
no touch control	2.12	1.03	-	-	-	-
robot-initiated	2.56	1.09	2.17	0.96	3.00	1.06
reciprocal touch	2.84	1.42	2.19	0.80	3.49	1.61
human-initiated	2.48	1.23	2.27	1.15	2.70	1.28
Total per intimacy	-	-	2.21	0.98	3.07	1.37

As hypothesized in H5a, when intimate HRT was presented higher relational closeness between the human and the robot was perceived than when formal HRT was presented (Table 43). When formal forms of HRT were included, perceived closeness was still higher than when no touch was presented. Post hoc comparisons with Bonferroni correction showed that the differences between intimate and formal touch, and intimate and no touch, were significant (both *ps* < .001).

With regard to the different directions of touch that were presented in the pictures, the mean ratings (Table 43) demonstrate that perceived closeness was highest when the touch form was reciprocal compared with being initiated by the robot, followed by touch initiated by the human, as hypothesized in H6a. In contrast, no touch control stimuli were perceived as least close (Table 43). However, post hoc comparisons (Bonferroni) showed that the differences between reciprocal and non-reciprocal touch forms were not statistically significant (reciprocal and human-initiated: $p = .058$; reciprocal and robot-initiated: $p = .281$).

According to the significant interaction effect between intimacy and direction, it can be observed that intimate reciprocal touch conveyed more closeness than intimate robot-initiated touch, which in turn conveyed more closeness than intimate human-initiated touch. In contrast, more closeness was conveyed through formal human-initiated touch than through formal reciprocal and formal robot-initiated touch (Table 43). In all touch direction combinations, intimate touch forms conveyed more closeness than formal ones, in line with H5a.

Formality

For the perceived formality conveyed through the robot's behavior, no main effect of the context manipulation (H2b) was observed, but main effects of touch intimacy (H5b; $F[1, 461] = 32.46$, $p < .001$, $\eta_{part.}^2 = .066$), and touch direction (H6b; $F[2, 461] = 34.03$, $p < .001$, $\eta_{part.}^2 = .129$), were observable. H2b was thus rejected with regard to formality of the relationship. Touch intimacy and direction further showed a significant interaction (RQ1; $F[2, 461]$ 14.64, $p < .001$, $\eta_{part.}^2 = .060$).

The means for intimacy of HRT revealed that no touch was interpreted as most formal (*M* = 3.48, *SD* = 1.00), followed by formal HRT (*M* = 3.13, *SD* = 1.25), while intimate HRT was perceived as conveying least formality (*M* = 2.52, *SD* = 1.18). Post hoc comparisons (Bonferroni) revealed that intimate HRT differed significantly from formal HRT (*p* < .001). H5b was therefore supported.

With regard to the impact of touch direction on perceived formality, the mean ratings showed that no touch was perceived as conveying the most formality (*M* = 3.48, *SD* = 1.00), which was then followed by human-initiated touch (*M* = 3.36, *SD* = 1.13). Reciprocal HRT (*M* = 2.84, *SD* = 1.32) and robot-initiated touch (*M* = 2.28, SD = 1.06) conveyed less formality when only the direction of touch was considered, contrary to H6b. However, as stated above, a significant interaction between touch intimacy and direction was observed, which revealed that formal reciprocal touch (handshake) conveyed the most formality (Table 44). While intimate human-initiated touch conveyed more formality than robot-initiated and reciprocal HRT, formal reciprocal touch conveyed more formality than human- and robot-initiated touch (Table 44). In conclusion, support for H6b was observed within intimate touch forms only.

Table 44. Means and standard deviations for the relational message formality according to intimacy and direction of touch form.

	Total per direction		formal		intimate	
	M	*SD*	*M*	*SD*	*M*	*SD*
no touch control	3.48	1.00	-	-	-	-
robot-initiated	2.28	1.06	2.41	1.21	2.13	0.85
reciprocal touch	2.84	1.32	3.57	1.16	2.12	1.04
human-initiated	3.36	1.13	3.41	1.06	3.30	1.21
Total per intimacy	-	-	3.13	1.25	2.52	1.18

Significant interaction effects occurred between the context and the intimacy of touch, $F(2, 461) = 4.03, p < .001, \eta_{part.}^{2} = .060$, as well as between the context and direction of touch, $F(4, 461) = 3.14, p = .015, \eta_{part.}^{2} = .027$.

For formal touch forms, formality was higher when no context information was given than when affective or functional context information was presented (Table 45). Instead, when intimate HRT was presented in combination with a functional vignette, more formality was perceived than when intimate touch was presented together with no context or affective contextual information (Table 45). The findings regarding intimate HRT were in line with H2b; however, simple effects analysis solely within intimate HRT demonstrated that the difference between the affective and functional context was not significant. Hence H2b was still not supported with regard to formality.

Table 45. Interaction effect of context and intimacy of HRT on perceived formality.

	Intimacy			
	Formal		Intimate	
HRT context	*M*	*SD*	*M*	*SD*
None	3.28	1.22	2.40	1.16
Functional	3.00	1.28	2.79	1.07
Affective	3.06	1.26	2.38	1.27

The interaction effect between context and touch direction demonstrated that robot-initiated touch was rated as more formal in a functional context, whereas human-initiated and reciprocal touches were perceived as conveying more formality when no context or an affective context were provided in comparison with a functional context (Table 46).

Table 46. Interaction effect of direction and context on perceived formality of HRT

	Context for HRT					
	None		Functional		Affective	
HRT Direction	*M*	*SD*	*M*	*SD*	*M*	*SD*
Robot-initiated	2.25	1.11	2.71	1.35	2.33	1.20
Reciprocal touch	3.96	0.89	3.05	1.36	3.62	1.07
Human-initiated	3.76	0.78	3.22	1.13	3.23	1.19

Robot Dominance

An ANOVA for perceived robot dominance (H6c) revealed a main effect of touch direction, $F(2, 461) = 57.04, p < .001, \eta_{part.}^2 = .198$. The perceived dominance of the robot was highest if robot-initiated touch was depicted (M = 2.77, SD = 1.04), while reciprocal touches (M = 1.88, SD = 0.82), no touch (M = 1.79, SD = 0.82), and human-initiated touch (M = 1.71, SD = 0.77) conveyed considerably less perceived dominance. Post hoc comparisons (Bonferroni) further confirmed that the differences between robot-initiated touch and all other forms of touch were significant (all *ps* < .001), supporting H6c.

In conclusion to the relational interpretation of HRT, it can be summarized that the intimacy of the touch form had an effect on the conveyed affection, composure, formality, attachment, and relational closeness, as hypothesized: intimate HRT conveyed more affection, composure, closeness, and attachment (H5a), but less formality (H5b) than formal HRT. Furthermore, it was observed that the intimacy of touch significantly interacted with the direction of touch with regard to composure, formality, closeness, and attachment (RQ1).

When touch direction was regarded separately, mixed support for H6a and H6b was observed. Further, the interaction between touch intimacy and direction revealed that intimate reciprocal touch conveyed more closeness, attachment, and less formality than intimate non-reciprocal HRT, in line with H6a and H6b. Instead, formal human-initiated touch conveyed more closeness, attachment, and composure than formal reciprocal or formal robot-initiated touch. More formality was, however, conveyed through a formal reciprocal handshake touch than through a non-reciprocal formal touch to the arm. In conclusion, support for H6a and H6b was observed within intimate forms of HRT. With regard to the perceived dominance, H6c was, however, fully supported.

With regard to the research question RQ1 (interaction of intimacy and direction), it can thus be noted that interactions between intimacy and direction play a role in the interpretation of HRT.

8.6.2.2.3 Evaluation of HRT

With regard to the evaluation of HRT, it was hypothesized that HRT in a functional context is more likely to be evaluated favorably than touch in an affective context (H3). Furthermore, human-initiated touch was expected to be more desirable than reciprocal and robot-initiated touch (H7). It was hypothesized that within a functional context, formal touch is more favorable than intimate touch (H8), and it was questioned whether intimate HRT is instead desirable if the interaction context is affective (RQ2).

To test these hypotheses, four ANOVAs were conducted for the general evaluation and the three dimensions of the Self-Assessment Manikin (valence, arousal, and dominance), with context, intimacy, and direction as fixed factors.

8.6.2.2.4 General Evaluation

With regard to the general evaluation, a three-factorial ANOVA yielded a main effect of touch direction ($F[2, 461] = 27.82$, $p < .001$, $\eta_{part.}^{2} = .108$), but no main effect of the context and intimacy of HRT, contrary to H3 and H8. A significant interaction between the direction and intimacy of HRT (RQ1) was also observed ($F[2, 461]) = 3.76$, $p = .024$, $\eta_{part.}^{2} = .016$).

According to the mean ratings, the evaluation was most favorable when human-initiated touch was presented ($M = 3.47$, $SD = 0.55$). Reciprocal touch was also positively evaluated ($M = 3.37$, $SD = 0.60$), and better than no touch ($M = 3.34$, $SD = 0.58$) and robot-initiated touch ($M = 2.93$, $SD = 0.74$), in line with H7. Post hoc tests (Bonferroni) demonstrated that all touch forms differed significantly from robot-initiated touch (*ps* < .001).

The interaction effect with touch intimacy showed the following pattern: if intimate HRT was presented, the order was as hypothesized in H7, human-initiated touch ($M = 3.55$, $SD = 0.49$) was better than reciprocal ($M = 3.29$, $SD = 0.59$) and robot-initiated touch ($M = 3.04$, $SD = 0.70$). But if formal forms of touch were included, reciprocal touch ($M = 3.46$, *SD* = 0.60) had the highest evaluation, followed by human-initiated touch (*M* = 3.40, *SD* = 0.60) and robot-initiated touch (*M* = 2.83, *SD* = 0.76).

Self-assessed emotional state

As participants had to evaluate the emotional state they inferred from a third as well as a first person perspective ("Imagine you are the person on the picture, how would you feel?"), the values for valence, arousal, and dominance between both perspectives were compared first, to gather insights into potential variations (cf. Burgoon & Newton, 1991).

A paired sample t-test revealed that the means for valence and arousal did not differ significantly between either of the perspectives, but that imagined dominance was significantly $t(481) = -2.26$, $p = .025$, $d = -0.10$ more pronounced when participants rated the situation from a first person perspective (*M* = 3.73, *SD* = 0.97) than when they rated the situation from a third person perspective (*M* = 3.63, *SD* = 1.11), in line with earlier findings in interpersonal contexts (e.g., Burgoon & Newton, 1991).

The following analyses are based on the valence, arousal, and dominance ratings that were made from a third person perspective in order to remain in the "uninvolved" observer perspective.

Valence

For the assumed valence of the person in the situation, a three-factorial ANOVA indicated a main effect of touch direction ($F[2, 461] = 14.84$, $p < .001$, $\eta_{part.}^2 = .060$), as well as a significant interaction between direction and intimacy of touch ($F[2, 461] = 3.88$, $p = .021$, $\eta_{part.}^2 = .017$). Contrary to hypothesis H3 and H8, no main effects of interaction context or interaction with touch intimacy were observed with regard to perceived valence.

In line with hypothesis H7, valence was rated highest for pictures that showed human-initiated touches (*M* = 3.85, *SD* = 0.76), followed by reciprocal touch forms (*M* = 3.76, *SD* = 0.81). The perceived valence was also higher for no touch control stimuli (*M* = 3.48, *SD* = 0.62) than for pictures that presented touch initiated by the robot (*M* = 3.38, SD = 0.76), which still manifested a high mean value on a five-point scale. According to post hoc comparisons with Bonferroni correction, human-initiated touch differed significantly form robot-initiated touch ($p < .001$) and no touch ($p = .002$), and the differences between reciprocal and robot-initiated touch ($p < .001$), and reciprocal and no touch, were significant ($p = .044$).

The interaction between touch direction and intimacy further revealed that an intimate human-initiated touch to the face of the robot elicited higher perceived valence (*M* = 3.93, *SD* = 0.53) than intimate reciprocal touch (embrace, *M*= 3.66, *SD* = 0.96) and intimate robot-initiated touch (*M* = 3.52, *SD* = 0.67), whereas formal reciprocal touch (handshake) elicited better feelings (*M* = 3.85, *SD* = 0.61) than formal human- (*M* = 3.77, *SD* = 0.71) or robot-initiated touch to the arm of the other (*M* = 3.85, 0.61). In conclusion, support for hypothesis H7 can be found within intimate touch forms, but not within formal ones.

Arousal

With regard to the perceived arousal of the person in the picture, it was observed that higher ratings were visible when the context of touch was affective (*M* = 2.74, *SD* = 0.99) than when it was functional (*M* = 2.40, *SD* = 1.00), or if no contextual information was given (*M* = 2.40, *SD* = 0.95). An ANOVA revealed that the differences were statistically significant, $F(2, 461) = 5.71$, $p = .003$, $\eta_{part.}^2 = .024$. Post hoc pairwise comparisons (Bonferroni) demonstrated that arousal in the affective context differed significantly from arousal in the functional context ($p = .006$), and from no context ($p = .005$), as hypothesized in H3.

Furthermore, the ANOVA revealed a significant main effect of touch direction, $F(2, 461) = 4.84$, $p = .008$, $\eta_{part.}^2 = .021$. As hypothesized in H7, lowest arousal was indicated when human-initiated touch was depicted (*M* = 2.37, *SD* = 0.94), followed by reciprocal touch (*M* = 2.45, *SD* = 1.03), and no touch (*M* = 2.53, *SD* = 0.92). In contrast, the highest arousal was perceived when robot-initiated touch was presented (*M* = 2.71, *SD* = 1.02). Post hoc comparisons (Bonferroni) revealed that robot-initiated touch differed significantly only from human-initiated touch ($p = .020$). No effect of touch intimacy on arousal was observed, contrary to H8.

Dominance

An ANOVA yielded no main effect of touch context on perceived dominance, thus H3 was rejected. Instead, the dominance that observers assigned to the person in the picture were significantly influenced by touch direction (H7; F]2, 461] = 27.41, $p < .001$, $\eta_{part.}^2$ = .106). Perceived dominance was highest when human-initiated touch was presented (M = 3.96, SD = 0.83), followed by no touch (M = 3.82, SD = 0.94) and reciprocal touch (M = 3.64, SD = 0.87), whereas dominance was lowered when robot-initiated touch was presented (M = 3.18, SD = 1.00). According to post hoc analysis, all touch forms differed significantly from robot-initiated touch ($ps < .001$). Beyond this, human-initiated touch was also significantly different from reciprocal touch ($p = .018$). The findings support H7 with regard to perceived dominance.

Furthermore, touch intimacy also showed a significant main effect on perceived dominance (F[1, 461] = 24.64, $p < .001$, $\eta_{part.}^2$ = .051), with more dominance perceived when no touch (M = 3.82, SD = 0.94) or formal touch (M = 3.81, SD = 0.91) was included compared with when intimate forms of HRT were included (M = 3.38, SD = 0.95). Post hoc analysis demonstrated that the difference between intimate and formal touch was significant (p < .001).

Finally, there was no two-way interaction, as hypothesized in H8 (RQ2), but a significant three-way interaction effect was found with regard to dominance, $F(4, 461) = 3.33$, $p = .011$, $\eta_{part.}^2$ = .028. As is visible in Table 47, within the functional context, formal human-initiated and reciprocal touch evoked the highest perceived dominance, followed by intimate human-initiated and reciprocal touches, whereas less dominance was perceived when formal or intimate robot-initiated touch was presented. Instead, in an affective context, formal touch gestures evoked more feelings of dominance than intimate touches, whereas more dominance was perceived when non-reciprocal formal touch was presented than when reciprocal formal touch was presented. Perceived dominance in the affective context was lowest if intimate robot-initiated touch or intimate reciprocal touch was depicted. When no context information was given, formal touch also conveyed more dominance than intimate touch, with the exception of intimate human-initiated touch, which conveyed the second most dominance (Table 47).

Table 47. Mean and standard deviations for the three-way interaction effect of context, intimacy and direction for perceived dominance.

		Intimacy			
		formal		intimate	
Context	**Direction**	*M*	*SD*	*M*	*SD*
none	no touch control	3.71	1.06		
	robot-initiated	3.36	0.87	2.90	1.09
	reciprocal touch	4.04	0.79	3.35	0.81
	human-initiated	3.88	0.88	3.95	0.58
functional	no touch control	3.89	0.88		
	robot-initiated	3.10	0.89	3.05	1.02
	reciprocal touch	3.95	0.87	3.50	0.96
	human-initiated	4.35	0.83	3.78	0.85
affective	no touch control	3.82	0.95		
	robot-initiated	3.90	0.89	2.71	0.90
	reciprocal touch	3.57	0.81	3.42	0.81
	human-initiated	4.14	0.83	3.68	0.84

In summary, with regard to the evaluation of HRT (H3, H7, H8, RQ2), it can be observed that the context for HRT only affected the perceived arousal, as hypothesized in H3, but not the general evaluation, perceived valence, or dominance.

Additionally, no significant interaction effect between touch context and intimacy of touch was observed with regard to the evaluation of HRT, as hypothesized in H8 (see also RQ2). Instead, touch intimacy showed a significant interaction with touch direction on the general evaluation of the interaction, and also in the perceived valence: intimate human-initiated touch to the face of the robot was better evaluated than reciprocal embrace touch and robot-initiated touch to the human's face, while formal reciprocal handshake touch was better evaluated than formal human- and robot-initiated touch to the arm of the counterpart. In conclusion, support for H3 was only observed with regard to the arousal level that participants assigned to the person observable in the picture.

However, strong support was gathered for hypothesis H7 that human-initiated touch is more likely to receive a favorable evaluation than reciprocal HRT and robot-initiated touch. The results regarding all dependent measures (evaluation, valence, arousal, and dominance) confirmed the hypothesis. Beyond this, significant interaction effects between touch direction and intimacy of touch were observed for the general evaluation and perceived valence (RQ1), which demonstrated that the hypothesized sequence of touch forms applies to intimate touch forms, but not to formal ones. While intimate human-initiated touch was better evaluated than reciprocal intimate touch (embrace), formal reciprocal touch (handshake) was favored over human-initiated touch.

Table 48. Overviews of the means and standard deviations for all dependent variables divided by context for touch.

	Context of HRT					
	No context control		Functional		Affective	
Dependent variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
Functional relationship	3.30	0.84	**3.34**	0.79	3.23	0.83
Personal relationship	2.72	0.81	**2.71**	0.84	2.67	0.83
Affection	3.30	0.80	3.26	0.81	**3.38**	0.86
Robot dominance	2.06	0.98	**2.12**	0.97	2.02	0.98
Composure	3.47	0.91	**3.48**	0.94	3.34	0.98
Formality	2.96	1.25	**2.97**	1.19	2.87	1.28
Attachment	2.70	0.89	**2.78**	0.93	2.61	0.91
Closeness	2.57	1.18	2.48	1.17	**2.60**	1.37
Prior touch expectancy	2.96	0.90	2.77	0.94	**2.93**	0.96
Expectedness	2.89	0.86	2.75	0.87	**2.88**	0.94
Evaluation	3.29	0.63	**3.29**	0.68	3.24	0.67
Valence	3.62	0.73	**3.69**	0.76	3.59	0.73
Arousal	2.40	0.95	2.40	1.00	**2.74**	0.99
Dominance	3.61	0.94	**3.68**	0.98	3.61	0.94

With regard to the context for HRT (H1, H2, H3, H8), a significant main effect was only observed for perceived arousal, but not for the other dependent measures. Table 48 demonstrates that according to the mean ratings, the relationship between the human and the robot in the picture was more likely to be perceived both as a functional and as a personal relationship in the functional context than in the affective context, contrary to expectations; however, the differences were not statistically significant. Furthermore, the ratings for the relational interpretation of the presented stimuli revealed that perceived affection was higher in the affective context, whereas in the functional context, dominance, composure, formality, and attachment were rated higher for HRT. In contrast, participants' prior expectations that touch will be included in the interaction with the robot, as well as the assessed expectedness after the stimulus presentation, demonstrate that HRT was more expected in an affective context, albeit the difference was not significant. Finally, in the functional context the evaluation of the interaction was higher, and thus more positive than in the affective context, as hypothesized, but the mean differences were only minimal.

In the following section, the analyses concentrate on the expectations participants held with regard to HRT, and how the context, direction, and intimacy of HRT alter them.

8.6.2.3 Touch Expectations

8.6.2.3.1 A priori touch expectancies

To test whether the context manipulation affected HRT expectations (RQ3) a priori to being exposed to HRT, a MANOVA with the formulated touch expectations ("Human and robot touch each other", "The human touches the robot", "The robot touches the human") as dependent variables and touch context as a fixed factor was conducted. The analysis revealed no significant multivariate or univariate effects. Expectations about reciprocal HRT were on average highest in the affective context condition (M = 2.90, SD = 1.23), which was followed by no context (M = 2.83, SD = 1.18), while they were lowest in the functional context (M = 2.66, SD = 1.20). According to the mean ratings, human-initiated touch was most likely to be expected in the no context control condition (M = 3.46, SD = 1.03), followed by the affective context (M = 3.40, SD = 1.13), and finally the functional context (M = 3.19, SD = 1.18). Robot-initiated touch was also most likely to be expected when no context was given (M = 2.58, SD = 1.12), but was still slightly more likely to be expected when the context was affective (M = 2.48, SD = 1.14) than when it was functional (M = 2.44, SD = 1.11). In summary, all forms of HRT were slightly more likely to be expected when an affective context was presented compared to a functional context, although the differences were insignificant. Furthermore, within each context, touch initiated by a human was more expected than reciprocal touch, which in turn was more expected than touch from a robot to a human. With regard to RQ3, the findings suggest that touch expectancies prior to being exposed to HRT were not significantly affected by the announced interaction context.

Although touch expectations for HRI were not significantly affected by the context described in the vignette, the manipulation showed a significant impact on the other interaction expectations. A MANOVA with the expectations that the human and the robot "look at each other", "talk to each other", and "work with each other" as dependent variables and context as a fixed factor yielded a significant multivariate effect: Pillai's trace = 1.81, $F(6, 956) = 15.82$, $p < .001$, $\eta_{part.}^2 = .090$.

Significant univariate effects for all three statements (see Table 49) demonstrated that higher expectations with regard to attention ("look at each other") and conversation ("talk to each other") were evoked by the affective context vignette than when no context or a functional description was provided. Furthermore, participants rather expected the human and the robot to work with each other in the functional context, more so than when no context or an affective context was given. According to this finding, which is somewhat redundant to the manipulation check, context did in fact affect participants' expectations regarding HRI, but not with regard to HRT in particular.

Table 49. Means, standard deviations and MANOVA results for general interaction expectancies.

Context for HRT	*M*	*SD*	Univariate effects			
			F	*df*	*p*	*eta*
I expect that the human and the robot....						
... look at each other.			39.99	2	< .001	.143
no context	3.67	1.10				
functional	3.03	1.25				
affective	4.12	0.93				
... talk to each other.			4.25	2	.015	.017
no context	3.44	1.06				
functional	3.30	1.25				
affective	3.67	1.11				
... work with each other.			8.61	2	< .001	.035
no context	3.96	0.96				
functional	4.21	0.98				
affective	3.75	1.10				

The following paragraph continues with the expectedness of HRT that was assessed after the stimulus was presented.

8.6.2.3.2 Expectedness of HRT

With respect to the question whether HRT violates the expectations of observers of touch in different contexts (H9 – H11), an ANOVA with interaction context, touch direction, and touch intimacy as fixed factors and expectedness as a dependent variable was calculated.

The analysis revealed a main effect of touch direction (H10; $F[2, 461] = 31.76$, $p < .001$, $\eta_{part.}^2 = .121$), and intimacy of touch (H11; $F[1, 461] = 19.22$, $p < .001$, $\eta_{part.}^2 = .040$) on expectedness, but no main effect due to the context manipulation appeared (H9). However, a significant interaction effect between context and intimacy was observed ($F[2, 461] = 5.40$, $p = .005$, $\eta_{part.}^2 = .023$). Formal HRT (handshake, arm touch) was more expected in an affective context ($M = 3.17$, $SD = 0.90$) than in a functional context ($M = 2.86$, $SD = 0.88$) or no context ($M = 2.88$, $SD = 0.80$), whereas intimate HRT (embrace and face touch) was more expected in a functional ($M = 2.60$, $SD = 0.93$) than an affective context ($M = 2.45$, $SD = 0.91$). When no contextual information was given, intimate HRT was even more expected ($M = 2.93$, $SD = 0.96$) than when a functional or affective context was presented by means of a vignette. With regard to the hypothesis H9, the hypothesized pattern for intimate touch met the expectations (functional > affective), whereas formal forms of touch were more expected in an affective context than in a functional context. Additional simple effects analysis, however, revealed that the differences in expectedness between the functional and affective context were not significant, neither within intimate nor formal touch forms. In conclusion, H9 had to be rejected.

With regard to the effect of HRT direction on the expectedness (H10), the mean values showed that human-initiated touch ($M = 3.23$, $SD = 0.86$) was the most expected, followed by the control stimuli that showed no touch ($M = 3.07$, $SD = 0.70$). Pictures that depicted reciprocal HRT ($M = 2.63$, $SD = 0.93$) rather violated observers' expectations, as did pictures that depicted robot-initiated touch ($M = 2.52$, $SD = 0.80$). Post hoc comparisons with Bonferroni correction demonstrated that the differences between human-initiated touch and reciprocal ($p < .001$), as well as human-initiated and robot-initiated touch ($p < .001$), differed significantly, but reciprocal and robot-initiated touch did not. In line with H10, the mean ratings support the assumption that human-initiated touch was more expected than reciprocal and robot-initiated touch. Moreover, it was revealed that human-initiated touch was equally expected than the no touch control stimulus.

As stated above, a main effect of touch intimacy on expectedness was also observed. According to the means, formal touches were significantly more likely to be expected (*M* = 2.96, *SD* = 0.86) than intimate HRT forms (*M* = 2.62, *SD* = 0.94), which rather violated expectations, as hypothesized in H11. However, a significant interaction effect between touch direction and intimacy of touch was observed (RQ1; $F[2, 461] = 20.75$, $p < .001$, $\eta_{part.}^2 = .083$), which demonstrated that formal touch initiated by the robot (touch to human's arm) violated expectations rather more than formal human-initiated (touch to robot's arm) and formal reciprocal touch (handshake, see Table 50). Instead, for the intimate forms of HRT, non-reciprocal touch (face touch) from the human to the robot was the most expected, followed by robot-initiated touch, with intimate reciprocal touch (embrace) violating observers' expectations (Table 50). Consequently, the hypothesized expectedness of HRT directions (H5) was supported with respect to the formal forms of HRT, whereas for intimate forms of HRT, robot-initiated touch to the face of the human was even more expected than reciprocal touch (embrace), contrary to H10. In summary, mixed support for H10 was demonstrated.

Table 50. Means and standard deviations for the expectedness of HRT according to intimacy and direction of touch.

Intimacy of HRT	Direction of HRT	*M*	*SD*
Control (n = 77)	no touch	3.07	0.70
Formal (n = 207)	robot-initiated	2.55	0.81
	reciprocal touch	3.16	0.79
	human-initiated	3.18	0.85
Intimate (n = 198)	robot-initiated	2.48	0.80
	reciprocal touch	2.11	0.74
	human-initiated	3.27	0.87

As it has been demonstrated that different expectations for different forms of HRT prevail, the following analyses focus on the HRT appraisal process and the question of how the evaluation of HRT can be predicted through the included variables.

8.6.3 HRT Appraisal Process and the Role of Expectancies

According to EVT, it was hypothesized that the expectedness (H12a) and the affective interpretation of HRT (affection from the robot to the human and attachment from the human to the robot, H12b) were positively related to the evaluation of HRT.

Furthermore, it was assumed that the effect of touch direction on the evaluation was mediated by the expectedness and interpretation of HRT, and that the mediation effect depends on the moderating role of the rewarding nature of the robot (social and task attraction) (H13). Hence, a conditional indirect effect of HRT direction on the evaluation through expectedness and interpretation of HRT was assumed, and also that this would be moderated by robot reward (Figure 12).

To test these assumptions, a moderated mediation analysis was calculated by means of the latest version of the PROCESS macro for SPSS (Hayes, 2015), with 5000 bootstrap resamples and a 95% confidence interval level. According to the assumed effects (Figure 12), model 16 (Hayes, 2013) was chosen, which allows the test of a moderated mediation model with two moderators.

The direction of touch (robot- versus human-initiated, N = 270) was entered as an independent variable, expectedness, affection, and attachment were entered as mediators, social attraction and task attraction as moderators, and evaluation as a dependent variable (see Figure 12 for the theoretical model).

The analyses only focused on the impact of touch direction, as earlier analyses demonstrated that the evaluation of HRT is mainly affected by the direction. Furthermore, the largest differences were observed between human- and robot-initiated touch, thus the model concentrates on this distinction.

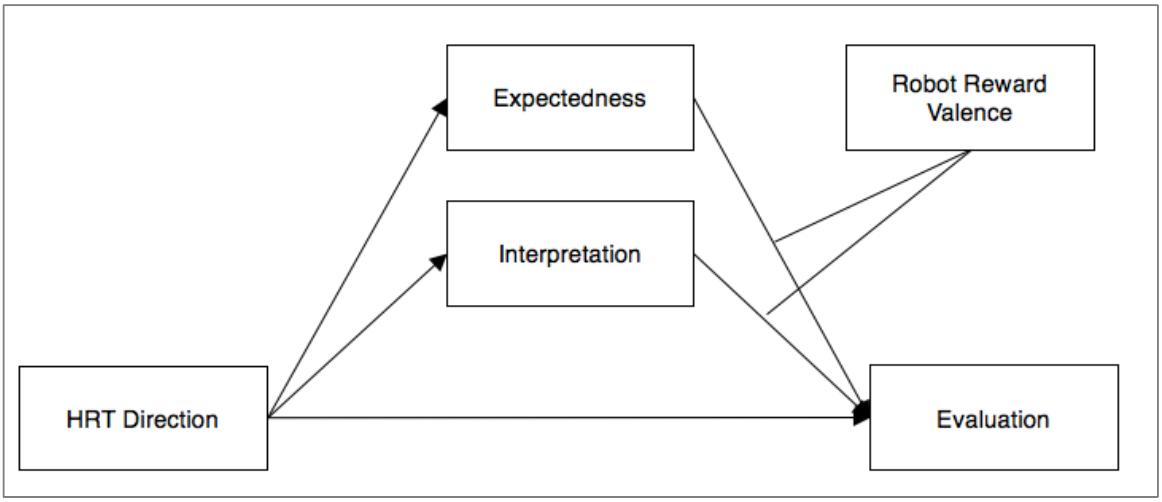


Figure 12. Theoretical model of the moderated mediation of touch direction on evaluation through expectedness and interpretation moderated by reward.

The multiple moderated mediation analysis revealed a significant model (see Figure 13) for the evaluation of HRT ($F[12, 257] = 24.50$, $p < .001$), which explained half of the variance, $R^2 = .50$. As revealed in the earlier ANOVA (see above), the direct effect of touch direction on the evaluation was in favor of human-initiated touch: HRT was significantly better evaluated if the touch was directed from the human to the robot rather than vice versa.

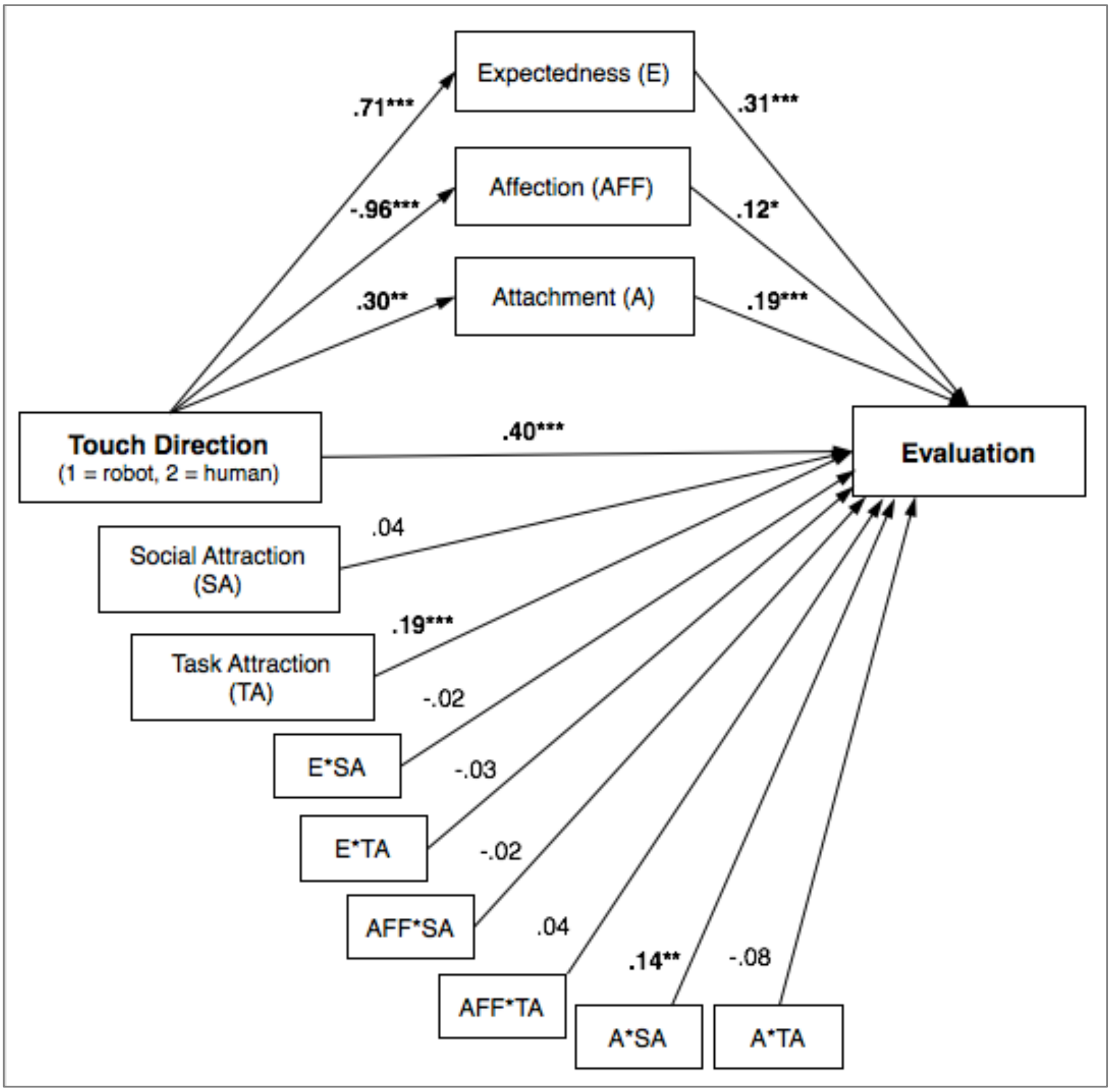


Figure 13. Statistical model for the moderated mediation analysis with regression coefficients. * p < .05. ** p < .01, *** p < .001

Furthermore, as hypothesized in H12a and H12b, (a) expectedness and (b) the interpretation of HRT as affection and attachment were positively related to the evaluation of HRT (see Figure 13). A significant conditional indirect effect of touch direction on the evaluation through attachment moderated by social attraction was also revealed, with the index of partial moderated mediation (0.04, 95% confidence interval [0.008, 0.088]) demonstrating that if task attraction was kept constant, the indirect effect was strongest if social attraction was high, 95% *CI* [0.026, 0.178], less when social attraction was average, 95% *CI* [0.015, 0.111], and insignificant if social attraction was low, 95% *CI* [- 0.019, 0.066]. Hence, it can be stated that the effect of touch direction on evaluation is mediated by the perceived attachment if the robot is medium to highly rewarding in terms of social attractiveness, in line with H14b (moderated mediation effect).

In summary, the reward valence of the robot, operationalized by perceived attraction of the robot, has been demonstrated to affect the relationship between the interpretation of HRT and the evaluation of HRT, as a conditional indirect effect of touch direction on evaluation through attachment was revealed if reward (here: social attraction) was at least average or high. As hypothesized in H14b, if the robot's reward was high and touch is interpreted as conveying attachment, the evaluation of HRT is likely to be favorable, lending further support to H13b.

With regard to the expectedness of HRT, no conditional indirect effect was observed, as hypothesized in H14a. However, an additional mediation analysis (Hayes PROCESS Model 4) of touch direction on evaluation through expectedness revealed that the indirect effect was significant, $b = .246$, bootstrapped $SE = .049$, bootstrapped CI [0.157, 0.350]. Hence, it has been revealed that the expectedness of the observed behavior mediated the effect of touch direction on evaluation, as hypothesized in H13a, but that robot reward did not moderate this indirect effect through expectedness, as hypothesized in H14a.

In summary, the final analyses demonstrated that the HRT appraisal process of non-reciprocal touch forms can be explained through the expectedness and relational interpretation of HRT, as theorized in expectancy violation theory. With regard to the evaluation of touch, human-initiated touch was again favored over robot-initiated touch. According to the model, this could be explained by a higher expectedness of human-initiated touch, with lower attachment but higher affection from the robot to the human, which is only favorably evaluated if the robot is perceived as medium to highly rewarding.

A summary of all hypotheses and their support or rejection according to the findings can be found in Table 51.

Table 51. Overview of the findings and their meanings for the hypotheses.

Hypothesis	Hypothesized direction	Result (main effects)	Interaction effects
Influence of the context manipulation			
H1	Functional relationship definition: functional > affective	Not supported	Direction × intimacy of HRT: Intimate: human & robot > reciprocal Formal: human > reciprocal > robot
H2	Relational Interpretation a) intimacy: affective > functional b) formality: functional > affective	a) Intimacy Affection: not supported Composure: not supported Attachment: not supported Closeness: not supported b) Formality: not supported	Direction × intimacy of HRT: *Attachment & Closeness* Intimate: reciprocal > human & robot Formal: human > reciprocal > robot Context × intimacy of HRT: *Formality* Formal: affective > functional Intimate: functional > affective
H3	Evaluation: functional > affective	Evaluation: not supported Valence: not supported Arousal: supported Dominance: not supported	*Evaluation & Valence* Intimate: human > reciprocal > robot Formal: reciprocal > human > robot
Influence of touch form (direction and intimacy)			
H4	Functional relationship definition: non-reciprocal > reciprocal	Not supported	
H5	Relational Interpretation a) intimacy: intimate touch > formal touch b) formality: formal touch > intimate touch	a) Intimacy Affection: supported Composure: supported Attachment: supported Closeness: supported b) Formality: supported	
H6	Relational Interpretation a) intimacy: reciprocal > non-reciprocal b) formality: non-reciprocal > reciprocal c) dominance: robot-initiated > human-initiated and reciprocal	a) Intimacy Affection: not supported Composure: not supported Attachment: supported Closeness: supported b) Formality: not supported c) Dominance: supported	
H7	Evaluation: human-initiated > reciprocal > robot-initiated	Evaluation: supported Valence: supported Arousal: supported Dominance: supported	
H8	Evaluation: formal > intimate	Not supported	
Expectedness of HRT according to the manipulations			
H9	Expectedness: functional > affective	Not supported	Context × intimacy of HRT: Formal: affective > functional Intimate: functional > affective
H10	Expectedness: human-initiated > reciprocal > robot-initiated	Not supported	Direction × intimacy of HRT: Formal: human > reciprocal > robot Intimate: human > robot > reciprocal
H11	Expectedness: formal > intimate	Supported	
Appraisal process of HRT			
H12	a) Expectedness → evaluation (+) b) Interpretation → evaluation (+)	a) supported b) supported	
H13	a) direction → expectedness → evaluation b) direction → interpretation → evaluation	a) supported b) supported	
H14	a) Expect *robot reward → evaluation b) Interpretation*robot reward → evaluation	a) not supported b) supported	

8.7 Discussion

The present study focused on the impact of contextual information and expectations regarding different forms of touch in HRI. For this purpose, an experimental online study was conducted that compared HRT forms depicted in photographs with varying direction and intimacy. This was considered to be the most controlled way to investigate the perception, interpretation, and evaluation of HRT. Furthermore, the presentation of the stimuli was embedded in a functional or affective context, to test whether the context influences how touch is interpreted and evaluated. In the following, the results are summarized and interpreted in the light of previous theoretical assumptions and empirical evidence. Since most assumptions have been based on literature from interpersonal touch research, with the presumption that these findings can be applied to HRT (Nass & Moon, 2000; Reeves & Nass, 1996; cf. Chapter 1), the present findings are contrasted to related work from interpersonal touch research, with attention paid to potential similarities and distinctions between interpersonal touch and HRT.

8.7.1 Influence of the context of HRT

One aim of the present online experiment was the systematic comparison of the interpretation and evaluation of HRT in distinct contexts. Therefore, the photographs that depicted HRT were presented in either an affective context where the human and the robot are getting to know each other, or in a functional context in which the human and the robot solve a task together.

Contrary to the assumed impact that contextual information was believed to have on the expectedness, interpretation, and evaluation of HRT, only a significant main effect on the perceived arousal participants assigned to the person in the picture was observable. Furthermore, an interaction effect for the expectedness of HRT showed that formal touch forms (and no touch) were more likely to be expected in an affective context than in a functional context, but that intimate touch forms were instead more likely to be expected if the interaction context was functional in nature.

The following paragraphs summarize the findings regarding the relational definition and interpretation, and also those with regard to the evaluation of HRT.

Relational definition and interpretation. Contrary to the assumptions, the analyses revealed that the context of HRT did not affect the relational definition of the human-robot relationship (H1) or the relational interpretation (H2a and H2b). According to Jones and Yarbrough (1985), it has been hypothesized that touch in an affective context should carry meanings of affection and inclusion, while touch in a more functional task-related context should convey less intimacy and affection (H2a). Although the average ratings (cf. Table 48) mostly pointed in the assumed direction (more affection and closeness in the affective context, more formality and dominance in the functional context), the differences did not approach significance. For formality that was conveyed by the gesture of the robot, interaction effects of touch context and direction, as well as context and intimacy of touch, revealed that robot-initiated touches and intimate touch forms, conveyed higher formality in the functional context than in the affective context, in line with H2b.

On the basis of the findings and discussion brought up in Burgoon and Newton (1991), the missing difference for the other variables may be dependent on the observer perspective. According to Burgoon and Newton (1991), observers of touch and participants in touch interactions have distinct attributional bases that determine their interpretations and evaluations of touch. Whereas participants are more involved in the interaction and are sensitive to contextual factors, observers focus their attention on the interacting partners, and thus make more dispositional attributions, while participants make more situational attributions. In conclusion, contextual information was less important to observers of HRT. Furthermore, it appears as if the depicted situation in the photograph, i.e., the touch form that was presented, has an even stronger impact on the interpretation of HRT. Regardless of the given context, the observer's interpretations of HRT were dependent on the direction and intimacy of the touch form that was presented (summary on the results of touch form below). However, it is still conceivable that contextual information has a stronger impact if one is actually interacting with a robot, touching the robot, or getting touched by the robot, instead of passively observing HRT.

Evaluation. The evaluation of HRT was based on a general evaluation of the interaction (as in Burgoon & Walther, 1990; Burgoon et al., 1992), and also on the feelings observers assigned to the person in the picture (SAM, valence, arousal, and dominance). As the analyses demonstrated, the context manipulation had a significant effect on assigned arousal, but not on the overall evaluation and the perceived valence and dominance of the person. Arousal was higher in the affective context than in the functional context, which can be regarded as in line with H1 if higher arousal is interpreted as a negative emotional state and lower arousal as a positive emotional state. Although it can be argued that arousal can also be positively valenced, e.g., if arousal stands for excitement, the negative correlations between arousal and valence support the assumption that arousal was a negatively associated emotional state for the participants in the present sample. The finding is comparable to that of Nilsen and Vrana (1998) who reported increased physiological arousal after affectively motivated touch between humans as opposed to functional touch that resulted in decreased arousal. The authors argued that affective (social) touch conveys meanings of intimacy, which are inappropriate in a professional setting and hence increase arousal.

In the present study where participants observed touch between a human and a robot, it seems as if the affective context added some information to the stimulus that resulted in higher assigned arousal than when the context was described as functional or when no information was given. Initially, it appeared as if higher arousal was perceived, because an affective interaction scenario was overall less expected than a functional context for HRT. However, mean ratings for the expectedness according to the context were higher in the affective context, contradicting this explanation.

These results are in line with earlier work on robot touch. Chen et al. (2014) demonstrated that affectively framed robot-initiated touch led to higher levels of arousal (self-reported arousal of the participants, assessed with the SAM) than instrumentally framed robot-initiated touch. Furthermore, they reported more enjoyment of the touch when the intent was instrumental compared to an affective intent. The average ratings for the evaluation, valence, and dominance in the present study pointed to the same direction, but the differences were quite small and were statistically insignificant. As mentioned above, this might be caused by the lower involvement of the participants due to the observer perspective, and also a stronger focus on dispositional factors than on contextual variables (Burgoon & Newton, 1991).

Against the background that functional touch between humans, as well as between humans and robots, had so far been demonstrated to be favored in professional settings (Chen et al., 2014, 2011; Nilsen & Vrana, 1998), it had furthermore been hypothesized that formal forms of HRT would be better evaluated than intimate forms of touch in a functional professional context (H8). However, as no interaction effect between context and intimacy in the evaluation of HRT was evident, the findings of the present study did not support this assumption. Accordingly, the question as to whether intimate forms of HRT are more favorably evaluated in an affective context (RQ2) has to be answered in the negative.

8.7.2 Influence of touch direction and intimacy, and the interplay

As determined in the findings regarding the context, the form of touch had a significant influence on the perception and interpretation of HRT, as well as on the evaluation.

Relational definition and interpretation. In line with H4, the direction of HRT influenced the relational definition of the human-robot relationship: human-initiated touch was more likely to evoke functional relational definitions than reciprocal touch, but robot-initiated touch evoked less functional definitions than reciprocal touch. Hence, only mixed support for H4 was observable. Regarding the relational interpretation (H5), the analyses demonstrated that HRT intimacy influenced the perceived affection, composure, formality, attachment, and closeness. As hypothesized in H5a, more affection composure, closeness, and attachment, and as hypothesized in H5b, less formality, were perceived to be conveyed through intimate touch forms than through formal forms of HRT. The findings resemble earlier findings gained in the context of interpersonal touch. As Burgoon (1991; see also Burgoon & Walther, 1990) demonstrated, more relational meanings of intimacy were assigned to interpersonal touches that were more intimate, such as an arm around the shoulder. As already reported in Study 1, this finding revealed that interpretations of touch between humans and robots follow similar rules to interpersonal touch. Burgoon (1991) speaks of a social meaning model that individuals share about nonverbal behaviors. In conclusion, individuals seem to transfer this social meaning model when they observe touch between humans and robots.

Beyond this, it was revealed that touch direction also significantly affected the interpretation of HRT. As hypothesized in H6a, perceived attachment and relational closeness were rated highest when reciprocal touch was depicted, as compared to non-reciprocal human- or robot-initiated touch. But contrary to the assumed order, more affection was perceived when the robot touched the human than when reciprocal and human-initiated touch was presented, and more composure was perceived when human-initiated touch was shown compared to reciprocal and robot-initiated touch. Regarding the perceived formality of HRT (H6b), the results showed that no touch was perceived as most formal, followed by human-initiated and reciprocal touch, with robot-initiated touch being perceived to convey least formality. For the last dimension of dominance, it was revealed that highest robot dominance was perceived when robot-initiated touch was presented, as opposed to other forms of touch being depicted, in line with H6c. In conclusion, robot-initiated touch has been revealed to be perceived as conveying affection and dominance, but less formality.

That robot-initiated touch was perceived as conveying more affection than reciprocal touch could be ascribed to the wording of the items, e.g., "The robot is showing affection for the person." As the formulation indicates a clear direction of affection from the robot to the human, it is plausible that higher ratings were observed if the robot-initiated touch was present than when reciprocal touch was depicted, which in turn was rated higher than human-initiated touch. However, the finding demonstrates that observers did in fact perceive the gesture of the robot as affective, which means that robot touch is linked with affective meanings rather than only instrumental or functional meanings. Additionally, the finding that robot-initiated touch conveyed least formality also supports this assumption.

Further interaction effects between touch intimacy and direction occurred with regard to the relational definition as functional, the conveyed composure, formality, perceived attachment, and relational closeness (RQ1). Attachment and closeness were more strongly conveyed through intimate reciprocal touch than through non-reciprocal touch forms, whereas formality was rather more conveyed through formal reciprocal touch. The results support the notion of Henley (Henley, 1973, 1977, 2012), that reciprocal touch forms are more associated with closeness, whereas non-reciprocal touch is more associated with dominance and status; this also appears to hold in the context of HRI. In addition, the interaction effects between intimacy and touch direction demonstrated that the degree of touch intimacy determines the meaning of reciprocal and non-reciprocal HRT. Overall, intimate touch forms are in line with the notion made by Henley (Henley, 1973, 1977, 2012): intimate non-reciprocal touch led to more relational definitions in a functional relationship, and conveyed more formality than intimate reciprocal touch, while intimate reciprocal touch conveyed more attachment and closeness than non-reciprocal intimate touch forms. Instead, formal forms of HRT followed a different pattern, where touch initiated by the human evoked more attachment and closeness, and more functional relational definitions than reciprocal and robot-initiated touch. One reason could be that observers of HRT imagined a stronger bond between the human and the robot if the human touched the robot's arm, rather than when a handshake was presented, because handshakes are more associated with distanced relationships (cf. Burgoon, 1991; Burgoon & Walter, 1990). Maybe observers perceived the relationship as least close when the robot touched the human's arm, because a formal touch from a robot is less related to relational closeness, while observers might have assumed that a stronger bond must exist if the person touched the robot.

The comparison of the different touch forms (directions) to the no touch control stimulus further demonstrated that, similar to observations made in the interpersonal context (Kleinke, Meeker, & La Fong, 1974), perceived relational closeness and attachment were higher when any form of touch was presented compared to no touch. Therefore, the observation of touch between humans and robots increases the perceived relational bond between then, and also the evoked relational interpretations similar to those described for interpersonal touch observations (Burgoon, 1991; Burgoon & Walther, 1990). Hence, it can be concluded that HRT in general, and specific forms of HRT in particular, affect the perception and interpretation of human-robot relationships.

As Heslin and Alper (1983) stated, the congruency between relational intimacy and touch intimacy is important to ensure that comfort and not discomfort is evoked by touch. Consequently, it should be clarified how HRT forms that convey relational messages of affection and closeness are evaluated.

Evaluation. With regard to the evaluation of HRT, it was overall supposed that human-initiated touch elicits the most positive reactions, followed by reciprocal and robot-initiated touch (H7). This supposition was made according to earlier investigations on interpersonal touch that demonstrated that the initiation of touch is more favorably evaluated than the reception of touch (Major & Heslin, 1982). The analyses revealed that, in line with H7, human-initiated touch forms elicited more favorable overall evaluations, and higher reported valence and dominance, than reciprocal and robot-initiated touch forms, while the assigned arousal pointed in the opposite direction. Beyond this, significant interaction effects between touch direction and intimacy showed that the assumed order (H7) applied to intimate touch forms, whereas formal reciprocal touch was even more favorably evaluated in comparison with human- and robot-initiated formal touch. In conclusion, formal reciprocal touch such as a handshake between a human and a robot is more desirable than non-reciprocal formal touch (cf. Burgoon & Walther, 1999), but if intimate touch forms are involved, human-initiated touch is the most desirable form of touch, in line with the findings of Major and Heslin (1982). Although participants in this study were only observers of HRT, it seems as if they identified themselves with the person in the picture when they evaluated the interaction, and hence rated pictures that depicted human-initiated touch more favorably than robot-initiated touch; it is better to give than to receive, according to Heslin and Alper (1982). Comparable to the findings from Study 1, it can also be inferred that human-initiated touch is favorably evaluated, as it is most likely to be interpreted functionally, on the basis of the interest or curiosity of the human person in the picture. Hence, this form of touch was the most natural and understandable, and therefore the least surprising to the participants (see next section on expectedness).

The results are somehow contradictory to those reported in Shiomi et al. (2016; see also Nakagawa et al., 2011), who demonstrated that a robot was evaluated more favorably (here: marginally more friendly) when it actively touched the hand of a participant compared to a condition in which the human participant touched the hand of the robot or no touch happened at all. Hence, it seems as if robot-initiated touch was preferred over human-initiated touch in Shiomi et al. (2016). It should be remarked on that the robot in the study always invited the participant to put her or his hand on the robot's hand first. Because of this, the active touch that followed the touch from the human to the robot can be understood as a reciprocation of touch, which might have caused a more favorable evaluation than passively requested touch to the robot's hand on its own. Consequently, human-initiated touch in advance of robot-initiated touch seems to have a positive influence on the evaluation of robot-initiated touch. A reason for this preference might be the tendency to prefer the initiation of touch rather than the reception of touch (Major & Heslin, 1982). Furthermore, this suggests that the acceptance for robot-initiated touch might be increased if users were first invited to touch a robot, as in a familiarization phase. In this sense, the findings of the present study did not contradict the findings of Shiomi and colleagues. However, future work should study the effect of robot-initiated touch on the evaluation separately, to understand its effects more clearly.

8.7.3 Expectedness of HRT

Following *expectancy violation theory* (Burgoon, 1993; Burgoon & Hale, 1988), touch expectations were considered, as they can help to understand the appraisal process that determines the evaluation of HRT.

As the analyses demonstrated, the context that was presented by means of vignettes did not affect touch expectations prior to exposure to the stimulus picture, but general interaction expectations, such as the human and the robot pay attention and talk to each other. The analyses of the additional statements revealed that higher expectations regarding conversation and mutual attention were evoked when affective context information was given in advance, as opposed to functional context information or no information at all. Hence, it seems as if the distinction between a functional and an affective context was reasonable, as it affected participants' expectations, although not expectations regarding HRT. It can be suspected that the effect of the context on prior touch expectancies was lower, as touch (especially reciprocal and robot-initiated) was generally less expected. Maybe participants already had developed expectations about robots' abilities to talk, which are more pronounced in an affective context, whereas they might not have had specific expectations for the occurrence of touch in HRI.

Furthermore, the contextual information alone did not affect the expectedness of HRT after the stimulus presentation, contrary to H9. However, a significant interaction effect between context and intimacy of touch revealed that intimate forms of HRT were more expected in the functional context, as hypothesized in H9, whereas formal forms of HRT were more expected when the context was affective or when no context information was presented. On the basis of the choice of touch forms, it seems obvious that, for example, a handshake was more expected if the scenario was described as the human and the robot are getting to know each other (affective context) than when the vignette said that they work with each other. Alternatively, intimate forms of touch such as a touch to the face might have been more expected in a functional context where touch serves a specific function, e.g., repair or test (cf. findings from Study 1). Since a touch to the face of the human was rated as quite unexpected, it can be imagined that observers of this gesture might have asked themselves why a robot should do this. And as the comments of the interviewees (Study 1) revealed, observers of HRT think of goal-directed behaviors that move a robot to reach out to touch a human.

Moreover, touch direction also significantly affected the expectedness of HRT, in line with H10. Human-initiated touch was not only more favorably evaluated; it was furthermore the most expected form of HRT. As already mentioned in the realm of Study 1, touching a physically present robot that co-exists in the same room appeared plausible to many interviewees. Some further reported that they would also touch a robot out of curiosity or interest (functional reason), which resembles the finding that human-initiated touch was also more likely to elicit functional relationship definitions in the present study.

The expectedness of HRT presented in photographs was further affected by the intimacy of HRT. As hypothesized in H11, formal forms of HRT were, overall, more expected than intimate forms of touch between a human and a robot. Also, a significant interaction between touch intimacy and touch direction demonstrated that formal reciprocal touch (handshake) was significantly more expected than intimate reciprocal HRT (embrace), whereas non-reciprocal touch forms did not strongly differ according to the intimacy of HRT. While expectation of formal human-initiated touch was nearly the same as formal reciprocal touch, both were more expected than formal touch initiated by the robot. Instead, intimate non-reciprocal HRT (human > robot) was more expected than intimate reciprocal touch, with human-initiated touch in turn still more expected than robot-initiated touch.

The results with regard to the expectedness of HRT are in line with earlier findings on interpersonal touch expectancies reported in Burgoon and Walther (1990). In their study, a formal reciprocal handshake touch between humans was also the most expected touch form, followed by no touch, while intimate non-reciprocal touches (face touch and arm around the shoulder) were the least expected. Therefore, the expectations individuals hold with regard to interpersonal touch also seem to apply to HRI.

In the work of Burgoon and Walther no differentiation in regard to the direction of touch was considered. Hence, no comparisons with regard to differences caused by who initiated and who received the touch are possible. However, the findings of the present study again highlight the significance of touch direction if one interaction partner is a robot.

Why is reciprocal and robot-initiated touch less expected?

In contrast to interpersonal interactions where touch can be expected or unexpected from an interaction partner due to social norms or idiosyncrasies (Burgoon & Walther, 1990; Burgoon et al., 1992), the abilities of robots further play a role in HRI. If a handshake from another human is unexpected, then it is unexpected because the recipient does not expect a handshake, e.g., from a lower status person, but the ability of the person to shake hands is not in doubt. In HRI, however, the capability of a robot to initiate or perform touch can also be unexpected, regardless of other influencing factors such as status, and context. Hence, two factors should be distinguished when speaking of HRT expectancies. One of these is the expectations about touch as a sophisticated ability of a robot. What skills does a human anticipate from a robot? Is the ability to execute touch expected? It seems conceivable that observers did not ascribe robots the ability to initiate touch, meaning that the mere presence of robot-initiated touch was unexpected. The same is true for reciprocal touch where the robot must have been capable of responding to touch. If this is the case, the occurrence of touch might have represented a positive adaptation gap, which exceeds the expected functions of a robot, as Komatsu et al. (2012) pointed out. However, even if reciprocal and robot-initiated touch represented a positive violation of expectations, both forms were still less desirably evaluated than human-initiated touch forms. Different to expectancy violations theory (Burgoon, 1993; Burgoon & Hale, 1988), which that makes assumptions with regard to interpersonal encounters, individuals seemed to favor conformity to their expectations when they were confronted with touch in HRI.

The second factor is expectations about touch according to situational, dispositional, or relational characteristics. Is touch appropriate in a given situation? Is the degree of intimacy of touch matching the relational closeness? Does the appearance of a robot evoke certain expectations about touch? Since touch often carries affective/emotional meanings and is thus associated with closeness and warmth (Burgoon, 1991; Burgoon & Hale, 1984; Henley, 1977; Register & Henley, 1992), it seems that touch is less expected with robots, because they are still inanimate objects. This is especially the case when reciprocal touch forms (e.g., embrace) are strongly associated with closeness and friendship, which are so far not expected with regard to human-robot relationships (cf. Dautenhahn et al., 2005; Ray et al., 2008). In contrast to interpersonal interactions, both factors play a role during expectation formation, and might thus have affected the expectedness and evaluation (desirability) of HRT.

To understand the underlying appraisal process in HRT evaluations, a model to predict the evaluation of HRT on the basis of touch form (direction), expectations, and interpretation of touch is discussed next.

8.7.4 Application of the HRT appraisal process

For the purpose of predicting the evaluative outcome of HRT observations, the effect of touch direction (human- versus robot-initiated) on the evaluation through expectedness and interpretation were regarded, under consideration of the moderating role of robot reward valence (robot attraction in this case). A moderated mediation analysis demonstrated that expectedness and the relational interpretation (affection, attachment) were positively related to the evaluation, as hypothesized in H12a and H12b.

Furthermore, a significant conditional indirect effect of touch direction on evaluation, through attachment moderated by social attraction of the robot, was yielded. As assumed in H13b and H14b, perceived attachment mediated the effect of touch direction on the evaluation if social attraction was moderate or high, but the effect was insignificant if social attraction was low. Hence, it can be inferred that the interpretation of HRT as demonstrating attachment evokes a favorable evaluation if social attraction is at least medium to high. In line with H14b, an intimate/affective interpretation of HRT only evoked a positive evaluation if the robot's attractiveness (reward valence) was medium or high, whereas the effect diminished if the reward was low. With regard to the expectedness, an indirect effect of touch direction on the evaluation through expectedness was observed, as hypothesized in H13a, but the effect was not significantly moderated by social or task attraction, as assumed in H14a. Regardless of the apparent reward from the robot, human-initiated touch was more likely to be expected and better evaluated than robot-initiated touch, which was less expected and accordingly less favorably evaluated. It is possible that the relationship between the expectedness of a behavior and the evaluation in HRI is so strong that reward does not affect this relationship. Above all, as discussed before, the results reveal that humans prefer behavior that is more expected when it comes to interactions with robots. Although robot-initiated touch might have constituted a positive expectancy violation, human-initiated touch was favored because it was more expected, more comprehensible, and maybe perceived as more secure. Even if participants only observed HRT depicted in photographs, it can be assumed that they took the perspective of the person in the picture when they evaluated the interaction. That they preferred pictures where the human touched the robot over others where the robot touched the human, might be explained by the higher dominance that was assigned to robot-initiated touch. Individuals might prefer interactions with robot's that are inferior instead of superior, and if the initiation of touch comes along with increased dominance, people do not like this image. The attractiveness of the robot seems to be minor in this case. However, to gain a deeper understanding of the role of robot reward, it should still be tested how HRT is appraised if a robot is low in attraction, or if an eerie robot touches a human.

The correlation analysis (Table 39, p. 165) revealed that expectedness was negatively related to the interpretation of HRT as a sign of affection and attachment (although the correlation with attachment was not significant). This indicates that robot-initiated touch that represents a violation of observers' expectations carries meanings of affection, or that in turn, robot-initiated touch carries meanings of affection that are less expected in an interaction with a robot.

Overall, it can be concluded that touch from a human to a robot is in the first place more likely to be expected and hence evaluated more positively, than touch initiated by a robot. But with regard to the global question as to whether robot-initiated touch can be accepted by human users so that the beneficial effects of touch have a chance to be elicited by social robots, it can be stated that the evaluations of observers in the present study are promising. The average evaluation of human-initiated and reciprocal touch was overall more favorable than robot-initiated touch, but the means for robot-initiated touch were still above the midpoint of the scale (2.7 and higher on a five-point scale). Accordingly, the results indicated that robot-initiated touch, which evoked relational interpretations of affection comparable to interpersonal touch (Burgoon, 1991; Burgoon & Walther, 1990), was evaluated favorably, although it represented a violation of expectations (Burgoon, 1993; Burgoon & Hale, 1988; Burgoon & Walther, 1990). Expectancy violations theory was thus successfully applied to a new context where one interacting partner is a robot instead of a human. The results of the present study demonstrated that several assumptions based on interpersonal theories applied to touch in HRI, while some idiosyncrasies, such as the importance of the touch direction and the preference for expectancy confirming behaviors, were revealed.

8.7.5 Limitations and Future Work

In conclusion, limitations of the present work that might have affected the results and should be considered further in future studies are discussed.

First of all, the context manipulation can be criticized. Although participants correctly remembered the context as described in the vignette, it is possible that the text of the vignettes was not effective in eliciting the expected effects, as the text did not refer to touch. Alternatively, vignettes might have been included that directly referenced the touch gesture, for instance "The robot touches the human's face to calm him/her" or "The robot touches the human's face to remove a spot." A drawback of this formulation could have been that the effect of the vignette on touch expectations would not have been possible in advance, and also that the interpretation of the touch gesture could have been anticipated in advance, which would have made the question about the participants' interpretations pointless. Beyond this, the strong effects of touch form might have overwritten the effect of the context manipulation. To examine the unique effect of the context, future studies should replicate the comparison of functional and affective context while keeping the touch form equal.

Next, the measure of expectedness can be critically regarded. It can be argued that the statements that should have assessed the expectedness of HRT are formulated too generally without a reference to touch, e.g., "The behavior of the human and the robot was as I expected". Hence, it is possible that participants' evaluations were based on something other than touch, e.g., posture, eye-contact, or an assumed conversation between the human and the robot. Although this may be true, the alternative of presenting statements referring to touch might have led to priming. Furthermore, the same questions have already been utilized in interpersonal touch research (Burgoon & Walther, 1990; Burgoon et al., 1992), and were thus used to compare the present findings with those from interpersonal contexts.

As the experiment was conducted online, environmental constraints that might have affected the attention of the participants, such as noise or the presence of other people, remain unknown. However, the decision to recruit participants online was reasonable in order to reach a broad sample. Moreover, each participant only had to evaluate a stimulus picture, which should have been easily performed, even with reduced attention.

Of course, it can be argued that the evaluation of HRT from mere observation is not suitable for gathering information about actual reactions to robot touch. However, as outlined at the beginning of the empirical studies section (Chapter 5), this form was chosen to involve several forms of HRT that differ in direction and intimacy, as already considered in the interview study (Study 1) in combination with varying contexts. There is also evidence from interpersonal touch research that observer ratings are a reliable source to estimate relational interpretations of touch, as well as the expectedness and evaluation of different touch forms (Burgoon, 1991; Burgoon & Newton, 1991; Burgoon & Walther, 1990). Furthermore, it was of interest to gather broader knowledge of several touch forms first, before actual robot-initiated touch became the focus of the final laboratory experiment (Study 4).

8.7.6 Generalization of the results

The generalizability of the present results can be questioned on the basis of the stimulus material. It can be argued that the results may be dependent on the robot depicted in the stimuli. According to the findings from Study 1 that included five different kinds of humanoid robots, it can be assumed that the results are applicable to other humanoid robots that have a comparable size and lining (no visible motors and wires). Future studies are thus needed to replicate the findings with other humanoid robots. In addition, it could be worthwhile to continue the investigation of HRT appraisal by means of video clips instead of static photographs, once the hypothesized appraisal process has been confirmed for diverse robots. Touch is of course, a dynamic act that is difficult to evaluate from static pictures; however, the static representation was the most controlled form to present HRT to observers in this initial step in the exploration of HRT.

8.7.8 Conclusion on the evaluation of HRT from an observer perspective

In conclusion, the findings so far considered HRT by means of observer descriptions and evaluations of stimulus pictures (Study 1 and Study 3) and textual descriptions (Study 2). The results demonstrated that similar to interpersonal touch, wherein context matters, HRT is manifold and one form of HRT does not equal another form of HRT. The size and morphology of a robot, the direction and intimacy of touch, and to a lower part the context in which HRT happens, determine the expectedness, interpretation, and evaluation of HRT. As assumed in expectancy violation theory (Burgoon, 1983, Burgoon & Hale, 1988), the evaluation of HRT can be predicted on the basis of the expectedness of touch and the relational interpretation that accompanies touch. Support for the moderating role of the rewarding nature of a robot was also revealed in the present study.

What is currently missing with regard to the hypothesized appraisal process of HRT is the outcome, i.e., the actual reaction of human subjects to robot-initiated touch. Hence, the knowledge about the appraisal process of HRT was ultimately applied to a real interaction. As individual well-being cannot easily be estimated from mere observation of HRT, robot-initiated touch to human participants was finally implemented in a laboratory experiment to investigate the actual effects of touch (see Study 4).

9 Study 4: Laboratory Experiment on The Effects of actual HRT

The major question that was pursued through this thesis is whether HRT can be designed in a way so that similar positive effects as in interpersonal encounters occur that contribute to human well-being. Therefore, the acceptability and appraisal of different possible forms of HRT with different humanoid robots that are capable to initiate touch in diverse contexts was first regarded from an outstanding observer perspective. Now initial reactions to robot-initiated touch should be considered and compared to earlier findings within the present thesis that were based on observation.

Since it is assumed that theories from interpersonal communication represent a useful basis to predict reactions to artificial entities as robots, assumptions and hypotheses are based on earlier work in the context of interpersonal touch research.

As outlined in the theoretical background at the beginning of this thesis, a touch from another individual can have positive effects on the recipient of touch as well as on the toucher (cf. Chapter 2). On a behavioral level it has been demonstrated that touch increases disclosure (Pattison, 1973), compliance (Guéguen, 2004; Guéguen & Fischer-Lokou, 2002; Kleinke, 1977; Patterson, Powell, & Lenihan, 1986; Smith, Gier, & Willis, 1982; Willis & Hamm, 1980), helping (Paulsell & Goldman, 1984), and lowers stress (Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005; Field, 2010). Furthermore, higher positive affect after touch has been reported (Fisher et al., 1976), as well as better evaluations of the toucher and the surroundings (Alagna et al., 1979; Crusco & Wetzel, 1984; Erceau & Guéguen, 2007; Fisher et al., 1976; Hornik, 1992a, 1992b; Wilson et al., 2009). Hence, it was anticipated that robot-initiated touch could similarly evoke positive reactions in humans.

Earlier work that considered touch with robots showed that it affects the state of the human interaction partner (e.g., mood and stress level: Robinson, MacDonald, & Broadbent, 2014; Shibata & Tanie, 2001; Wada, Shibata, Saito, Sakamoto, & Tanie, 2005). In particular, effects of robot-initiated touch have been shown with respect to participants' motivation to continue a monotonous task (Nakagawa et al., 2011; Shiomi et al., 2016), participants' emotional state and arousal when a robot touched them with or without a given reason (Chen et al., 2014, 2011), and even with regard to neural reactions to unfair offers from a robot that touched or did not touch a participant (Fukuda, Shiomi, Nakagawa, & Ueda, 2012).

In respect of the question whether robot-initiated touch can be implemented to heighten individual's well-being, it remained open how participants actually evaluate and react to robot-initiated touch in a context different from a hospital setting (cf. Chen et al., 2014, 2011). Also, in the work of Shiomi et al. (2016; see also Nakagawa et al., 2011), it remained open whether the touch from the robot was perceived as an exclusively robot-initiated touch, or as a reciprocation of touch, since the participant first had to put her or his hand on one hand of the robot before the robot started stroking the participant's hand with its second hand. The studies reported in this thesis (Study 1-3) demonstrated that observers of human-robot touch interpret and evaluate different forms of touch between a human and a robot diversely, and that observers assign relational meanings to human-robot touch that resemble those known from interpersonal touch research (cf. Burgoon, 1991). Hence it can be assumed that individuals that experience reciprocal touch will react differently than individuals that experience robot-initiated touch.

First insights into the individuals' reaction to robot-initiated touch can be found in Chen et al. (2014, 2011). Certainly, the scenario where the participants had to lie in bed as in a hospital was quite specific. Moreover, the focus of the work of Chen and colleagues was on the intent of touch and the presence of a verbal warning, while participants were touched by the robot in all conditions. In order to see whether touch initiated by a robot is responsible for positive reactions, the reactions should be compared to a control condition in which no touch happens.

In summary, previous studies that considered the effects of robot-initiated touch indicate that touch from a robot impacts the interaction. However, with respect to the global question whether HRT can increase human's well-being, more daily life scenarios as a conversation should be regarded in contrast to touch in specific settings as in a hospital (cf. Chen et al. 2014; 2011). Furthermore, earlier shortcomings that concern the initiation of touch (cf. Nakagawa et al., 2011; Shiomi et al., 2016)) should be overcome to identify the immediate reaction to touch that is initiated by a robot without further instruction.

9.1 Objective

The aim of the present study was to test whether actual robot-initiated touch can be implemented in a common conversational scenario so that positive reactions occur. In addition, the underlying appraisal process of HRT based on expectancy violations theory (cf. Study 3) was reconsidered, but this time from an active participant perspective. As depicted in Figure 14, the appraisal process explains how HRT is evaluated in virtue of its perception, expectedness and interpretation. Above, in an actual interaction the focus was directed on individuals' reactions to robot touch, e.g., facial reaction and compliance. According to the model it is assumed that the final reaction to robot touch is positively related to the evaluation of HRT, and hence predicts the outcome (reaction). Although the preceding studies in this thesis (Study 1-3) revealed how the perception, interpretation and evaluation of HRT differs according to different forms of touch, it is necessary to test whether the results can be replicated with participants that actually interact with a robot, i.e., get touched, instead of only observing HRT based on photographs.

In the following the research questions, hypotheses and methodological procedure are presented in detail.

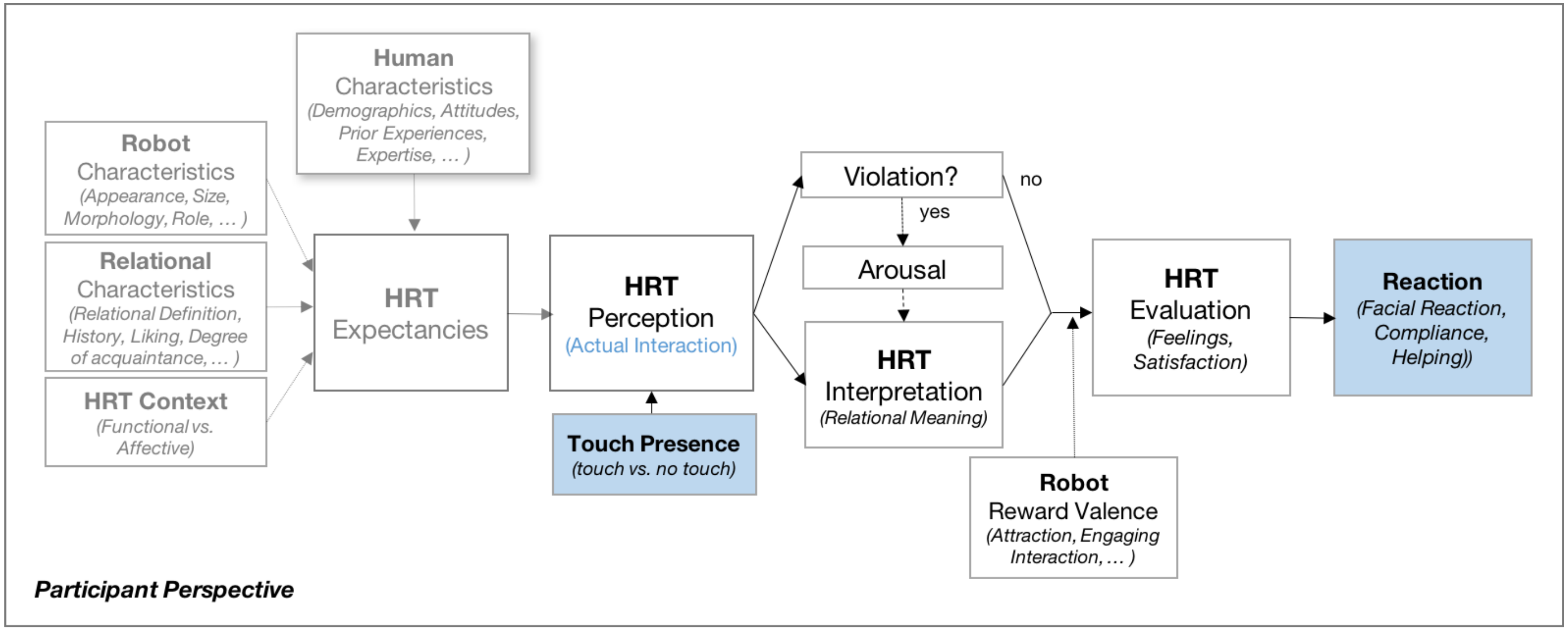


Figure 14. Human-Robot Touch appraisal process from an active participant perspective as regarded in Study 4.

9.2 Research Question and Hypotheses

The research questions and hypotheses are based on the theoretical background on interpersonal as well as HRT. As mentioned above, the appraisal of HRT should finally be regarded from a participant perspective in an actual interaction between a human and a robot. The resulting reaction to robot-initiated touch is of peculiar interest, since it could not have been regarded in the preceding studies (within this thesis). To test the assumed coherencies in the appraisal process (Figure 14), hypotheses were posed with regard to the expectedness, relational interpretation, evaluation and reaction to robot-initiated touch.

9.2.1 Expectedness

As already discussed, individual expectations about the nonverbal behavior of another influence the perception, interpretation, evaluation and reaction to touch. Related studies on the expectedness of interpersonal touch (cf. Burgoon & Walther, 1990), as well as the results of the preceding studies (Study 1 and Study 3), concordantly demonstrated that the observation of touch between two interaction partners is less expected than an interaction without touch. With regard to different forms of HRT it was further revealed that human-initiated touch was the most expectable form of touch, followed by reciprocal and robot-initiated touch. Consequently, being touched by a robot during interaction seemed to be unexpected, at least for observers of HRT. Furthermore, robot-initiated touch might be a less expected feature of a robot than a mere conversational interaction. This does also support the presumption that touch from a robot is less expected than an interaction without touch. Hence it is hypothesized:

> H1: Individuals who are touched by a robot during a conversation, evaluate the interaction as less matched to their expectations than individuals who are not touched.

9.2.2 Relational Interpretation

Findings from Burgoon and Walther (1990) revealed that the observation of an interaction between two individuals that does not include touch was interpreted as more formal but less affectionate than an interaction that includes a touch to the arm. Equally, Kleinke, Meeker and Fong (1974) demonstrated that observers of videotaped couples perceived the relationship as more close and loving when both touched each other compared to no touch. Based on these findings, it is expected that the relational interpretation with regard to the relationship to a robot will also differ depending on whether touch was included in the interaction or not. The studies within this thesis that considered the evaluation of HRT based on photographs further confirmed that more intimacy (e.g., closeness, attachment, affection) was perceived between the person and the robot when touch was included in the stimuli compared to no touch (Study 1 & 3). Actually, intimate forms of touch confirmed the most intimacy, followed by more formal forms of touch, whereas least intimacy was perceived when no touch was presented. With respect to the direction of touch, reciprocal touch was perceived as conveying more closeness than non-reciprocal forms of touch, which still conveyed more closeness than no touch (see Study 3).

In line with earlier findings that demonstrated that observers and participants overall share a social meaning model of touch (Burgoon & Newton, 1991) it was hypothesized that more affection and closeness will be experienced if a robot touches an individual than when it does not.

> H2: Individuals who are touched by a robot during a conversation, interpret the robot's behavior as showing (a) more affection and (b) the relationship as closer, than individuals who are not touched by the robot.

9.2.3 Emotional Reaction and Interaction Evaluation

Related work on interpersonal touch that concentrated on real interactions, in which participants are actually touched by a confederate, suggest that touch leads to a better emotional stated, and better evaluations of the toucher and the surroundings than no touch (e.g., the evaluation of a librarian and the library: Fisher, Rytting, & Heslin, 1976; the evaluation of a counseling experience: Alagna & Whitcher, 1979; or the evaluation of a car seller: Erceau & Guéguen, 2007, to name just a few).

Also, robot touch has been shown to affect the perceived enjoyment of an interaction, whereby instrumental robot-initiated touch was revealed as being favored over affective touch (Chen et al., 2014, 2011). In addition, Chen and colleagues observed that participants experienced more positive affect when no warning in advance to touch from the robot was given.

This is somehow contradictory to earlier work on the evaluation of touch from an observational perspective, where no touch interactions have been evaluated as more pleasant than interactions that include non-reciprocal touch (Burgoon & Walther, 1990). Also, the studies based on observation of HRT depicted on photographs that were presented in this thesis (Study 1 & 3) demonstrated that pictures without touch were better evaluated as pictures that depicted robot-initiated touch. The findings from the previous studies further showed that robot-initiated touch was still not unfavorably evaluated (means above 2.5/3 on a five-point scale, cf. Study 3), but the other forms of touch, namely: reciprocal and human-initiated touch, were simply better evaluated.

Against this background, it was hypothesized that robot-initiated touch in comparison to no touch in an actual interaction will evoke better feelings in the touched individual, and a more favorable evaluate of the interaction (cf. Fisher et al., 1976).

H3: Individuals who are touched by a robot report a better emotional state (a) during and (b) after the conversation.

H4: Individuals who are touched by a robot (a) evaluate the interaction as more desirable, and (b) the conversation as more satisfying than individuals that were not touched.

9.2.4 Robot Evaluation

Besides the evaluation of the interaction, studies on interpersonal touch demonstrated that the initiator of touch – the toucher – also received a more favorable evaluation after touch (e.g., Erceau & Guéguen, 2007; Fisher, Rytting, & Heslin, 1976; Steward & Lupfer, 1987; Wilson, Stadler, Schwartz, & Goff, 2009). For instance, Fisher et al. (1976) revealed that a library clerk was more favorably evaluated when s/he touched the subjects while handing out books.

In the realm of HRT research Nakagawa et al. (2011; also Shiomi et al., 2016) demonstrated that a robot that stroke the hand of a participant was evaluated as being more friendly than a robot that did not touch the participant. Furthermore, Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009) reported that a robot that proactively offered help to a person in need was rated as more dependable when it touched a person (represented in a video recording) than when it did not. Against this background, it was hypothesized that a robot that initiates touch will, likewise, be more favorably evaluated.

> H5: Individuals that get touched by a robot during a conversation will evaluate the robot more favorable than individuals that were not touched.

9.2.5 Outcome and reaction to robot-initiated touch

When a robot actually touches an individual for the first time, the individual's immediate reaction is of pivotal interest. Does the person increase distance? Does s/he reciprocate the touch or refuse it? Which facial reactions do individuals show if a robot touches them?

First indicators for the reactions can be found in Chen et al. (2014). Although the authors did not analyze the video recordings of the experimental sessions in detail, they included some example pictures that showed the participants' facial expressions while the robot touched them (rubbed their arm). The reactions ranged from amused (smile, raised mouth corners) to skeptical, surprised, or even fearful (raised eyebrows, wide open eyes). Since arousal (galvanic skin response) increased in all conditions when the robot touched the participant, it can be concluded that touch evoked positive as well as negative arousal in the participants according to the facial responses. However, since the reactions seem manifold and no information was provided whether the different reactions belong to certain experimental conditions, it remained open which reaction can be expected if a robot initiates touch without any warning.

Walker and Bartneck (2013) also considered participants' facial expressions while a robot, a human, or the participants themselves, conducted a head massage with a massage tool. As a result, they found more facial expressions that indicated happiness (e.g., smiling) in the robot condition. Although the massage from the human masseur was better evaluated than the massage from the robot, the authors inferred that the facial expressions are a reliable indicator for the pleasurable experience of a massage from the robot. The authors further posited that the facial reaction is more involuntarily than the self-reported evaluation that could have been subject to a socially desirable response.

In consequence of the aforementioned findings, bodily reactions (facial expressions as well as changes in distance or bodily posture) appeared to be one interesting variable that should be considered as a consequence of robot-initiated touch.

Since earlier work did not report much about the reactions of participants when a robot touched them, a research question was formulated with respect to the reactions to robot-initiated touch:

RQ1: How do individuals react to actual robot-initiated touch?

9.2.6 Compliance

The final outcome of an interaction that includes touch, had so far primarily been regarded in interpersonal contexts. Several observations have been made that support the presumption that interpersonal touch increases disclosure (Pattison, 1973), compliance (Guéguen, 2004; Guéguen & Fischer-Lokou, 2002; Kleinke, 1977; Patterson et al., 1986; Smith et al., 1982; Willis & Hamm, 1980), and the probability of helping (Paulsell & Goldman, 1984).

With regard to compliance, it has been shown that individuals were more willing to comply to small requests as lending a dime in a shopping mall (Kleinke, 1977), or tasting a product (Guéguen & Jacob, 2006; Hornik, 1992b; Smith et al., 1982) when touch occurred in advance. Also compliance to larger requests as watching after a tall dog in front of a pharmacy has been demonstrated (Guéguen & Fischer-Lokou, 2002). It has been theorized that higher compliance follows touch, because the person who touched another seems to be in genuine need (Gallace & Spence, 2010).

In the realm of human-robot interactions, so far only Cramer, Kemper, Amin, Wielinga, et al. (2009) considered the impact of touch on compliance. Their findings demonstrated no differences in observers' estimation of how willing they would be to follow the recommendation of a robot if it used touch or not. Albeit, it has to be remarked that participants in that study watched a video recording of an interaction between a person and a robot were several forms of HRT were included (or no touch at all) and rated their willingness based on that observation. Hence, it was hypothesized that actual robot-initiated touch has the potential to make individuals comply more frequently, similar to observations from interpersonal touch research.

H6: Individuals that are touched by a robot during conversation, are more likely to comply to the robot's request than individuals that are not touched.

9.2.7 Helping

Furthermore, it was of interest to test whether a touch by a robot might lead to other observable outcomes as a higher willingness to help, similar to findings by Patterson et al. (1986) and Paulsell and Goldmann (1984), who demonstrated this effect for interpersonal touch. To include an easily applicable and objectively observable outcome measure, the same paradigm as used in Paulsell and Goldman (1984) was adopted. As described in the theoretical background (Chapter 2.4), during their study the confederate "accidentally" dropped sheets of paper after s/he touched the participant at the shoulder, upper arm, lower arm, hand, or not at all. The participants' willingness to lift the sheets was than observed as an objective measure for participants' helpfulness after touch. The results showed that more helping was observable after touch to the lower and upper arm compared to no touch if the confederate (the toucher) was female.

Besides interpersonal touch, Tai, Zheng, and Narayanan (2011) demonstrated that touch to a teddy bear after (experimentally manipulated) social exclusion increased participants' willingness to participate in further experiments compared to other subjects that were not allowed to touch the teddy bear.

Conclusively, a robot might evoke similar reactions in individuals. Moreover, a robot allows to test for the effect of touching on helping without considering effects of the sex of the toucher (cf. Paulsell & Goldman, 1984), as far as the robot is seen as gender neutral. Although it has been revealed that individuals can perceive artificial entities as male or female if their appearance or voice is manipulated (e.g., male versus female voice: Nass, Moon, & Green, 1997; short versus long hair: Eyssel & Hegel, 2012), it can be assumed that a robot with a neutral appearance and voice can be regarded as gender neutral[5]. Hence a main effect of touch, regardless of the sex of the toucher, was hypothesized for robot-initiated touch:

> H7: Individuals who are touched by a robot during conversation, will show more willingness to help afterwards, than individuals who are not touched.

9.2.8 Differences according to participants' sex

So far, studies on the impact of touch in human-robot interaction did not report different reactions according to the participant's sex. However, research on interpersonal touch demonstrated differences because of the sex of the recipient of touch (e.g., Burgoon, Walther, & Baesler, 1992; Fisher et al., 1976; Sussman & Rosenfeld, 1978). Hence, a research question was formulated to ask whether differences according to participants' sex emerged.

> RQ2: Do males and females react differently to robot-initiated touch in a conversational scenario?

9.2.9 HRT Appraisal Process

Although it can be easily supposed that robot-initiated touch will violate individual's expectations about human-robot interaction, it remains unclear whether this violation has a positive or negative valence when actual contact happens, causing a positive or negative evaluation and outcome, respectively. According to expectancy violation theory

[5] In the present study, Aldebaran's Nao robot was used that can be seen as gender neutral due to its appearance and voice.

(Burgoon, 1983; Burgoon & Hale, 1988), and the proposed model for HRT (cf. Figure 14) it is hypothesized that expectedness of touch and an affective interpretation of touch are positively related to the evaluation.

H8: The (a) expectedness and (b) affective interpretation of human-robot touch are positively related to its evaluation.

In addition, it is assumed that the direct effect of robot-initiated touch on the evaluation is mediated by the expectedness and affective interpretation of touch. Hence, it is hypothesized:

H9: The effect of touch on the evaluation is mediated by (a) the expectedness and (b) affective interpretation of touch.

Finally, research in the realm of interpersonal touch demonstrated that the evaluation of a behavior after a violation is moderated by the perceived reward valence of the violator (Burgoon & Hale, 1988; Burgoon et al., 1989, 1992; Burgoon & Walther, 1990). If the violator – in this case the toucher – is perceived as rewarding (e.g., physically attractive or high in status), the evaluation of touch will be favorable regardless of whether it was expected or not. Moreover, a touch from a high rewarding communicator that is unexpected will even evoke a more pronounced positive evaluation than a touch that confirms expectations. In turn, unexpected touch from a low rewarding communicator will cause more negative reactions (evaluation) than touch that is expected.

In the online experiment (Study 3) it has already been demonstrated that the reward valence of a robot, measured by the perceived social attraction, moderated the effect of HRT, through the interpretation of the touch as affective, on the evaluation. Because of that it is assumed that the perceived robot reward valence will also affect the evaluation of actual robot-initiated touch that is mediated by the expectedness and interpretation of touch.

H10: The robot reward valence moderates the effect of touch through expectedness and affective interpretation on the evaluation, in the sense that (a) low expectedness and (b) an affective interpretation of touch only have a positive impact on the evaluation if the robot was perceived as highly rewarding.

9.3 Method

The aim of the present study is to examine the impact of touch that is initiated from a robot to a body region of the participant that is generally accessible to touch from strangers, and might further convey ambiguous meanings of instrumental as well as functional purposes. Therefore, an experimental setup was chosen in which participants had a conversation with a humanoid robot under circumstances that facilitated robot-initiated touch without a prior warning or request.

9.3.1 Independent Variable: Presence of Touch

The presence of robot-initiated touch was varied as a between-subjects factor in the present study. Therefore, half of the participants were touched by the robot at their hand, whereas the other half was not touched at all. The choice of the touch form and the implementation are described in detail in the following sections.

9.3.1.1 Decision upon touch form

With the aim of overcoming shortcomings of earlier studies that regarded mixtures of HRT (e.g., reciprocal and non-reciprocal touch forms: Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, & Evers, 2009; robot-initiated touch that followed requested human-initiated touch: Nakagawa et al., 2011; Shiomi et al., 2016), only one form of touch was considered in the present study. In order to pursue the explanation of the underlying appraisal process (cf. expectancy violations theory: Burgoon & Hale, 1988), robot-initiated touch was chosen, since it has been revealed to be an unexpected form of HRT (cf. Study 3). In detail, a directed touch from the robot to the hand of the participant was chosen, since it appeared casual and rather ambiguous in its meaning. A casual form of touch was further chosen because it appeared to be more successful to evoke a positive effect if it is less salient.

Although we know from work of Chen et al. (2014, 2011) that instrumental touch is preferred over affective touch in a healthcare scenario, the present study focused on touch that could occur during daily interactions, in which affective touch might be less unfavorable. Albeit a touch to the hand is ambiguous in its meaning and might be perceived as affective, it can be regarded as little intrusive and not susceptible to be sexually motivated. The relational meaning of a touch to the arm, which appears to be quite similar to a touch to the hand, had furthermore been demonstrated to be perceived as moderate in intimacy and formality in studies on interpersonal touch (Burgoon & Walther, 1990).

Moreover, the repeated trial reported in Chen et al. (2014) demonstrated that participants' positive feelings (self-reported valence, SAM) decreased significantly from the first to the second trial, indicating that the first positive impression of the robot (novelty effect) might have decreased from trial one to two. In order to control for such positivity bias after the first exposure to touch, the same touch gesture was repeated four times during the conversation to see whether the reaction to touch changes over time. Furthermore, four touches seemed to be enough to evoke an effect in the participants, but not too much to evoke suspicion about the aim of the study (cf. Burgoon et al., 1992).

9.3.1.2Realization and timing of touch

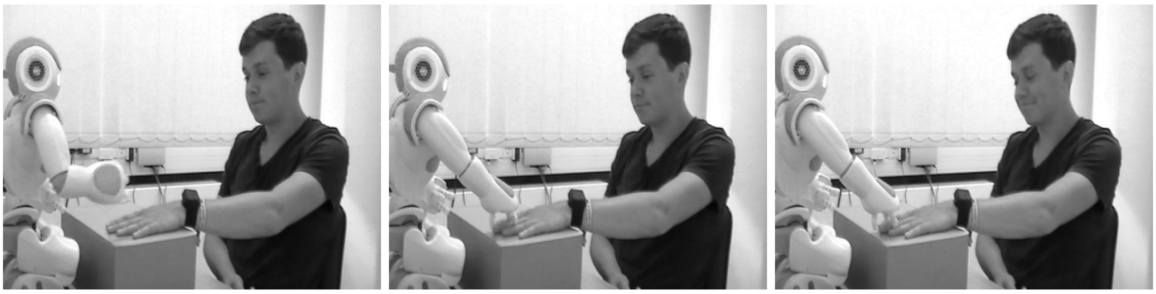
As earlier studies demonstrated, it is not easy to design a human–robot interaction in which a robot touches the participant without a prior warning or a request to get into a specific position. Therefore, a cover story was invented that ensured that the robot was able to reach each participant without further effort of the participant.

It has been decided that the robot touched the hand of the participant four times in proper moments during the conversation (see below). The whole conversation was therefore scripted in advance, and the robot's behavior was operated by a confederate in a separate room (Wizard of Oz: Dahlbäck, Jönsson, & Ahrenberg, 1993).

The inclusion of touch during the conversation followed the procedure of Alagna and Whitcher (1979) who investigated the effect of interpersonal touch in a counseling context. In their study the counselor touched the client at seven times during the interaction: First the counselor initiated a handshake to introduce him/herself, then s/he put his/her hand on the client's back while they walked in. During the main counseling interview, the counselor touched the hand or lower arm of the client three times while asking for clarification or to reflect on a specific point. Finally, the counselor touched the back of the client again when the session ended and shook the client's hand. Since the focus of the present study was on non-reciprocal touch initiated by the robot, no handshake was included in the interaction. The robot was further static in its place, and did not walk the participant in. But similar to the work of Alagna and Whitcher (1979), the robot touched the participant's hand during the interaction while posing questions.

The first touch was initiated in combination with a question for clarification: *"Wait, please! I'm not sure whether I understood you right. Could you give an example of what you exactly learned or did during your studies so far?"* The next touch was paired with an understanding comment that started when the participant finished speaking: *"Yes, I understand. Did you know that most students tell that the parties are the best part of studying? I can imagine that, although I have never been to a party."* The third touch was introduced as an interruption, as I the robot abruptly had a new idea: "*Wait a minute! It occurs to me that a course for business English takes place in the next semester. The course is quite popular and will leave a good impression in your CV. Are you interested in such a course?*" Lastly, the final touch was paired with an announcement that the conversation reaches the end: *"Okay, that's it for today. It was a pleasure talking to you. I'm sorry to say that but I have many more appointments today, let me just ask you a final question: If you could choose your dream job, which one would it be?"*

In the no touch condition, the movement of the robot's arm was manipulated so that it did not touch the participant at all while the speech was exactly the same. In order to reduce the effect of higher perceived competence and aliveness in the touch condition compared to the no touch condition that might have occurred if the robot would have remained immobile instead of touching, the robot's arm was raised so that it did not reach the participant, but the gesticulation was retained in the air (see Figures 15 and 16).



1) robot reaches out to participant's hand

2) robot touches participants hand

3) robot touches participants hand (moves down and up 3x)

4) robot retracts its arm from the participant

5) robot continues gesticulating without touch

6) robot finishes touch sequence

Figure 15. Robot's movements in the touch condition.

1) robot lifts its arm to start the no touch sequence

2) robot moves its arm in the air

3) robot moves its arm in the air (moves down and up 3x)

4) robot lowers its arm again

5) robot continues gesticulating without touch

6) robot finishes no touch sequence

Figure 16. Robot's movements in the no touch condition.

9.3.2 Dependent Measures

As dependent variables, behavioral (objective) and self-reported (subjective) measures were collected within the experiment.

9.3.2.1 Objective Measures

As objective measures the participants' facial reactions (RQ1), their compliance to a request of the robot (H6), and their willingness to assist/help the experimenter after the interaction with the robot (H7) were collected.

The behavior of the participants during the interaction with the robot was recorded by means of two video cameras with different angles. The first one was positioned left to the table where the interaction took place and recorded a total view of the robot and the participant. On the basis of this shot it was possible to analyze whether the hand of the participant was in the right position, whether the robot reached the participant's hand (in the *touch condition*) and how the human reacts to the robot-initiated touch (see Figures above). Furthermore, a second camera behind the robot recorded a frontal shot of the participant, which facilitates the analysis of facial reactions compared to the profile view (e.g., laughing, see Figure 17 for an example of the camera view). The video recordings further recorded the participant's voice during the conversation with the robot, what was especially important with regard to a question in which the robot formulated a request (see below).

Figure 17. Example shots of the webcam that was positioned behind the robot to capture the participants' facial expressions.

Compliance. In order to test whether robot-initiated touch affected participants' willingness to comply to a suggestion of the robot (H6), the robot recommended a university course for business English during the conversation and asked participants if they were interested to take part in such a course. The answers to this question were later analyzed on the basis of the video recordings. It was assumed that participants complied to the robot's suggestion if they answered yes, and did not comply if they answered no.

Helping. The participants' helping behavior (H7) was assessed immediately after the interaction with the robot. Therefore, the experimenter seemingly accidentally dropped a pile of papers she was carrying (cf. Paulsell & Goldman, 1984), and noticed whether or not participants helped to pick them up. In order to give the participants a chance to help, the experimenter slowly lifted one sheet after another. Afterwards the experimenter noted down "yes" if the participant picked up at least one sheet, or "no" if not. In addition, a note was taken if something unscheduled happened (e.g., only one sheet dropped down, paper dropped down out of reach of the participant).

9.3.2.2 Subjective Measures – Questionnaire

Beside the objective measures, participant's self-reported evaluation of the interaction was assessed by means of a web-based questionnaire that includes questions about the participants' emotional state, the evaluation of the interaction and the robot itself. The operationalization of each dependent measure is explained in detail in the following paragraphs. All items had to be rated on five-point Likert-type scales from 1= "strongly disagree" to 5= "strongly agree," if not otherwise stated below.

Expectedness. How the situation matched the expectations of the participants was gathered by means of six statements as in Study 3 (Chapter 8.5.3.1). Four items were adopted from (Burgoon & Walther, 1990), e.g., "The robot's behavior was appropriate," plus two statements that exactly point to the expectedness of the robot's behavior ("The robot's behavior totally matched my expectations," "I did not expect the conversation to be like this" (reversed)). If participants rated the statement "The robot's behavior was unusual" (reversed) three or lower, a conditional question followed that asked for an explanation ("Please describe what was unexpected with regard to the robot's behavior").

The items were collapsed into one score (6 Items, *Cronbach's* α = .456). Since the initial reliability was bad, the items "The robot's behavior was appropriate" and "The robot showed typical conversational behavior" were excluded leaving a four-item scale (*Cronbach's* α = .629).

Relational evaluation. Beside the evaluation of the conversation itself, an interpretation of the relationship between the participants and the robot was demanded by means of the *Relational Communication Scale* (RCS; Burgoon & Hale, 1987; Burgoon, 1991) and the *Inclusion of the Other in the Self Questionnaire* (IOS; Aron, Aron, & Smollan, 1992; cf. Study 3). Both scales were assessed from an actual participant perspective. The statements from the RCS (Burgoon, 1991) were reformulated to match the first person perspective of the participant after the interaction with the robot, e.g., "The robot tried to establish common ground with me", "The robot acted like it was more powerful than me." The items were summarized into intimacy/affection (6 items, *Cronbach's* α = .850), detachment (2 items, *Cronbach's* α = .406), composure (2 items, *Cronbach's* α = .001) and dominance (2 items, *Cronbach's* α = .403). Due to the low consistencies and the focus on the affective interpretation, detachment, composure and dominance were not further regarded in the analyses.

Again, relational closeness was assessed with the one item pictorial IOS scale. The scale was introduced with the question "How close would you describe the relationship between the robot and you?" The pictures were coded from 1= "not close" to 7= "very close."

Emotional Reaction. Participants emotional state during the interaction was inquired with the dimensions valence, arousal and dominance of the *Self-Assessment Manikin* (SAM; Bradley & Lang, 1994) as in Study 1 and Study 3. But this time their assessment was based on an actual interaction instead of the observation and imagination of HRT. Furthermore, participants' affective state after the interaction was assessed by means of the *Positive and Negative Affect Schedule* (PANAS; Watson, Clark, & Tellegen, 1988). The instrument consists of 20 adjectives that are divided into two subscales: positive affect (10 Items, e.g., active, excited; *Cronbach's* α = .831) and negative affect (10 items, e.g., hostile, nervous; *Cronbach's* α = .862).

Interaction Evaluation. The overall interaction with the robot first had to be evaluated with regard to participant's overall satisfaction with the conversation. Therefore, 16 items from the *Interpersonal Communication Satisfaction Inventory* (Hect, 1978) were applied to the context of HRI. The original inventory consists of 19 positively and negatively formulated statements that concern conversations, e.g., "We each got to say what we wanted" or "I was very dissatisfied with the conversation" (reversed). Statements that include "person," e.g., "The other person expressed a lot of interest in what I had to say," were adjusted to "The robot expressed…" Negatively worded items were reverse coded before all items were collapsed into one reliable score (16 items, *Cronbach's α* = .856).

Furthermore, the interaction had to be evaluated as in Burgoon and Walther (1990; see also Study 3). Again, four statements were adopted from Burgoon and Walther (1990), but this time they were formulated to match an active (first person) participant perspective instead of an observational (third person) perspective. Additionally, the tense was changed to past tense because the statements had to be rated in retrospective. The statements were: "Most people would like to interact with this robot", "The robot's behavior pleased me", "The robot's behavior was undesirable" (reversed), and "I enjoyed the conversation with the robot." A sum score was calculated of the four items that can be regarded as reliable (*Cronbach's α* = .798).

Robot evaluation. The evaluation of the robot was assessed with six statements that described how the participants perceived the robot (comparable to person perception), e.g., "The robot appeared warm." The other items were "... humanlike" (cf. (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009), "…sympathetic" and "eerie" (cf. Nie, Park, Marin, & Sundar, 2012). Furthermore, two statements were included to control whether the robot in this study was perceived as rather male or female ("The robot appeared male/female," cf. influence of the sex of the toucher, Paulsell & Goldman, 1984).

9.3.2.3 Moderating variable: robot reward

In order to pursue the aim of examining the underlying appraisal process of HRT following expectancy violations theory (Burgoon, 1983; Burgoon & Hale, 1988) as in Study 3, the robot's reward as the communicator of touch was again considered. Robot rewards was again operationalized as the robot's attractiveness measured by the *Interpersonal Attraction Scale* (McCroskey & McCain, 1974). This time all three subscales, namely: social attraction (5 items, Cronbach's α = .678), physical attraction (4 items, Cronbach's α = .634), and task attraction (5 items, Cronbach's α = .758) were used. Example items for the social and task dimension can be found in Study 3, for the physical dimension example items are: “The robot is physically attractive,” “I do not consider the robot very good looking,” and “The robot is quite handsome.”

9.3.2.4 Control Variables

Manipulation Check. With the aim of checking whether the touch manipulation was successful, participants were finally asked whether the robot touched them during the conversation, how often and at which part of their body. In addition, they were also asked if they touched the robot during the conversation, and if so, when and why.

Touch evaluation. It is assumed that robot-initiated touch has a positive impact on a human individual similar to interpersonal touch, but only under the premise that the touch itself is not negatively experienced. If individuals perceive the touch as unpleasant, it can be anticipated that the evaluation of the interaction will likewise be less favorable. Therefore, participants in the touch condition were further asked to evaluate the touch gesture itself. For that purpose, a five-point semantic differential was presented, on which the robot-initiated touch should be rated. The bipolar scale consisted of eight pairs of adjectives, which cover several facets, namely: unpleasant/pleasant, expected/unexpected, strong/weak, not painful/painful, positive/negative, warm/cold, appropriate/inappropriate, functional/useless, and natural/artificial. All item pairs except of unpleasant/pleasant were reversed before a mean score was built (6 Items, *Cronbach's* α = .646).

Individual differences. Potential person characteristics that might influence the perception, evaluation and reaction to robot-initiated touch were mainly collected prior to the conversation (pre-questionnaire). Comparable to Studies 2 and 3 the questions dealt with subjective feelings of loneliness measured with a revised German version of the UCLA Loneliness scale (Döring & Bortz, 1993; 20 items, *Cronbach's* α = .936), prior exposure to different technologies (6 Items, *Cronbach's* α = .580), expertise dealing with new technologies (6 items, *Cronbach's* α = .804), attitudes towards robots (NARS S1: 6 items, NARS S2: 5 items, NARS S3: 3 items, *Cronbach's* α = .707, .598, .663). Above, interaction specific expectations and fears were accessed by means of the *Robot Anxiety Scale* (RAS, (Nomura & Kanda, 2008; Nomura et al., 2004). The scale consists of eleven statements that refer to three dimensions of robot anxiety: *anxiety towards communication capabilities of robots*, for instance “I am concerned whether the robot might not understand difficult conversational topics" (RAS S1: 2 items, *Cronbach's* α = .654), *anxiety towards behavioral characteristics of robots* (RAS S2: 4 items, *Cronbach's* α = .919), e.g., "I am concerned what kinds of movements the robot will make", and *Anxiety towards discourse with robots,* e.g., "I am concerned how I should respond when the robot talks to me" (RAS S3: 4 items, *Cronbach's* α = .795).

Furthermore, individuals' need to belong (Baumeister & Leary, 1995), was assessed by means of a ten-item scale (*Cronbach's* α = .710) that has already been applied in the context of HRI (Krämer et al., 2013). The scale consists of statements as "I have a strong need to belong" and "If other people don't seem to accept me, I don't let it bother me." And has been used to media usage and acceptance based on individual's need to belong.

After the completion of the post-interaction questionnaire (dependent measures), participants were additionally asked whether they already knew the robot Nao. Finally, participants' general attitudes towards interpersonal touch (*Need for Interpersonal Touch* Scale, NFIPT, Nuszbaum, Voss, & Klauer, 2014, cf. Study 3, 20 items, *Cronbach's* α = .863) were collected in retrospective to avoid a priming effect.

9.3.3 Procedure

Participants were invited to a robotic counseling interview for students. The interview dealt with questions about the participant's discipline and opportunities for further qualification like language courses and internships. The topic was chosen to make sure the questions asked are not too intimate, but also relevant to the interviewees/participants.

When participants entered the laboratory, they were welcomed by the experimenter who explained the general procedure before both signed an informed consent about the recording of the physiological data and video during the interaction.

Than participants filled in a web-based pre-questionnaire concerning their attitudes towards robots, anxiety regarding interactions with robots, and other characteristics (demographical data, prior experiences, need to belong, loneliness – see above).

When the participant finished the first part of the questionnaire (pre-questionnaire) the experimenter handed over the *empatica E4* wristband and explained how to adjust it at the wrist of the left arm, and how to start the device. Afterwards experimenter and participant walked to the back of the laboratory where the robot was placed on a table (cf. Figure 15, 16). The robot than welcomed the participant and asked him/her to have a seat, before the experimenter told the cover story to explain why the participant should place his/her hand(s) on the box during the interaction (cover story). The experimenter further told the participant how to set a marker at the start and end of the interaction. Actually, they were told that they start and stop the recording when they press the button. The experimenter then left the room so that the conversation between the robot and the participant could take place undisturbed.

In fact, the experimenter explained the functions of the wristband and the box as follows:

> "In order to record your physiological data, the wristband measures your heart rate comparable to a fitness tracker by means of the silver buttons inside the wristband. In addition, your skin response is measured through your fingertips which should be placed on the box during the conversation. Please try to place your hand on the marks on the box. The contact points are located at the upper parts of the finger marks [*experimenter demonstrates how to place the hand correctly on the box*]. Put your hand on the box for test purpose [*experimenter checks whether the fingertips are close enough to the robot, and asks for correction if necessary*]. Okay thank you, the robot will tell you when to start the recording and place your hand on the box. So long you can remove your hand from the box. I will wait outside until you finished. Enjoy the interaction!"

The experimenter then left the room and the robot continued the conversation. In order to support the cover study, the robot first told the participant to put her/his hand on the box and to relax while instrumental music was played (3:20 minutes). Afterwards the robot asked questions about the participant's studies and gave some general information about language courses and studying abroad (see Appendix for the interaction script). In the *touch condition* the robot touches the participants left hand that was placed on the box four times during the conversation, whereas no touch happened in the *no touch condition,* while the content, i.e., the robot's speech, remained equal.

At the end of the conversation (ca. after 12 Minutes) Nao tells the participant to move back to the PC and finish the second part of the web-based questionnaire. When the robot said goodbye to the participant, the experimenter re-entered the laboratory to enter a password on the PC, so that the participant could continue the questionnaire. The experimenter held a clipboard with sheets which seemingly accidentally drop down in front of the participant. The experimenter excuses herself and lifts one sheet at a time. Afterwards the experimenter typed in the password and left the room again. Outside the room the experimenter noted down whether the participant helped her collecting the sheets or not.

When the participant finished the post-interaction questionnaire, which is concerned with the feelings of the participant, as well as the evaluation of the interaction and the robot (for details consult the questionnaire in the Appendix), the experimenter re-entered the laboratory and posed final question with regard to the conversation (e.g., Did you enjoy the conversation with the robot? What was special about it? Do you remember something especially good/bad?).

Finally, the experimenter debriefed the participants about the purpose of the study and the cover story and asked them not to talk to others about the study as long as the experiment was running. Participants were than thanked for participation and handed course credit or five euro before they were dismissed.

9.3.4 Participants

The number of participants was determined by means of a priori power analysis that were calculated in G*Power (Faul, Erdfelder, Buchner, & Lang, 2008). The analysis for an independent sample t-test (one-tailed) was conducted using an alpha of 0.05, a power of 0.95 and a large effect size (d = 1.0) The analysis revealed that N = 46 participants are required to find the assumed effects, that means n = 23 participant per condition if participants are equally distributed.

In total, N = 49 volunteers participated in the laboratory experiment and were randomly assigned to the experimental conditions while balancing participant's sex across the conditions. The assignment to the condition was done by a confederate (Wizard) in a second room who operated the robot to keep the experimenter blind of the condition (see

Table 52). The participants were recruited on campus between the 6th and the 21st of June 2016. Participants were compensated with course credit or 5 Euro at the end of the experimental session. According to the interaction scenario that covered topics related to studying, only students were recruited.

A little bit more female (n = 27) than male (n = 22) participants took part in the experiment, in the age between 18 and 30 years (M = 21.27, SD = 2.32). One female participant was deleted from the final analyses due to a strongly deviating tendency towards touch (see 9.3.5). It would have been advantageous to compare participants with negative attitudes towards others with positive attitudes, but in this specific case, the inclusion of the participant caused a bias (findings that were significant due to the outlier disappeared if VP43 was excluded). Conclusively, it has been decided to exclude VP43 from the main analyses but the case was separately presented as an estimate for the impact of negative attitudes (see 9.3.5). Finally, N = 48 participants remained in the sample, what was still enough to accomplish the minimum of n = 23 per condition (see power analysis). An overview of the distribution of male and female participants to the experimental conditions is given in Table 52.

Table 52. Amount of male and female participants per experimental conditions (N = 49).

	Condition		
	Touch	No touch	Total
Female	13 (14)	13	26 (27)
Male	11	11	22
Total	24 (25)	24	48 (49)

Note: Participant number 43 who was finally excluded is listed in parentheses.

9.3.5 Exceptional case

Participant number 43 was excluded from further analyses as stated above. The participant was female, 27 years old, and was assigned to the touch condition. During the debriefing the participant already explained that she felt quite uncomfortable due to the touch of the robot. This tendency was reflected in all questionnaire ratings (Table 53)

When asked what was unexpected during the conversation, she answered: “It was quite unusual that the robot touched me. A real person wouldn’t have done that.”

Table 53. Overview of the ratings of participant 43 in comparison to average ratings of others.

	VP43	Other participants (N = 48)	
	Scale ratings	M	SD
Loneliness	1.5	1.87	0.60
Need to Belong	3.3	3.50	0.54
NFIPT	2.40	3.51	0.54
Expertise	1.67	3.07	0.59
NARS S1	2.83	2.64	0.70
NARS S2	4.00	3.04	0.67
NARS S3	4.67	3.35	0.74
RAS S1	3.5	3.41	0.93
RAS S2	1.75	2.48	1.11
RAS S3	3	3.20	0.83
Physical Attraction	2.5	2.39	0.83
Social Attraction	1.80	2.55	0.85
Task Attraction	2.2	3.35	0.71
Expectedness	1.50	3.34	0.76
Affection	4.67	3.23	0.83
IOS-P	1	1.96	0.87
SAM Valence	1	3.88	0.82
SAM Arousal	4	2.17	0.86
SAM Dominance	4	3.48	1.01
Positive Affect	1.30	3.06	0.63
Negative Affect	3.80	1.44	0.50
Evaluation	1.50	3.56	0.82
Touch Evaluation	5.00	3.06	0.59
Communication Satisfaction	1.88	3.15	0.63

Especially the evaluation of touch, as well as the extreme ratings regarding a negative emotional state as well as arousal point to the discomfort of the participant. In advance to the interaction, NFIPT was already low, and negative attitudes towards robot were high.

In the following, only the remaining $N = 48$ participants are regarded.

9.4 RESULTS

The questionnaire data was analyzed with SPSS Version 23. The statements were all rated on five-point Likert-type scales from 1 = “fully disagree” to 5 = “fully agree” if not else recorded. For the analyses of the participants' behavior, the video recordings were coded with regard to participants' immediate reaction to touch, as well as their answer to the robot's suggestion to attend a business English course.

9.4.1 Coding

The video recordings were inductively coded with regard to participants' reactions during the conversation. A focus was on their immediate reaction to the four touches the robot initiated. The most apparent behaviors were gaze/attention, eyebrow raise, smiling/laughing, and frowning, and where thus coded as 1 = "occurred" or 0 = "did not occur". Furthermore, participants' answers to the robot's question whether they were interested in an English course were transcribed and coded with respect to the question whether they complied or not (1 = "yes," 0 = "no").

9.4.2 Control Variables and Manipulation Check

Knowing the robot in advance. A large part of the participants (n = 27, 56%) already knew the robot from participation in other unrelated studies. Only three (6%) had heard of the robot before but never seen it, and the remaining 18 participants (38%) stated that they did not knew the robot before. A χ^2 test for the distribution of participant who knew or not knew the robot before across the experimental conditions showed no significant result, so that a systematical influence could be precluded.

Perceived robot's sex. For the purpose of verifying whether the robot was perceived as gender neutral, the statements "The robot appeared male" and "The robot appeared female" were more precisely regarded. As the average ratings demonstrated, the robot was perceived as slightly more male (M = 2.75, SD = 1.38) than female M = 2.44, SD = 1.29). However, mean ratings around the midpoint of the scale (2.5) indicted that the robot was perceived as moderately – but not strongly – male as well as female. In addition, the ratings were compared between the experimental groups by means of independent sample t-tests to see whether touch influenced the evaluation. In fact, a significant effect of touch on the evaluation as male was observable, $t(46) = 2.94$, p = .003, d = 0.85 (one-tailed, cf. Field, 2013), but the difference for female was not significantly affected. The average ratings per condition disclosed that the robot was perceived as less male (M = 2.21, SD = 1.35) in the touch compared to the no touch condition (M = 3.29, SD = 1.20).

Touch manipulation. First, it was verified that the robot reached each participants hand and touched it respectively with the help of the video recordings from the total view. All participants (*N* = 48) correctly indicated whether they were touched from the robot or not. Those who were in the touch condition furthermore all (*n* = 24) remarked that they were touched several times at the left hand. Above, three female participants spontaneously initiated a touch to the robot. Thereof two participants were in the touch condition and one in the no touch condition. Participants number eight and number 37 touched a hand of the robot at the end of the interaction due to curiosity as they later stated in the post-interaction interview. Participant number 46, instead stroke the robot's head while saying that the robot is kind.

Touch evaluation. In the touch condition, participants further had to evaluate the robot-initiated touch itself. As depicted in Figure 18 the touch from the robot was on average perceived as not painful, functional, warm, positive, appropriate, pleasant and natural, but rather weak and unexpected.

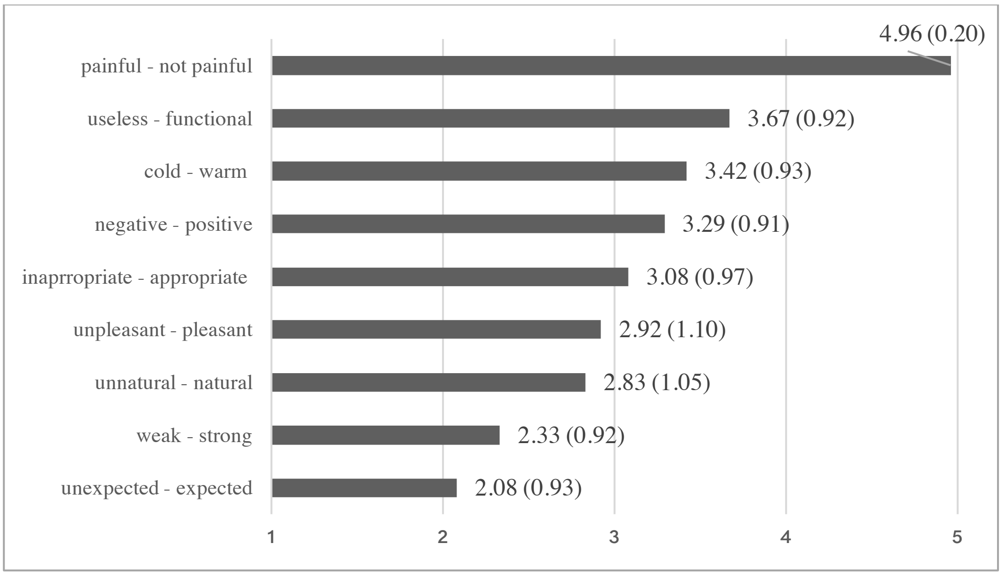


Figure 18. The bars represent the mean ratings of the adjective pairs. Standard deviations are noted in parentheses.

Correlations between the questionnaire scales. Table 54 gives a comprehensive overview of the bivariate correlations between all continuously assessed variables in the present study.

Table 54. Pearson product moment correlations for all person variables (1-11) and dependent measures (12 – 22).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1 Loneliness	1	-.366*	-.267	-.031	.271	.271	.170	.255	.246	.451**	.167	.063	-.050	-.085	-.024	.167	.026	-.148	.270	-.194	-.260	-.202
2 NTB	-.366*	1	.211	-.116	-.206	.147	.104	.082	-.230	-.017	.071	-.356*	.236	.099	-.169	.225	-.418**	.298*	.185	.282	.362*	.202
3 NFIPT	-.267	.211	1	.107	.088	-.109	.210	-.196	-.110	-.123	-.190	.315*	-.120	-.022	.204	-.257	.350*	.196	-.205	.119	.228	.147
4 Expertise	-.031	-.116	.107	1	.679**	-.402**	-.330*	-.171	-.003	-.203	.019	.133	.045	.013	.101	.194	.173	.170	.003	.113	.116	.072
5 Exposure	.271	-.206	.088	.679**	1	-.251	-.188	-.119	-.060	-.049	.084	.069	.114	.131	.179	.138	.286*	.180	-.028	.202	.148	.110
6 NARS S1	.271	.147	-.109	-.402**	-.251	1	.384**	.583**	.374**	.525**	.523**	-.050	-.089	-.307*	-.370**	.323*	-.322*	-.124	.330*	-.240	-.286*	-.274
7 NARS S2	.170	.104	.210	-.330*	-.188	.384**	1	.245	.312*	.493**	.112	.013	-.166	-.136	-.069	-.050	.071	-.057	-.049	-.068	-.012	-.042
8 NARS S3	.255	.082	-.196	-.171	-.119	.583**	.245	1	.256	.299*	.303*	-.054	-.218	-.175	-.433**	.208	-.205	-.310*	.280	-.414**	-.426**	-.332*
9 RAS S1	.246	-.230	-.110	-.003	-.060	.374**	.312*	.256	1	.259	.422**	.249	-.172	-.292*	-.142	.100	.049	-.072	.068	-.375**	-.159	-.254
10 RAS S2	.451**	-.017	-.123	-.203	-.049	.525**	.493**	.299*	.259	1	.362*	-.131	-.056	-.116	.033	.182	-.122	-.009	.132	-.018	-.110	-.082
11 RAS S3	.167	.071	-.190	.019	.084	.523**	.112	.303*	.422**	.362*	1	-.273	.198	-.061	-.362*	.570**	-.197	.054	.335*	-.057	-.061	-.011
12 Expectedness	.063	-.356*	.315*	.133	.069	-.050	.013	-.054	.249	-.131	-.273	1	-.560**	-.234	.199	-.407**	.459**	-.259	-.142	-.321*	-.289*	-.410**
13 Affection	-.050	.236	-.120	.045	.114	-.089	-.166	-.218	-.172	-.056	.198	-.560**	1	.500**	.107	.390**	-.343*	.510**	.043	.621**	.619**	.736**
14 Closeness	-.085	.099	-.022	.013	.131	-.307*	-.136	-.175	-.292*	-.116	-.061	-.234	.500**	1	.440**	-.019	-.001	.343*	-.183	.605**	.602**	.619**
15 Valence	-.024	-.169	.204	.101	.179	-.370**	-.069	-.433**	-.142	.033	-.362*	.199	.107	.440**	1	-.304*	.436**	.381**	-.288*	.386**	.431**	.414**
16 Arousal	.167	.225	-.257	.194	.138	.323*	-.050	.208	.100	.182	.570**	-.407**	.390**	-.019	-.304*	1	-.241	.099	.450**	.114	.076	-.001
17 Dominance	.026	-.418**	.350*	.173	.286*	-.322*	.071	-.205	.049	-.122	-.197	.459**	-.343*	-.001	.436**	-.241	1	.068	-.156	-.100	-.046	-.088
18 Positive Affect	-.148	.298*	.196	.170	.180	-.124	-.057	-.310*	-.072	-.009	.054	-.259	.510**	.343*	.381**	.099	.068	1	.012	.498**	.657**	.582**
19 Negative Affect	.270	.185	-.205	.003	-.028	.330*	-.049	.280	.068	.132	.335*	-.142	.043	-.183	-.288*	.450**	-.156	.012	1	-.135	-.242	-.144
20 Communication Satisfaction	-.194	.282	.119	.113	.202	-.240	-.068	-.414**	-.375**	-.018	-.057	-.321*	.621**	.605**	.386**	.114	-.100	.498**	-.135	1	.756**	.644**
21 Evaluation	-.260	.362*	.228	.116	.148	-.286*	-.012	-.426**	-.159	-.110	-.061	-.289*	.619**	.602**	.431**	.076	-.046	.657**	-.242	.756**	1	.774**
22 Robot Evaluation	-.202	.202	.147	.072	.110	-.274	-.042	-.332*	-.254	-.082	-.011	-.410**	.736**	.619**	.414**	-.001	-.088	.582**	-.144	.644**	.774**	1

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.

Due to significant correlations between individual differences (person variables) and some dependent measures (expectedness, interpretation, feelings and evaluation), hypotheses (H1 – H5) were once tested by means of independent samples t-test, and once as ANCOVAs that controlled for the influence of need to belong (NTB), need for interpersonal touch (NFIPT), earlier exposure to technology, negative attitudes towards robots (NARS S1, S3) and anxiety towards robots (RAS S1 and S3). The comparison of both analyses demonstrated that no differences in the main effects of touch presence occurred under control of the covariates. Hence, only the results of the t-tests are reported in the following.

9.4.3 Hypotheses testing

9.4.3.1 Expectedness of HRT

In order to test, whether participants that were touched by the robot evaluate the interaction as less expected (H1), an independent samples t-test with touch condition (0 = no touch, 1 = touch) and the expectedness scale as dependent variable was calculated. The analyses yielded no main effect (p > .05; Table 55).

Table 55. Mean values and standard deviations for all metric/continuous dependent measures according to the experimental condition.

	No touch (n = 24)		Touch (n = 24)		T-test (one-tailed, df = 46)	
	M	*SD*	*M*	*SD*	*t*	*p*
Expectedness	3.27	0.76	3.42	0.77	- 0.66	.257
Affection	3.13	0.79	3.33	0.86	- 0.87	.194
Relational Closeness	2.00	0.89	1.92	0.88	0.33	.373
SAM Valence	**3.67**	**0.82**	**4.08**	**0.78**	**- 1.81**	**.038**
SAM Arousal	2.21	0.83	2.13	0.90	0.33	.371
SAM Dominance	3.33	1.09	3.63	0.92	- 1.00	.162
Positive Affect	3.02	0.58	3.10	0.69	- 0.41	.343
Negative Affect	**1.57**	**0.59**	**1.30**	**0.35**	**1.92**[1]	**.032**
General Interaction Evaluation	3.52	0.86	3.59	0.80	- 0.30	.382
Communication Satisfaction	3.17	0.77	3.12	0.47	0.31[2]	.379
Robot Evaluation	3.22	0.91	3.29	0.70	- 0.31	.379

[1] df = 37.21; [2] df = 37.88

Opposite to the assumed difference, the conversation with touch was evaluated as more expected than the interaction without touch (Table 55), however the difference was not statistically significant. Hence, H1 that assumed a higher expectedness of a touchless interaction was not supported.

9.4.3.2 Relational interpretation

Contradictory to H2, an independent samples t-test showed that touch did neither affect the perceived affection from the robot to the human (H2a), nor the perceived closeness between the participant and the robot (H2b, see Table 55). According to the average ratings, the interpretation of the robot's behavior as conveying affection was higher in the touch than in the no touch condition, but perceived relational closeness between the participant and the robot was on average slightly lower in the touch than in the no touch condition, but the differences were nonsignificant (Table 55). Relational closeness was on average quite low in both conditions. Mean ratings around two on the seven-point pictorial scale indicate that participants perceived their relationship to the robot as less close.

9.4.3.3 Emotional state

Regarding the assessment of participants' emotional state during and after the interaction (H3a, H3b) independent samples t-test revealed a significant influence of touch on the participants' self-reported valence during the interaction (SAM valence), as well as on the negative affect (PANAS NA) after the interaction (Table 55). Participants felt significantly better (valence) when the robot touched them during the conversation than when it did not (Table 55). Furthermore, participants that were not touched indicated a higher negative affect after the conversation with the robot than participants that were touched before, however, all participants reported on average low negative affect after the interaction (means below 1.6). The dimensions: arousal and dominance, and the reported positive affect after the interaction (PANAS PA) were not significantly affected by touch. According to the mean values feelings of dominance and positive affect were higher in the touch condition, in line with H3a and H3b, whereas arousal was minimal higher in the no touch condition (Table 55). In conclusion, support for H3a and H3b was only gathered with respect to valence and negative affect.

9.4.3.4 Evaluation

With regard to the desirability of the interaction (H4a) and the satisfaction with the communication (H4b), t-tests yielded no significant differences between the touch and no touch condition. Moreover, participants in both conditions experienced the conversation as highly desirable and the communication as equally satisfying (Table 55). No support for a better evaluation after touch is hence reportable, contradictory to hypotheses H4a and H4b.

9.4.3.5 Robot evaluation

Besides the evaluation of the robot as male and female (see above) participant further had to rate how warm, humanlike, sympathetic or eerie the robot appeared to them, what was later summarized as the evaluation of the robot (H5). Taken together, the robot evaluation was slightly better in the touch condition in line with H5, while the difference was not significant (Table 55).

In order to give a detailed overview of the average ratings for each item, Table 56 presents the mean ratings per condition, and overall. As a result, the robot was perceived as quite sympathetic and warm, regardless of the experimental condition. Furthermore, the average ratings indicate that the robot appeared moderately humanlike, although the ratings were slightly higher in the no touch condition. The robot also did not appear eerie to the participants; however, the ratings were a little bit higher in the no touch condition. The comparisons between the single items were also not significantly different based on independent samples t-tests.

Table 56. Means and standard deviations for the evaluation of the robot (single items).

	No Touch		Touch		Overall	
	M	*SD*	*M*	*SD*	*M*	*SD*
The robot appeared warm.	3.00	1.25	2.92	1.21	2.96	1.22
The robot appeared humanlike	2.46	1.18	2.29	1.20	2.38	1.18
The robot appeared sympathetic.	3.38	1.31	3.50	1.14	3.44	1.22
The robot appeared eerie.	1.96	1.23	1.54	0.83	1.75	1.06

9.4.3.6 Interaction outcome: Behavioral data

In order to examine the participants' behavioral reactions to touch, three major outcomes were regarded: first, the facial reaction to touch (RQ1), second, the verbal reaction to the robot's suggestion to take part in an English course (H6), and third, the participants' willingness to help the experimenter lift sheets of paper (H7). Finally, it was considered whether female and male participants react differently to robot-initiated touch as related work on interpersonal touch to male and female participants indicated (e.g., Paulsell & Goldman, 1984).

9.4.3.7 Reaction to robot touch

In order to answer RQ1, how individuals immediately react to being touched by a robot, the parts of the video recordings in which the robot touched the participant were regarded (in the no touch control condition the same part of the conversation according to the robot's speech). Overall, three behaviors reappeared several times, namely: smiling/laughing, eyebrow raise, and directed gaze.

Laughing was coded as 0 = no laughing at all, 1 = smiling (if mouth corners are raised but the mouth is closed), and 2 = laughing (mouth corners raised combined with open mouth, visible teeth, or shaking shoulders). The coding has been done twice by one coder with an interval of 12 weeks (see Schreier, 2012). The coding from both points of time showed 100% consensus. The assigned codes were then counted and compared between the experimental conditions, and furthermore within subjects with regard to the four sequential touches that were included.

Smiling. As Figure 19 demonstrates, participants in the touch condition smiled and laughed more frequently during the touch sequence than participants in the control condition.

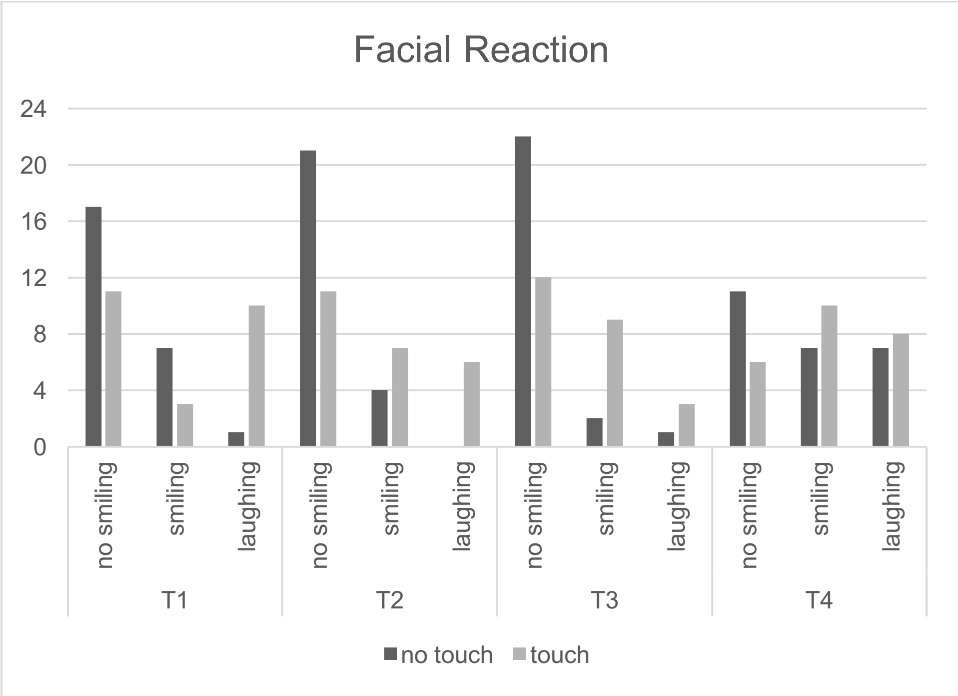


Figure 19. Frequencies of smiling and laughing after touches T1 to T4 compared to the no touch control condition.

χ^2-test for each touch moment (T1-T4) demonstrated that the amount of smiling and laughing interacted/differed significantly between touch conditions at touch T1 (χ^2 [2, N = 48] = 9.58, p = .008), T2 (χ^2 [2, N = 48] = 9.43, p = .009) and T3 (χ^2[2, N = 48] = 7.91, p = .019), whereas no significant difference was observable at T4 (p > .05). During all touch sequences, more smiling and laughing occurred in the touch condition. However, during T4 also a high frequency of smiling and laughing was observable in the no touch condition.

Eyebrow raise. In total, eyebrow raises were only two times observed in the no touch condition, and once in the touch condition. All eyebrow raises were noted during the first touch sequence.

Conclusively, it can be summarized with regard to RQ1 that participant's reactions to robot-initiated touch were overall not dismissive. None of the participants pulled their hand away or told the robot to stop when it touched the participant's hand. As described above, only participant number 43 (who was excluded from the analyses) showed a negative reaction to touch from the robot according to her general tendency to avoid touch. From the video recordings, it was visible that she gulped when the robot touched her for the first time and moved on the chair. When the robot touched her hand again, she seemed distressed (touch 2, touch 4) and finally closed her eyes when the robot touched her for the fourth time (touch 4).

The other participants reacted with smiling and laughing, immediately or with a short delayed. The touch further gained attention by the majority of the participants that directed their attention to the robot's hand when it initiated the touch sequence. However, also participants in the no touch condition followed the hand movement of the robot several times.

9.4.3.8 Compliance to robot's suggestion

In order to test whether participants followed the robot's request to attend a course for business English (H6), the frequencies of participants who clearly answered with yes (1) or no (0) were regarded. Participants who made unclear decisions (e.g., "Maybe," "I don't know") were excluded from this analysis ($n = 6$). As depicted in Table 57, participants that were touched by the robot were significantly more willing to comply to the robot's suggestion (63%) than participants that were not touched (37%), $\chi^2 (1, N = 42) = 5.08, p = .024$. Hypotheses H6 was therefore confirmed.

Table 57. Number of participants that complied, or not, to the robot's suggestion (N = 42).

	Compliance		
Condition	No	Yes	Total
No touch	11_a (7.5)	10_a (13.5)	21
Touch	4_b (7.5)	17_b (13.5)	21
Total	15	27	42

Note. Expected frequencies are noted in parentheses. Frequencies with identical letters did not differ significantly.

9.4.3.9 Willingness to help

Participants' willingness to help after the interaction (H7) was assessed through observation of the participants' behavior when the experimenter dropped sheets of paper. Due to errors during the dropping of sheets (e.g., sheets dropped in an unintended direction, out of reach of the participant), data of two participants was excluded from this analysis. As the number of participants that helped revealed (Table 58), the willingness was higher in the touch condition (59%) compared to no touch condition (41%), but a χ^2-test showed that the difference was not significant ($p > .05$). Hypothesis H7 was thus not supported.

Table 58. Number of participants that helped the experimenter to lift sheets (N = 46).

Condition	Helping		Total
	Helped not	Helped	
No touch	14 (12)	9 (11)	23
Touch	10 (12)	13 (11)	23
Total	24	22	46

Note. Expected frequencies are noted in parentheses.

9.4.3.10 Sex differences

Studies on interpersonal touch indicated that the sex of the toucher as well as the sex of the recipient of touch matters (e.g., Fisher et al., 1976; Paulsell & Goldman, 1984). Hence, a robot with a gender-neutral appearance and voice was used to control for the effect of the toucher, and the impact of the participants' sex was tested by means of additional analyses. With respect to the continuous dependent variables (expectedness, interpretation and evaluation), two-factorial ANOVAS with touch condition and participant's sex as independent factors were calculated. As a result, participants' sex neither had a main effect on the expectedness, interpretation, or evaluation, nor were interaction effects between touch condition and sex observable. Regarding the categorical measures (laughing, compliance and helping) the analyses were separately repeated once for female and once for male participants. Only for laughing, χ^2-tests showed that the difference in laughing between the touch and the no touch condition was only significant for males (χ^2 [2, N = 48] = 8.26, p = .016) during the first touch, while the difference was only significant for females during the second (χ^2 [2, N = 48] = 6.80, p = .033) and third touch (χ^2 [1, N = 48] = 6.50, p = .011). However, no sex differences appeared for compliance and helping.

9.4.3.11 HRT appraisal after actual touch (process)

In order to test whether the appraisal process for HRT evaluations can be applied to the evaluation of an actual interaction with a robot that included touch, hypotheses H8, H9 and H10 regarded the interplay of the expectedness, interpretation, and evaluation of HRT, following expectancy violations theory (Burgoon, 1983; Burgoon & Hale, 1988, cf. Study 3).

First, the relationship between the expectedness, the affective interpretation, and the evaluation was regarded. Against H8a, a significant but negative correlation between expectedness and evaluation was observable, $r(46) = -.29$, $p = .047$): the less expected the conversation was rated by the participant, the better the evaluation of the conversation. With regard to the interpretation of the robot's behavior as showing affection, correlation analysis showed a positive relationship, $r(46) = .62$, $p < .001$, in line with H8b: the more affective the robot's behavior was interpreted, the better the evaluation of the conversation (see also Table 54).

Because a conditional indirect effect of touch presence on the evaluation of the conversation through expectedness and interpretation of HRT was presumed (H9) that is moderated by robot reward valence (H10), a multiple moderated mediation analysis was calculated. For that purpose, the PROCESS macro for SPSS (Hayes, 2015) was used. According to the assumed theoretical effects (see Figure 20), model 16 (Hayes, 2011, 2013, 2015) was chosen, which allows the test of a moderated mediation model with two moderators. Touch presence (touch versus no touch) was entered as independent variable, expectedness and affection were entered as mediators, social attraction and task attraction as moderators, and evaluation as the dependent variable. A confidence interval of 95% and 5000 bootstrap resamples were used for the calculation.

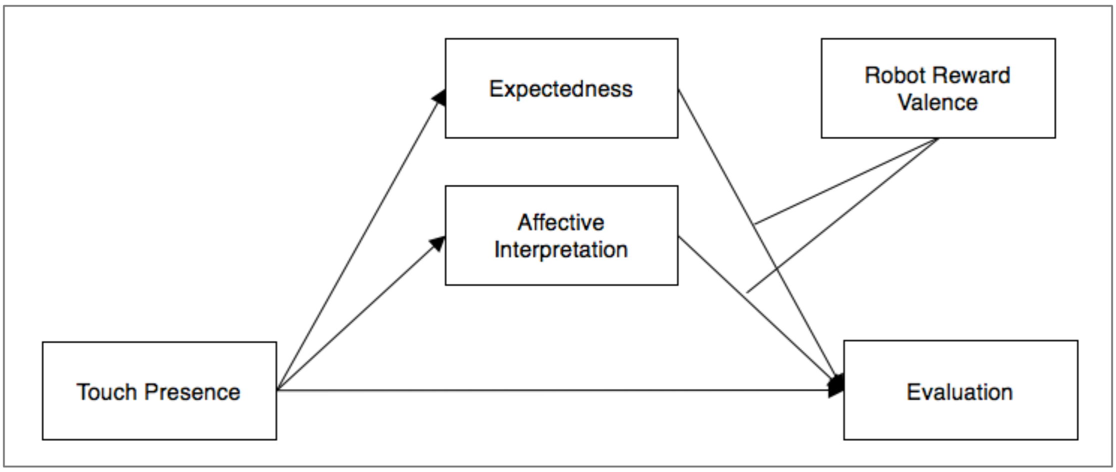


Figure 20. Theoretical model of the moderated mediation of touch presence on evaluation through expectedness and affective interpretation moderated by robot reward valence.

The multiple moderated mediation analysis revealed a significant model (see Figure 21) for the evaluation of HRT, $F(9, 38) = 12.45$, $p < .001$, which explained 68% of the variance ($R^2 = .68$). The analysis demonstrated that touch presence neither had a direct effect on the evaluation (as already demonstrated above, cf. H4a), nor were the indirect effects through expectedness (H9a) and affection (H9b) significant.

Although significant interactions between expectedness and social attraction, expectedness and task attraction, as well as affection and social attraction were observable (see Figure 21), no significant conditional indirect effects were visible through nonsignificant indexes of partial moderated mediation (for expectedness and social attraction: 0.07, CI [–0.147, 0.335]; for expectedness and task attraction: –0.06, CI [–0.301, 0.173]; affection and social attraction: 0.09, CI [–0.131, 0.330]). Hence hypotheses H10a and H10b that assumed a moderated mediation effect of touch through (a) expectedness and (b) affective interpretation on the evaluation moderated by robot reward valence (operationalized as social & task attraction) had to be rejected in the present study.

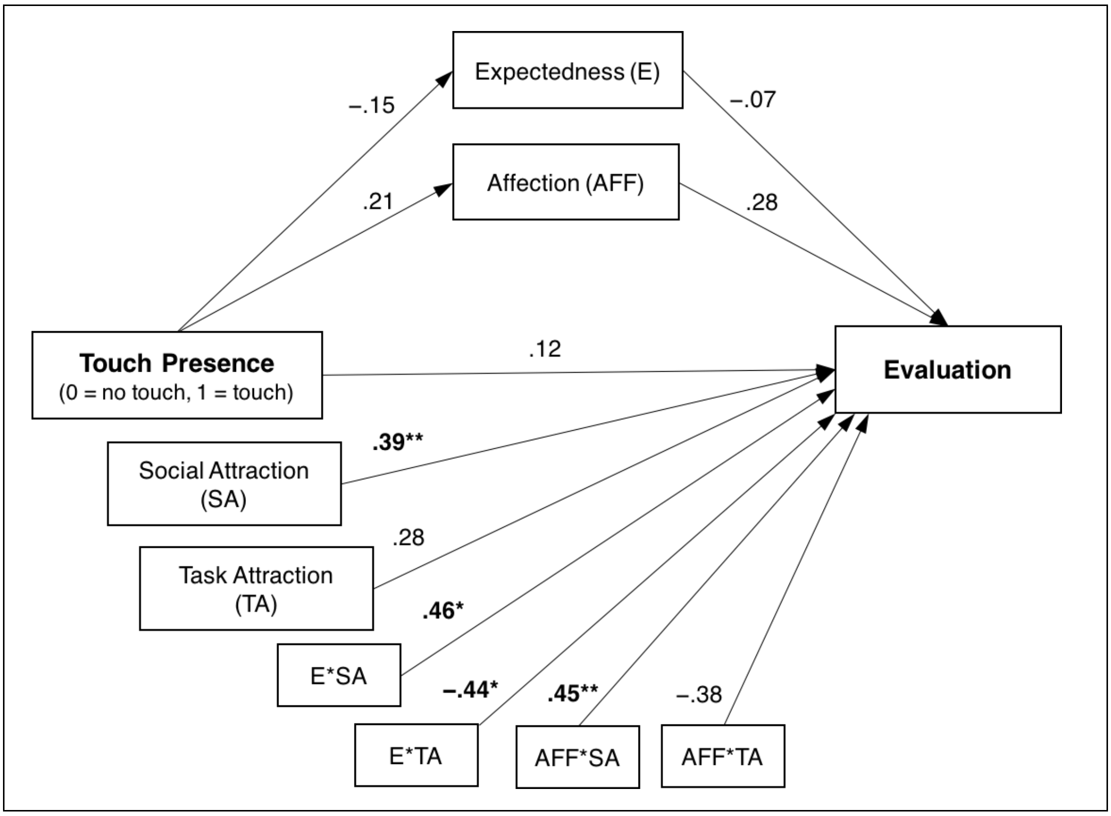


Figure 21. Statistical model for the moderated mediation analysis with regression coefficients. * p < .05. ** p < .01.

9.4.4 Additional Analyses

Since it has been demonstrated that the evaluation was independent from the presence of touch in the present study, and that the correlation between expectedness and evaluation was negative, opposite to the assumed positive relationship that has already been demonstrated in Study 3, an additional hierarchical linear regression analysis has been done to figure out how the evaluation was achieved in the actual interaction between the participants and the robot (Table 59).

Table 59. Multiple hierarchical regression analysis for evaluation.

		B	*SE B*	*β*	*t*	*p*	*ANOVA*
Step 1	Constant	3.56	0.12		29.62	.000	$F(1, 46) = 0.09, p = .763$
	Touch presence	0.04	0.12	.05	0.30	.763	
Step 2	Constant	1.15	0.82		1.41	.165	$F(4, 43) = 10.72, p < .001$
	Touch presence	-0.00	0.09	-.00	-0.01	.994	
	Expectedness	0.06	0.15	.06	0.44	.664	
	Affection	**0.46**	**0.15**	**.46**	**3.02**	**.004**	
	Closeness	**0.36**	**0.12**	**.39**	**3.06**	**.004**	
Step 3	Constant	0.81	0.77		1.06	.298	$F(7, 40) = 9.35, p < .001$
	Touch presence	0.46	0.08	.06	0.55	.587	
	Expectedness	-0.10	0.13	-.01	-0.08	.938	
	Affection	**0.32**	**0.15**	**.32**	**2.09**	**.043**	
	Closeness	0.12	0.14	.13	0.88	.382	
	Physical Attraction	-0.12	0.11	-.12	-1.07	.290	
	Social Attraction	0.28	0.14	.29	1.97	.056	
	Task Attraction	**0.33**	**0.15**	**.28**	**2.14**	**.038**	
Step 4	Constant	0.24	0.75		0.32	.751	$F(8, 39) = 10.17, p < .001$
	Touch presence	0.06	0.08	.07	0.74	.464	
	Expectedness	0.00	0.13	.00	0.02	.983	
	Affection	0.19	0.15	.19	1.28	.209	
	Closeness	0.06	0.13	.06	0.46	.650	
	Physical Attraction	-0.07	0.11	-.07	-0.66	.513	
	Social Attraction	0.20	0.13	.21	1.53	.135	
	Task Attraction	0.20	0.15	.17	1.32	.196	
	Comm. Satisfaction	**0.49**	**0.19**	**.38**	**2.58**	**.014**	

Note: $R^2 = .00$ for Step 1, $\Delta R^2 = .50$ for Step 2 ($p < .001$), $\Delta R^2 = .12$ for Step 3 ($p = .010$), $\Delta R^2 = .06$ for Step 4 ($p = .014$).

The analysis revealed that the interpretation of the robot's behavior as showing affection, the perceived relational closeness, task attraction and the reported satisfaction with the communication were the only significant predictors for the evaluation. The relationships were furthermore positively: the more affection was perceived, the higher the closeness, the more attractive the robot with regard to task fulfillment, and the more satisfied participants were with the communication, the more desirable was the interaction evaluated.

9.5 Discussion

The major aim of the present study was the examination of the effect that actual robot-initiated touch has on human subjects in a conversational scenario. Considering that earlier studies on HRT had difficulties to examine robot-initiated touch separately, because of technical restrictions, or a mixture of several touch forms in one study (see Chapter 3.5; e.g., Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, & Evers, 2009; Nakagawa et al., 2011; Shiomi et al., 2016), an experimental scenario that allowed touch from a humanoid robot to a participant without any further commitment of the participant was designed. During the experimental sessions participants had a conversation with the humanoid robot Nao, who either touch the participants hand four times during the conversation, or not at all. As dependent variables, participant's self-reported evaluation as well as observable measures of facial reaction, compliance and helping were considered. In the following, the findings are briefly summarized, and discussed along the hypotheses.

9.5.1 Expectedness of Robot-initiated Touch

Against the background of the expectedness of interpersonal touch (Burgoon & Walther, 1990), and the findings from Study 1 and 3, it was hypothesized that participants will experience the conversation with the robot as less expected when touch is included (H1). Contrary to the assumed difference, the expectedness of the robot's behavior did not vary significantly across conditions. On the one hand, participants might not have experienced touch as unexpected or surprising, or, on the other hand, the conversation with the robot could have surprised participants because of other features of the robot, as its appearance, speech or nonverbal behavior, so that touch had no additional impact on the expectedness of the robot's behavior. Directions for this explanation were gathered from the final interviews that were held after the experimental sessions. During this inquiry, some participants mentioned that the robot's behavior - especially its arm and hand gestures - were more elaborated than they expected them to be, or than they had already experienced them in the context of other experiments. This is somehow counterintuitive to the relative high expectedness ratings in both conditions, but might potentially account for the absent difference in expectedness between the experimental conditions.

Possibly, the general expectation to receive touch, might have been increased because of the demanded position with the hand on the table. In conclusion, touch from the robot might have been less expected if the robot reached them while they were, e.g., leaned back on their chair.

9.5.2 Relational Interpretation of Robot-Initiated Touch

With regard to the relational meaning that was supposed to be perceived if robot touch is similarly interpreted than interpersonal touch (cf. Burgoon, 1991), it was assumed that more affection and closeness will be experienced when touch is present (H2a, H2b). Again, the analyses revealed no significant difference between the conditions concerning the perceived affection (H2a) and relational closeness (H2b). The average ratings for perceived affection were in the hypothesized direction after all, i.e., more affection from the robot was perceived if the robot touched the participant, but with regard to relational closeness, the ratings were slightly higher in the no touch condition. Admittedly, it has to be remarked that closeness ratings were overall quite low (1.92 and 2.00 on a 7-point scale) in both conditions. Perhaps, the pictorial representation of the human–robot relationship by means of circles (IOS, cf. questionnaire in the Appendix) was ambiguous to the participants. Although the scale has been shown to be highly reliable in interpersonal contexts, it is not clear whether the instrument applies to human–robot interactions, too.

These findings discount earlier observation in interpersonal touch studies that demonstrated that touching individuals are perceived as more close (Kleinke et al., 1974). Furthermore, the findings distinguish themselves from those gathered in Study 3, where higher affection and closeness was remarkable if touch was presented compared to no touch. Indeed, it has to be remarked that particularly intimate forms of touch were evaluated as demonstrating more affection and closeness than formal forms of touch or no touch. Hence, it is possible that the less intimate touch to the participant's hand that was regarded in the present study had a smaller or no impact on the relational level.

On top of this, the results reported in Kleinke et al., (1974) and that from Study 3 were gained through observation, whereas the present study considered the estimation of the relational closeness from the perspective of participants that were involved, i.e., touched by the robot themselves. In consequence, the perspective of the participant seems to matter relating to the relational meaning that is assigned to robot touch (cf. Burgoon & Newton, 1991).

By contrast, Cramer and colleagues (Cramer, Kemper, Amin, & Evers, 2009; Cramer, Kemper, Amin, Wielinga, et al., 2009) also did not remark a difference in the perceived closeness, observers of video clips perceived between a robot and its user that touch each other. However, they reported that the perceived closeness was affected by participants' attitudes towards robots measured by the NARS: the more negative their attitude, the lower the perceived closeness between the person and the robot. Equally, a look at the correlations within the present study revealed that negative attitudes towards robots were negatively correlated with relational closeness. Hence, personal attitudes are relevant with regard to the closeness individuals perceive between them and robots.

To conclude on the impact of robot-initiated touch on the relational interpretation, conflicting evidence has been yielded between observer and participant perspectives that provoke a need for further exploration. As relational closeness has been emphasized as a prerequisite for the acceptance of intimate forms of interpersonal touch but not with regard to non-intimate touch (cf. Heslin & Alper, 1983), it can be argued that low levels of closeness as reported in the present study are sufficient for a touch to the back of the hand, without leading to discomfort.

In addition, it can be imagined that individuals did not develop a strong bind to a robot after one interaction. Hence, it remains open if individuals acquire a stronger feeling of closeness to a robot after repeated or long-lasting interactions. It is also possible that participants during an actual interaction do not reflect on their relationship to a robot, as observers of HRT did (cf. Study 3). Finally it is possible that the participants felt close to the robot, but denied it when asked, because it might have seemed inappropriate to confess the development of a close relationship to a robot, especially in an experimental scenario (Nass & Moon, 2000).

9.5.3 Emotional Reaction to Robot-initiated Touch

Since earlier work on interpersonal touch as well as studies in the realm of robot therapy (e.g., Shibata et al., 2001; Shibata, Tashima, & Tanie, 1999; Shibata & Wada, 2010; Wada, Shibata, Saito, Sakamoto, & Tanie, 2005) demonstrated beneficial effects of touch on individual well-being, it was hypothesized that robot-initiated touch has a positive impact on participants' emotional state during (H3a) and after the interaction (H3b). In line with this assumption, significant higher valence during the interaction, and less negative affect after the interaction, was yielded. Consequently, participants that were touched by the robot indicated that they felt better during the conversation, and reported lower negative affect subsequently. This implies that robot-initiated touch in fact improved participants' emotional state in comparison to the same interaction without touch.

Although no differences in the perceived relational meaning (affection and closeness) were observed, the results substantiate the power of robot-initiated touch to increase participants' feelings, what can be regarded as an indicator for well-being. Robot-initiated touch hence seems to evoke affective responses, just as interpersonal touch does (Heslin & Alper, 1983). The question that accompanies that result is what caused the difference, if no more affection was perceived in the touch condition compared to no touch.

In line with explanations for the positive impact of interpersonal touch, it can be claimed that pressure receptors in the human's skin were activated by the touch from the robot that evoked positive cognitions e.g., of award or gratitude (T. Field, 2010). The touch itself might also have caused a positive reaction due to neural linkages that associate interpersonal touch with a pleasant sensation (Gallace & Spence, 2010). If so, the same linkages must be activated if the touch is initiated by a robot.

Referring to Harris and Christenfeld's (1999) work on getting tickled by a machine, it can be argued that the more positive feeling after touch can be a bodily response (a reflex) that is independent from an interpersonal component. Notwithstanding, the robot did not tickle the participants in the present study, but it tapped the back of the participants' hand, what can be classified as an unpredictable movement, too.

9.5.4 Evaluation of the Robot and the Interaction after Robot-initiated Touch

Contradictory to the predicted better evaluation of the interaction and the robot after touch, no differences between the conditions were witnessed. By contrast, the desirability of the interaction (H4a), the satisfaction with the communication (H4b), and the evaluation of the robot as a warm, sympathetic, humanlike, but not an eerie interaction partner (H5) was equally favorable in all conditions. Comparable to the findings on the relational interpretation, these results create the impression that something else than touch was responsible for the exceedingly positive evaluation of the conversation, and the robot, respectively. Statements from the interviews of the participants after the interaction gave some hints that all participants enjoyed the interaction because they were impressed by the robot's ability to understand natural language, and to elaborate on their answers. As the analyses of the video recordings revealed, participants laughed more frequently during or after the touch sequence than non-touched participants. However, participants in both conditions laughed multiple times apparently because of the robot's speech (see next paragraph).

9.5.5 Reaction to Robot-Initiated Touch: Laughing

The question how individuals actually react to robot-initiated touch was addressed with the analysis of the video recordings. They showed that none of the participants pulled their hand or body away when the robot touched it. Generally, most participants remained in their position during robot-initiated touch. Changes were only remarkable in their facial reactions: The majority of the participants followed the robot's hand with their gaze when it touched the participant, or even when it just gesticulated in the air (no touch condition). When touched, a few raised their eyebrows when the robot touched them for the first time, whereas most participants in the touch condition smiled or laughed during or shortly after touch. The comparison of the conditions further demonstrated that touched participants laughed significantly more during the first, second, and third touch sequence. The result corresponds to those reported in Walker and Bartneck (2013), who compared head massages with a massage tool performed by a human, a robot, or by the participant oneself. Although the study did not consider immediate touch from a robot, the results showed that more positive facial expressions like smiling were observable in the robot condition.

In contrast to the first three touch sequences, no differences due to the presence of touch were remarked during the fourth touch sequence. One explanation for this observation might be found in the content of the conversation. When the robot touched the participants (or not) for the fourth time, it said:

> Oh, I'm sad to say that our time is declining *[looks at its wrist*]. I could have told you so much more. The experimenter will hand you all necessary information that could be important to you. *[pause - starts the initiation of touch]* Okay, that's it for today. It was a pleasure talking to you. I'm sorry to say that but I have many more appointments today, (…)

From the timing of the laughing, it seems as if participants found it funny that the robot pretended to look at a non-existing watch, and to have a busy day. These typical humanlike behaviors might have amused the participants independent from the presence of touch. As a result, the conversational content during the last touch sequence might have overwritten the effect of touch. In turn, this might have caused equal evaluations of the robot and the whole interaction, because the positive experience at the end is most likely to be remembered in retrospective.

With regard to the participants' stable posture, it can be suspected that the experimental instructions to keep the left hand on the box to ensure that the physiological data is accurately recorded might have accounted for this result. Certainly, participants might have left their hand on the box not to disrupt the experimental procedure, although they might have experienced the touch as surprising or undesirable. The example of participant 43 supports this option, because it was visible that she only closed her eyes instead of pulling away her hand when the robot touched her, although she stated afterwards that it was quite unpleasant for her. Because of that it can be criticized that the procedure might have restricted participants' reactions to robot-initiated touch. However, experimental control was instead higher because the comparability between participants would have been reduced if they were for instance free to avoid touch, or to initiate a touch to the robot on their own. All such variations might in turn would have altered the overall experience.

With respect to the laughing that happened during or after touch, it is noteworthy that several participants seemed to show a delayed reaction. Often their attention was traced to the hand when the robot started touching, then the attention was directed back to the robot's face, and the laughing often started a few seconds later. In some cases, it seems as if participants were first wondering what was going on before the positive reaction emerged. The evaluation of the robot's touch as rather unexpected within the touch condition supports this presumption. Additionally, the highly positive evaluation of the touch as warm, functional, positive, and not painful punctuate the favorable reactions after first astonishment.

9.5.6 Compliance and Helping as an Outcome of Robot-Initiated Touch

As outcomes of the conversation with the robot, participant's answer to the question whether they would have been interested in a course for business English (H6), and their willingness to help the experimenter that dropped some sheets (H7), were considered.

The comparison of participant's compliance to the robot's suggestion to take a course revealed that participants that were touched before the request was posed, were more likely to comply to the robot's request, i.e., showed more interest in the course, than participants that were not touched. Hence, robot-initiated touch, similar to interpersonal touch, seems to reinforce a request what increases compliance. One explanation for the impact of interpersonal touch on compliance is that the toucher is perceived as in genuine need, trusting the recipient of touch while raising his/her request (Gallace & Spence, 2010). The same could apply to the robot in the present study. Participants might have perceived the touch from the robot as demonstrating trust or a genuine need that in turn increased compliance.

Besides the participants' behavior during the conversation (e.g., facial reaction and compliance), it was tested whether robot-initiated touch also had an effect on their willingness to help the experimenter immediately after the conversation. Contrary to the hypothesized higher helping after touch (H7), no significant difference emerged. Participants that were touched by the robot helped the experimenter nearly as often as they did not, and so did participants in the no touch condition. The willingness to help thus seemed dependent on other factors than the presence of touch. That conflicts earlier observations in interpersonal encounters that yielded more helping after touch (e.g., Patterson, Powell, & Lenihan, 1986; Paulsell & Goldman, 1984).

A substantial difference between the present study, and studies on the effects of interpersonal touch on helping, is that the person that needed help was the same one that touched the participants before. In contrast, in the present study the robot touched the participants, whereas the experimenter needed help later on. Consequently, it is possible that the participant would have helped the robot more often after touch (what was not tested), but that the effect does not spread to the experimenter.

Based on different reactions to interpersonal touch according to the sex of the toucher (e.g., Paulsell & Goldman, 1984), participants were additionally asked whether they perceived the robot as rather male or female. Means around the midpoint of the scale revealed that the robot was perceived as moderately male and female. That means that the robot appeared neither particularly male or female. But when the estimation of the robot's sex was compared between the experimental conditions, a significant difference emerged, which showed that the robot was perceived as less male when it initiated touch during the conversation. However, this difference was independent of the participants' sex.

Based on these observations, it is difficult to explain why the robot was perceived as more male when it did not touch the participants. Contrary to this finding, males have been shown to initiate touch (to the opposite sex) more often (Major, 1981; Hall, 1996), whereas females receive touch more often (Jourard, 1966). However, it is likely that touching might have evoked the impression of sensitivity and warmth, which are person characteristics that do not match a male stereotype (Eckes, 1994, 2010).

9.5.7 Application of the Appraisal Process to Actual HRT

As a final step in the analyses, the appraisal process of HRT as acquired on the basis of expectancy violations theory (Burgoon, 1983; Burgoon & Hale, 1988) in the realm of Study 3, was reconsidered. In contrast to Study 3, in which the impact of different directions of HRT (robot-initiated vs. human-initiated touch) was considered, the impact of the presence of robot-initiated touch (no touch vs. touch) on the evaluation of HRT was regarded in the present study. Above that, the evaluation was based on actual touch compared to observer ratings of photographs as in Study 3.

In contrast to the assumed correlation between expectedness and the evaluation of HRT (H8a), it was revealed that a negative connection exists: the less expected participants judged the conversation, the better their evaluation. Against the background of expectancy violations theory, it seems as if a positive violation of expectations took place that caused a more favorable evaluation. However, neither the expectedness, nor the evaluation were significantly influenced by the presence of touch. The interpretation of the robot's behavior as showing affection was, however, positively related to the evaluation, as expected (H8b).

Hence, it appears as if the participants who actually interacted with a robot, base their evaluation of the interaction on their relational interpretation (cf. Burgoon, 1991), characteristics of the robot, and their overall satisfaction with the communication, whether touch was present or not. In this context, expectations seem to be subordinate, although the negative correlation between expectedness and the evaluation suggest that the conversation with the robot exceeded participants' expectations, what resulted in a favorable evaluation in both conditions.

9.5.8 Limitations

Several limitations need to be acknowledged. With regard to the appraisal of HRT, varying reasons can be cited that might have caused results that are somehow contradictory to the assumed HRT appraisal process (cf. Study 3). First, the tested model within Study 3 compared the effect of different directions of touch (human- and robot-initiated) on the evaluation, because both forms of touch have been demonstrated to vary significantly with regard to its expectedness. However, in the present study, robot-initiated touch was compared to a no touch condition. Hence, the findings cannot by compared one-on-one.

Second, unlike Study 3, the statements that were chosen to collect participants' expectedness of the interaction did not built a reliable score. Even after the deletion of two items the reliability was still not good (< .70). Hence the findings that concern the expectedness have to be interpreted with caution. In addition, the comparability is further reduced due to a necessary reformulation of the statements. While the statements focused on the expectedness of the interaction in Study 3, e.g., "The behavior of the human and the robot is what I would typically expect", the statements focused on the robot's behavior only in the present study, e.g., "The robot's behavior was what I typically expected." Hence, it cannot be ruled out that the expectedness in Study 3 referred to the behavior of the human in the picture.

Third, it can be argued that the expectedness measure did not directly address the expectedness of touch. Therefore, it is possible that the variations between the conditions were not that strong. Beyond, it seems as if the matching of the robot's verbal (conversational content) and nonverbal behavior (mere gesticulation or touch), determined the experience, and also the expectedness of the overall conversation.

In consequence, it seems as if the expectedness of an interaction with a robot is not only affected by touch, or to be more precise, touch did not make the conversation significantly more unexpected than a (well-engineered) conversation with a robot anyway.

In addition, it can be criticized that the cover story and the resulting static posture of the participants, with their left hand on the box, might have been experienced as very unnatural. However, to keep the interaction equal, all participants had to adopt this posture, regardless of the experimental condition. Furthermore, none of the participants mentioned that they felt uncomfortable due to the requested posture. When they were told during debriefing that the box was only utilized to ensure that the robot reached the participant's hand in the touch condition, participants were surprised and indicated that they have not been suspicious about the function of the box.

Finally, since the present experiment was conducted with undergraduate students, with moderate to high technological expertise, the generalizability of the findings to other populations is restricted. It remains open whether the findings will be replicable with other populations as children or elderly people, user groups that have been primary regarded in the realm of robot therapy where touch is directed from the subjects to therapeutic robot (cf. Chapter 3.2 on Robot Therapy). Notwithstanding, the scenario that was used in the present study was tailored to students, and thus would not have worked with another group of participants. However, it can be presumed that a conversational scenario with another topic that matches a broader sample would be comparable to the present study.

9.5.9 Conclusion

In summary, the present study demonstrated a possible way to investigate the effects of seemingly spontaneous robot-initiated touch on human subjects without any prior warning or request. The results revealed that touch in comparison to no touch affected participants' emotional state (collected via self-report), in a favorable direction. Moreover, the objectively observed behavior of the participants was also affected by the touch from the robot, manifested in more laughing and compliance in the touch condition. Contrary to the assumed model (cf. Figure 14, p. 208) the presence of touch did not have a direct, nor an indirect effect through expectedness and interpretation on the evaluation of HRT. Due to the observed differences based on the presence of touch on the affective state, as well as on the behavior during the conversation, it seems as if robot touch immediately affected the participants on a subconscious, emotional level, whereas no differences in the more cognitively effortful evaluation of the conversation and the robot occurred.

IV: GLOBAL DISCUSSION

Against the background of interpersonal touch research that yielded several positive effects on the recipient as well as the initiator of touch (see Chapter 2), the question was posed whether touch between humans and robots can also result in positive consequences for human well-being. Previous work on touch in the realm of human-robot interactions (see Chapter 3) demonstrated that interaction with pet like robots that are inherently tactile (cf. robot therapy), elicit favorable responses in humans as mood elevation, pain relief, improved vital signs, and lowered depression. These studies were primarily conducted with children in hospitals, or elderly people in care centers. In addition, experimental studies with other robot morphologies like humanoid and android robots have been conducted, that allowed other forms than human-initiated touch to the robot. In summary, the studies moreover represent individual observations, because more or less each study had a different focus. For example, the influence of the temperature of a robot's hand during handholding was studied in the context of the reception of a horror movie, whereas the impact of robot-initiated touch was considered with regard to the emotional reactions to functional or affectively intended touch in a hospital scenario, or the motivation to continue a monotonous task in a laboratory setting. All things considered, the related studies on HRT indicate that non-reciprocal touch, from a human to a robot and vice versa, as well as reciprocal touching between humans and robots cause some effects on a psychological and physiological level.

With the objective to contribute to the structuring of the field of HRT, the present dissertation addressed HRT in a systematical manner, based on theories that originated from interpersonal communication research. For the purpose of answering the question whether HRT has comparable effects as interpersonal touch and can thus contribute to human well-being, four consecutive empirical studies were conducted. A mixed-methodological approach was chosen that allowed the qualitative exploration of the perception of HRT by observers first (Study 1), followed-up by quantitative questionnaire studies (Study 2 & 3) that were used to test the hypotheses derived from Study 1, and finally resulted in a laboratory experiment that considered the impact of robot-initiated touch on self-reported and observable variables.

In the following, the findings of all studies were revisited with respect to the global research question that guided this dissertation.

10 Summary of Findings in Consideration of the Central Questions

10.1 How Do Humans Interpret HRT?

Regarding the question how individuals interpret touch with robots (GQ1), Study 1 and Study 3 considered relational interpretations of HRT from the perspective of observers, following the work of Burgoon (1991; see also: Burgoon & Hale, 1984). As stimulus material, pictures of five humanoid robots with varying sizes were taken, which depict these robots in physical contact with a human actor. Similar to Burgoon's (1991) study, pictures of reciprocal (handshake, handholding, embrace), and non-reciprocal touch forms (touch to the arm, touch to the face) were included. Additionally, the non-reciprocal touch forms were twice included, once demonstrating the touch directed from the robot to the human, and once from the human to the robot.

In Study 1, which followed a qualitative approach, 40 photographs representing all combinations of robot type and touch form were presented to interviewees. Their interpretations of the stimuli largely resembled personal relationship interpretations that are comparable to descriptions of interpersonal relationships. Moreover, the relational themes that were deduced from the interviews were also similar to relational themes known from the interpersonal literature (Burgoon & Hale, 1984), and the interpretations of different forms of HRT further varied in their meaning, in line with earlier observations on relational interpretations of interpersonal touch (Burgoon, 1991; Burgoon et al., 1984). In conclusion, HRT has been demonstrated to be relationally interpretable on the same terms as interpersonal touch.

In Study 3, a selection of seven pictures out of the total stimulus material was chosen that only displayed the robot Nao. The objective of Study 3 was again the examination of the perception of different forms of HRT, with a focus on the direction and intimacy of the touch forms that were depicted. Furthermore, the stimulus pictures were this time presented together with vignettes that described the interaction context as rather functional or affective.

Contrary to the assumptions, the analyses revealed that the context of HRT did not affect the relational interpretation of the human-robot relationship. Instead the intimacy of HRT significantly influences the relational interpretations: intimate forms of HRT were perceived as conveying more intimacy, and less formality than formal touch forms as the handshake. Moreover, the direction of touch affected the perceived dominance of the robot. Most dominance was interpreted when robot-initiated touch was presented, followed by reciprocal and human-initiated touch.

In contrast to Study 1 and 3, Study 4 was a laboratory experiment in which the presence (versus absence) of actual robot-initiated touch was considered. During the experimental session, participants were therefore seated at a table where the robot was located, and had to put their hand on a box that was said to measure their skin conductance. In fact, the box was only used to ensure that the robot reached the participants' hand. Regarding the relational interpretations, no differences between the touch and the no touch condition appeared with respect to the perceived affection the robot showed, and the relational closeness between the participant and the robot.

Taken together, the findings concerning observers of HRT suggest that a social meaning model also applies to the observation of HRT (cf. Burgoon, 1991; Burgoon & Hale, 1984; Burgoon & Walther, 1990). However, the relational interpretations form a participant perspective (Study 4) differed from that of observers of HRT (Study 1 and 3). Since observers assigned more closeness to intimate forms of HRT as a touch to the face, it can be argued that the formal form of touch that was used in the laboratory experiment, i.e., touch to the hand, did not have a strong impact on perceived affection and closeness. In addition, it has been discussed that the observer perspective allowed more descriptions of the human-robot relationship as close and personal, because of a third person perspective (cf. Davison, 1983), while participants that were actually touched by the robot might have denied that they felt close to the robot (Nass & Moon, 2000). So far it has been assumed that a social meaning model causes similar interpretations of interpersonal touch in observers as well as in participants. However, Burgoon and Newton (1991) also mentioned that observers of touch, and participants in touch interactions, have distinct attributional bases, which determine their interpretations of touch. While participants are more involved in the interaction and are sensitive to contextual factors, observers focus their attention on characteristics of the interlocutor. Hence, it is possible that observers of HRT make more differentiated relational interpretations, whereas participants interpret the experience as a whole, whereby the relational level seems of less importance during a one-time interaction with a robot.

10.2 Which forms of HRT are pleasant and acceptable to humans?

The question which forms of HRT appear pleasant and acceptable to humans (GQ2), were addressed in Study 1 – 3.

Study 1 and Study 2 both indicate that robot touch to some parts of the human body (e.g., the back and the legs) is more acceptable to humans than touch from a human stranger. As a reason for the lower inhibition threshold for robotic touch, the lack of ulterior motives or emotions was named in the interviews (Study 1). In Study 2, participants had to evaluate HRT only on the basis of textual questions without a given stimulus picture to consider general opinions. All studies (1-3) showed that human-initiated touch forms were more desirably evaluated than reciprocal, and robot-initiated touch forms.

Furthermore, the emotional reaction to HRT was shown to be anticipated to be better when human-initiated touch was anticipated than when reciprocal, or robot-initiated touch was included (Study 1 and 3). In contrast, robot-initiated touch in comparison to a no touch condition evoked a favorable emotional response in the participants in Study 3.

The evaluation of robot-initiated touch in the realm of Study 4 further demonstrated that the touch initiated by a robot was positively evaluated. However, the general evaluation of the interaction and the robot (its attractiveness) was not affected by touch. However, participants showed more positive emotional response in the touch condition (laughing) and reported more positive affect afterwards.

10.3 With which robots and under which circumstances is HRT acceptable?

The influence of the robot type on the perception and evaluation of HRT (GQ3) was considered in Study 1 and Study 2. In Study 1 by means of the stimulus pictures that depicted different robots, and in Study 2 based on textual descriptions of different robot morphologies and sizes (following the results from Study 1). As a result, the interviewees were open to touch with all robots except of the tallest, and further mechanically looking robot Rhoni. The comments of the interviewees revealed that touch with smaller robots as Lego's NXT, Robosapien, or Nao was perceived as pleasant and somehow funny. This might follow from the fact that the smaller robots possessed a lining, and were in addition often compared to toys.

Regarding the context in which HRT occurs, Study 3 revealed that only the anticipated arousal participants assumed to experience in the interaction with a robot was reported to be higher if HRT happens in an affective context, than in a functional one. Furthermore, no significant influence of the context manipulation on the expectedness, interpretation, or evaluation of HRT was observed for observers of touch in Study 3. However, based on Burgoon and Newton (1991) it can be expected that the context of touch would be even more meaningful in an actual interaction. In addition, it seems as if the effect of the touch forms was so strong, that the context manipulation did not cause a difference. Future research should thus examine the impact of different contexts on the interpretation and evaluation of HRT, while the touch form is kept equal. This could be repeated from an uninvolved observer perspective, and should in addition be considered from a participant perspective during an actual interaction to test whether individuals that experience actual HRT are more sensitive to context information (cf. Burgoon & Newton, 1991).

10.4 Which factors influence the appraisal of HRT?

Against the background of expectancy violations theory (Burgoon & Hale, 1988), a model was derived for the appraisal of HRT that includes the role of expectations in the appraisal of touch. It was hypothesized that touch constitutes a new, and thus unexpected feature of a robot, that can either be favorably or unfavorably regarded. Expectancy violations theory was taken as a framework that can explain positive as well as negative reactions to a violation of expectations. Applied to HRT, the model predicts that if HRT constitutes a violation of the expected behavior of the robot, the interpretation and evaluation of the violation determines the valence of the outcome. If touch by a robot is for instance interpreted as a sign of affection, and if this sign is positively valued by the individual, it is likely that the individual will react positively to touch. Instead, if the behavior is unexpected but interpreted and evaluated as undesirable, e.g., touch from an eerie robot that is interpreted as showing affection would result in a negative reaction (GQ4).

Since Study 1 already revealed that the different forms of HRT were evaluated as varyingly surprising, i.e., expected, Study 3 considered all variables in the appraisal process and tested the assumed relation between HRT its expectedness, interpretation, and evaluation. The analyses revealed that the interpretation of touch as demonstrating affection, as well as the expectedness of HRT mediate the effect of touch direction (human- or robot-initiated) on the evaluation. Moreover, the robot's perceived attractiveness was revealed to serve as a reward, as it has been assumed by Burgoon and Walther (1990). Hence, the effect of touch through expectedness and interpretation on the evaluation was further moderated by the perceived reward value (assessed with the perceived social attraction of the robot). Accordingly, the effect of touch direction on the evaluation was only significantly mediated by attachment if the robot was highly rewarding. Instead, touch that is interpreted as showing attachment to an unrewarding robot does not evoke a favorable evaluation, as predicted by expectancy violations theory.

In contrast, the model was again tested for actual HRT (Study 4) but did not result in the hypothesized effects. It is necessary to mention that the effect of human- and robot-initiated touch on the evaluation was tested in Study 3, whereas the effect of the presence of touch was investigated in Study 4. As the results demonstrated, the presence or absence of touch in Study 4 did not affect any of the evaluation items or scales.

Concluding on the appraisal of HRT, characteristics of humans, as a positive attitude towards touch and robots seem to facilitated the acceptance HRT (Study 2, 3 & 4). As the case of one touch avoidant participant in the realm of Study 4 demonstrated, the knowledge about individual preferences for touch is useful to avert negative consequences. For example, a robot could be equipped with a capability to recognize when touch is discomforting a person and react accordingly (e.g., stop touching).

10.5 Can HRT contribute to human well-being, as interpersonal touch does?

The final and most important question that was pursuit through this dissertation is whether HRT can contribute to human well-being (GQ5). By a contribution to human well-being it was meant that favorable emotional, psychological, or even physiological reactions to HRT are remarkable. Based on the evidence of the aforementioned studies, it can be derived that HRT was initially not unfavorably evaluated, with the exception of some negative comments respective to the huge robot Rhoni, and the childlike robot iCub in Study 1. Moreover, the evaluation of the different touch forms demonstrated that the direction of touch had a special meaning for the observers of HRT. Touch that is directed to a robot was overall not alarming and favorably evaluated in Study 1-3, while robot-initiated touch was mostly the least favorable form of HRT. However, the ratings for robot-initiated touch were not negative, but just less positive than those for human-initiated and reciprocal touches.

The findings form Study 4 furthermore support the assumption that robot-initiated touch is not generally refused by humans. Conversely, participants' reactions to the robot's touch was entirely positive as the high frequency of laughing and smiling in the touch condition demonstrated. Additionally, participants self-reported emotional state during and after the conversation with the robot revealed that robot-initiated touch actually had a positive effect on participants' feelings compared to the same interaction without touch.

Based on these findings, as well as based on findings in the realm of robot therapy (Chapter 3.2) the application of robot touch to contribute to human well-being appears promising.

10.6 Practical Implications and Future Directions

Practical implications for the design and application of HRT can be derived on the basis of the empirical studies.

Based on the findings from Study 2, it seems reasonable to recommend avoiding HRT for rather affective purposes, because a higher acceptance was revealed for functional compared to affective touch. In contrast, the findings of Study 3, however, did not revealed significant differences with regard to the evaluation of HRT in an affective versus a functional context. Future studies should thus further investigate the impact of HRT in different contexts.

Based on the findings of Study 1 and 2, it can be recommended to use robots that are at least taller than the human user, if touch should be included in the human-robot interaction. If a tall robot initiated touch to a human, negative emotions as feelings of inferiority could occur (Henley, 1973, 1977).

Furthermore, since it has been shown that the direction, reciprocity, and intimacy of touch affect the perception, interpretation, and evaluation (Study 1-3), future studies should consider comparing different touch forms, e.g., reciprocal versus non-reciprocal HRT, in actual human-robot interactions. Similarly, it would be interesting to compare a formal touch as in Study 4 to a more intimate form of touch and see whether relational closeness might be influenced by intimate touch from a robot.

Since the findings from the laboratory experiment (Study 4) are the most reliable to estimate human response to robot touch since actual touch was considered, the implications of Study 4 are of particular interest.

In summary, it has been revealed that participants showed more compliance to the robot's suggestion to take part in a course for business English. Compliance is not equal to well-being at first glance, but applications are imaginable where this persuasive power can be utilized to contribute to human well-being. For instance, compliance might be desirable in scenarios where a robot is used to convince its user, e.g., to take medicine, to exercise, or to stick to a diet. Of course, verbal reminders can also cause an effect on the user, but as the huge amount of studies in the interpersonal literature demonstrated, touch emphasizes the request, what causes even more compliance.

Furthermore, as mentioned in the theoretical background on interpersonal touch (Chapter 1), robots can be applied to study the effects of interpersonal touch in a more controlled manner. As touch research has always be confounded by other behaviors, e.g., eye gaze or body posture, that impede the controlled investigation of interpersonal touch (for a comprehensive overview see Lewis & Derlega, 1997), robots could potentially be used to overcome such problems. Since the behavior of robots is totally controllable the plain effect of touch could be investigated with a robot. Albeit, one could argue that the cofounds correspond to real life interactions. However, to gather an unbiased information about the mere impact of touch, a robot could represent an alternative to a human confederate. In advance, future studies should directly compare the impact of robot touch to that of human touch. Walker and Bartneck (2013) made a first step in this direction, when they compared a head massage between a human and a robot masseur. However, both used a tool to conduct the massage, what made the touch appear equal on the skin, but is in fact different from immediate touch from a robot. Future studies should thus consider immediate robot-initiated touch in comparison to human touch to participants.

10.7 Conclusion

According to the findings so far, small (at least smaller than the human partner) and pet like robots are favorably evaluated with regard to touch acceptance. As earlier work with pet like robots demonstrated, positive effects on human well-being can be elicited through physical interactions (human-initiated touch) with pet like robots (e.g., Shibata & Tanie, 2001; Wada & Shibata, 2006; Wada, Shibata, Saito, Sakamoto, & Tanie, 2005).

Consistent with the findings within this thesis, robot-initiated touch in a conversational interaction further showed a positive impact on the feelings and behavior of human participants. In line with the findings from Study 1 and 2, robot touch might be a useful alternative to human touch, for tasks in which a lower inhibition threshold is desirable, as in the transportation, bathing or cleaning of people in need of help. Furthermore, robot touch can be beneficial for lonely people to stimulate their sense of touch, especially with pet like robots as in the robot therapy approach.

Overall, it can be summarized that the effects of HRT are promising to support the evocation of positive reactions in humans. However, I would like to end this thesis with the notion that: *Human touch will still mean that much*.

REFERENCES

Alagna, F. J., Whitcher, S. J., Fisher, J. D., & Wicas, E. A. (1979). Evaluative reaction to interpersonal touch in a counseling interview. *Journal of Counseling Psychology*, *26*(6), 465–472. http://doi.org/10.1037/0022-0167.26.6.465

Andersen, P. A., & Leibowitz, K. (1978). The development and nature of the construct touch avoidance. *Environmental Psychology and Nonverbal Behavior*, *3*(2), 89–106. http://doi.org/10.1007/BF01135607

Argyle, M., & Dean, J. (1965). Eye Contact, Distance and Affiliation. *Sociometry*, *28*(3), 289–304. http://doi.org/10.1111/j.2044-8295.1970.tb01257.x

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology*, *63*(4), 596–612. http://doi.org/10.1037/0022-3514.63.4.596

Austermann, A., Yamada, S., & Funakoshi, K. (2010). Does the appearance of a robot affect users' ways of giving Commands and feedback? In *9th International Symposium in Robot and Human Interactive Communication* (pp. 234–239). IEEE.

Austermann, A., Yamada, S., Funakoshi, K., & Nakano, M. (2010). How do users interact with a pet-robot and a humanoid. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems* (pp. 3727–3732). ACM.

Banks, M. R., Willoughby, L. M., & Banks, W. A. (2008). Animal-assisted therapy and loneliness in nursing homes: use of robotic versus living dogs. *Journal of the American Medical*, *9*(3), 173–177.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. http://doi.org/http://dx.doi.org/10.1037/0033-2909.117.3.497

Berg, B. L. (2001). *Qualitative research methods for the social sciences* (5th ed.). Pearson Education.

Bevan, C., & Fraser, D. S. (2015). Shaking hands and cooperation in tele-present human-robot negotiation. In *Proceedings of the 10th Annual ACM/IEEE* (pp. 247–254). Portland, Oregon, USA: ACM. http://doi.org/10.1145/2696454.2696490

Bradley, M., & Lang, P. (1994). Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59.

Burgoon, J. K. (1978). A communication model of personal space violations: Explication and an initial test. *Human Communication Research*, *4*(2), 129–142. http://doi.org/10.1111/j.1468-2958.1978.tb00603.x

Burgoon, J. K. (1983). Nonverbal violations of expectations. In J. M. Wiemann & R. P. Harrison (Eds.), *Nonverbal Interaction* (Vol. 11, pp. 77–111). SAGE.

Burgoon, J. K. (1991). Relational message interpretations of touch, conversational distance, and posture. *Journal of Nonverbal Behavior*, *15*(4), 233–259. http://doi.org/10.1007/BF00986924

Burgoon, J. K. (1993). Interpersonal Expectations, Expectancy Violations, and Emotional Communication. *Journal of Language and Social Psychology*, *12*(1–2), 30–48. http://doi.org/10.1177/0261927X93121003

Burgoon, J. K., Buller, D. B., Hale, J. L., & de Turck, M. A. (1984). Relational Messages Associated With Nonverbal Behaviors. *Human Communication Research*, *10*(3), 351–378. http://doi.org/10.1111/j.1468-2958.1984.tb00023.x

Burgoon, J. K., & Hale, J. (1984). The fundamental topoi of relational communication.

Communication Monographs, *51*(3), 193–214. http://doi.org/http://dx.doi.org/10.1080/03637758409390195

Burgoon, J. K., & Hale, J. L. (1987). Validation and measurement of the fundamental themes of relational communication. *Communications Monographs*, *54*(1), 19–41.

Burgoon, J. K., & Hale, J. L. (1988). Nonverbal expectancy violations: Model elaboration and application to immediacy behaviors. *Communications Monographs*, *55*(1), 58–79. http://doi.org/10.1080/03637758809376158

Burgoon, J. K., & Jones, S. B. (1976). Toward a Theory of Personal Space Expectations and Their Violations. *Human Communication Research*, *2*(2), 131–146. http://doi.org/10.1111/j.1468-2958.1976.tb00706.x

Burgoon, J. K., & Newton, D. A. (1991). Applying a social meaning model to relational message interpretations of conversational involvement: Comparing observer and participant perspectives. *Southern Journal of Communication*, *56*(2), 96–113.

Burgoon, J. K., Newton, D. A., Walther, J. B., & Baesler, E. J. (1989). Nonverbal expectancy violations and conversational involvement. *Journal of Nonverbal Behavior*, *13*(2), 97–119. http://doi.org/10.1007/BF00990793

Burgoon, J. K., Pfau, M., Parrott, R., Birk, T., Coker, R., & Burgoon, M. (1987). Relational Communication, Satisfaction, Compliance-Gaining Strategies, and Compliance in Communication Between Physicians and Patients. *Communication Monographs*, *54*(3), 307–324. http://doi.org/10.1080/03637758709390235

Burgoon, J. K., & Saine, T. (1978). *The unspoken dialogue: An introduction to nonverbal communication*. Boston: Houghton Mifflin.

Burgoon, J. K., & Walther, J. B. (1990). Nonverbal expectancies and the evaluative consequences of violations. *Human Communication Research*, *17*(2), 232–265. http://doi.org/10.1111/j.1468-2958.1990.tb00232.x

Burgoon, J. K., Walther, J. B., & Baesler, E. J. (1992). Interpretations, evaluations, and consequences of interpersonal touch. *Human Communication Research*, *19*(2), 237–263. http://doi.org/10.1111/j.1468-2958.1992.tb00301.x

Bush, E. (2001). The use of human touch to improve the well-being of older adults. A holistic nursing intervention. *Journal of Holistic Nursing*, *19*(3), 256–270. http://doi.org/10.1177/089801010101900306

Caris-Verhallen, W. M. C. M., Kerkstra, A., & Bensing, J. M. (1999). Non-verbal behaviour in nurse-elderly patient communication. *Journal of Advanced Nursing*, *29*(4), 808–818. http://doi.org/10.1046/j.1365-2648.1999.00965.x

Chang, W.-L., & Šabanović, S. (2015). Interaction Expands Function. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction - HRI '15* (pp. 343–350). New York, USA: ACM Press. http://doi.org/10.1145/2696454.2696472

Chang, W., Šabanovic, S., & Huber, L. (2014). Observational study of naturalistic interactions with the socially assistive robot PARO in a nursing home. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN 2014* (pp. 294–299). IEEE. http://doi.org/10.1109/ROMAN.2014.6926268

Chen, T. L., King, C.-H. A., Thomaz, A. L., & Kemp, C. C. (2014). An Investigation of Responses to Robot-Initiated Touch in a Nursing Context. *International Journal of Social Robotics*, *6*(1), 141–161.

Chen, T. L., King, C.-H., Thomaz, A. L., & Kemp, C. C. (2011). Touched by a robot: An investigation of subjective responses to robot-initiated touch. In *Proceedings of the 6th international conference on Human-robot interaction* (pp. 457–464). Lausanne,

Switzerland: ACM. http://doi.org/10.1145/1957656.1957818
Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment*, *7*(3), 309–319. http://doi.org/10.1037/1040-3590.7.3.309
Clatterbuck, G. W. (1979). Attributional confidence and uncertainty in initial interaction. *Human Communication Research*, *5*(2), 147–157. http://doi.org/10.1111/j.1468-2958.1979.tb00630.x
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum.
Cohen, S., Janicki-Deverts, D., Turner, R. B., & Doyle, W. J. (2014). Does Hugging Provide Stress-Buffering Social Support? A Study of Susceptibility to Upper Respiratory Infection and Illness. *Psychological Science*, *26*(2), 135–147. http://doi.org/10.1177/0956797614559284
Collis, G., & McNicholas, J. (1998). A theoretical basis for health benefits of pet ownership: Attachment versus psychological support. Retrieved from http://psycnet.apa.org/psycinfo/1997-36468-006
Cramer, H., Kemper, N. A., Amin, A., & Evers, V. (2009). The effects of robot touch and proactive behaviour on perceptions of human-robot interactions. In *Late Breaking Report, Proceedings of the 4th ACM/IEEE international conference on Human robot interaction* (pp. 275–276). ACM.
Cramer, H., Kemper, N., Amin, A., Wielinga, B., & Evers, V. (2009). “Give me a hug”: the effects of touch and autonomy on people’s responses to embodied social agents. *Computer Animation and Virtual Worlds*, *20*(2-3), 437–445.
Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mix Methods Approaches. http://doi.org/10.1007/s13398-014-0173-7.2
Crusco, A. H., & Wetzel, C. G. (1984). The Midas Touch: The Effects of Interpersonal Touch on Restaurant Tipping. *Personality and Social Psychology Bulletin*, *10*(4), 512–517. http://doi.org/0803973233
Dahlbäck, N., Jönsson, A., & Ahrenberg, L. (1993). Wizard of Oz studies: why and how. *Proceedings of the 1st*, *6*(4), 258–266. http://doi.org/10.1016/0950-7051(93)90017-N
Dautenhahn, K., Ogden, B., & Quick, T. (2002). From embodied to socially embedded agents - Implications for interaction-aware robots. *Cognitive Systems Research*, *3*(3), 397–428. http://doi.org/10.1016/S1389-0417(02)00050-5
Dautenhahn, K., Woods, S., & Kaouri, C. (2005). What is a robot companion-friend, assistant or butler? In *International Conference on Intelligent Robots and Systems, 2005. (IROS 2005)*. http://doi.org/10.1109/IROS.2005.1545189
Davison, W. (1983). The third-person effect in communication. *Public Opinion Quarterly*, *47*(1), 1–15. http://doi.org/10.1086/268763
Döring, N., & Bortz, J. (1993). Psychometrische Einsamkeitsforschung: Deutsche Neukonstruktion der UCLA Loneliness Scale. [Psychometric research on loneliness: A new German version of the University of California at Los Angeles (UCLA) Loneliness Scale.]. *Diagnostica*, *39*(3), 224–239.
Dougherty, E., & Scharfe, H. (2011). Initial formation of trust: designing an interaction with Geminoid-DK to promote a positive attitude for cooperation. In *Third International Conference, ICSR 2011,* (pp. 95–103). Amsterdam, The Netherlands. http://doi.org/10.1007/978-3-642-25504-5_10
Eckes, T. (1994). Features of men, features of women: Assessing stereotypic beliefs about

gender subtypes. *British Journal of Social Psychology*, *33*(1), 107–123. http://doi.org/10.1111/j.2044-8309.1994.tb01013.x
Eckes, T. (2010). Geschlechterstereotype. In *Handbuch Frauen- und Geschlechterforschung* (pp. 178–189). VS Verlag für Sozialwissenschaften. http://doi.org/10.1007/978-3-531-92041-2_21
Erceau, D., & Guéguen, N. (2007). Tactile contact and evaluation of the toucher. *The Journal of Social Psychology*, *147*(4), 441–444. http://doi.org/10.3200/SOCP.147.4.441-444
Eyssel, F., & Hegel, F. (2012). (S) he's Got the Look: Gender Stereotyping of Robots. *Journal of Applied Social Psychology*, *42*(9), 2213–2230. http://doi.org/10.1111/j.1559-1816.2012.00937.x
Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2008). G*Power. Germany: Uiversität Kiel. Retrieved from http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/download-and-register
Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. London, UK: Sage Publications.
Field, T. (1995). Massage therapy for infants and children. *Journal of Developmental & Behavioral Pediatrics*, *16*(2), 105–111.
Field, T. (1998). Massage therapy effects. *American Psychologist*, *53*(12), 1270–1281. http://doi.org/10.1037/0003-066X.53.12.1270
Field, T. (2002). Infants' need for touch. *Human Development*, *45*(2), 100–103. http://doi.org/10.1159/000048156
Field, T. (2003). *Touch* (paperback). MIT Press.
Field, T. (2010). Touch for socioemotional and physical well-being: A review. *Developmental Review*, *30*(4), 367–383. http://doi.org/10.1016/j.dr.2011.01.001
Field, T. (2014). *Touch in early development*. New York, USA: Lawrence Erlbaum.
Field, T., Hernandez-Reif, M., Diego, M., Schanberg, S., & Kuhn, C. (2005). Cortisol decreases and serotonin and dopamine increase following massage therapy. *International Journal of Neuroscience*, *115*(10), 1397–1413. http://doi.org/10.1080/00207450590956459
Fisher, J. D., Rytting, M., & Heslin, R. (1976). Hands touching hands: Affective and evaluative effects of an interpersonal touch. *Sociometry*, *39*(4), 416–421. http://doi.org/10.2307/3033506
Flick, U. (2002). *Qualitative Sozialforschung: Eine Einführung*. Rowohlt.
Fogg, B. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity*, *1*(5). http://doi.org/10.1145/764008.763957
Fukuda, H., Shiomi, M., Nakagawa, K., & Ueda, K. (2012). "Midas touch"in human-robot interaction: Evidence from event-related potentials during the ultimatum game. In *7th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2012)* (pp. 131–132). IEEE.
Gallace, A., & Spence, C. (2010). The science of interpersonal touch: an overview. *Neuroscience & Biobehavioral Reviews*, *34*(2), 246–259. http://doi.org/10.1016/j.neubiorev.2008.10.004
Guéguen, N. (2002). Touch, awareness of touch, and compliance with a request. *Perceptual and Motor Skills*, *95*(2), 355–360. http://doi.org/10.2466/pms.2002.95.2.355
Guéguen, N. (2004). Nonverbal encouragement of participation in a course: The effect of touching. *Social Psychology of Education*, *7*(1), 89–98.

http://doi.org/10.1023/B:SPOE.0000010691.30834.14
Guéguen, N., & Fischer-Lokou, J. (2002). An evaluation of touch on a large request: A field setting. *Psychological Reports*, *90*(1), 267–269. http://doi.org/10.2466/pr0.2002.90.1.267
Guéguen, N., & Jacob, C. (2005). The effect of touch on tipping: an evaluation in a French bar. *International Journal of Hospitality Management*, *24*(2), 295–299. http://doi.org/10.1016/j.ijhm.2004.06.004
Guéguen, N., & Jacob, C. (2006). The Effect of Tactile Stimulation on the Purchasing Behaviour of Consumers : A Experimental Study In A Natural Setting. *International Journal of Management*, *23*(1), 24–33.
Haans, A., & IJsselsteijn, W. (2006). Mediated social touch: A review of current research and future directions. *Virtual Reality*, *9*(2–3), 149–159. http://doi.org/10.1007/s10055-005-0014-2
Haans, A., & IJsselsteijn, W. A. (2009). The virtual midas touch: Helping behavior after a mediated social touch. *IEEE Transactions on Haptics*, *2*(3), 136–140. http://doi.org/10.1109/TOH.2009.20
Hall, J. a. (1996). Touch, status, and gender at professional meetings. *Journal of Nonverbal Behavior*, *20*(1), 23–44. http://doi.org/10.1007/BF02248713
Haring, K. S., Watanabe, K., Silvera-Tawil, D., Velonaki, M., & Matsumoto, Y. (2015). Touching an Android robot: Would you do it and how? In *International Conference on Control, Automation and Robotics (ICCAR 2015)* (pp. 8–13). IEEE.
Harlow, H., & Zimmerman, R. (1959). Affectional Response in the Infant Monkey. *Science*, *130*(3373), 421–431.
Harlow, H., & Zimmerman, R. R. (1958). The development of affectional responses in infant monkeys. *Proceedings of the American Philosophical Society*, *102*(5), 501–509.
Harris, C. R., & Christenfeld, N. (1999). Can a machine tickle? *Psychonomic Bulletin & Review*, *6*(3), 504–510.
Hayes, A. (2011). My macros and code for SPSS and SAS. Retrieved December 8, 2016, from http://afhayes.com/spss-sas-and-mplus-macros-and-code.html?m
Hayes, A. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, USA: Guilford Press.
Hayes, A. (2015). An index and test of linear moderated mediation. *Multivariate Behavioral Research*, *50*(1), 1–22. http://doi.org/10.1080/00273171.2014.962683
Hect, M. L. (1978). The Conceptualization and Measurement of Interpersonal Communication Satisfaction. *Human Communication Research*, *4*(3), 253–264.
Henley, N. M. (1973). Status and sex: Some touching observations. *Bulletin of the Psychonomic Society*, *2*(2), 91–93.
Henley, N. M. (1977). *Body politics. Power, sex, and nonverbal communication.* Englewood Cliffs, NJ: Prentice-Hall.
Henley, N. M. (2012). Body politics revisited: What do we know today. In M. J. Kalbfleisch, P. J., & Cody (Ed.), *Gender, power, and communication in human* (pp. 27–61). Routledge.
Hensby, K., Wiles, J., Boden, M., & Heath, S. (2016). Hand in Hand: Tools and techniques for understanding children's touch with a social robot. In *11th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2016)* (pp. 437–438). http://doi.org/10.1109/HRI.2016.7451794
Hertenstein, M. J., Holmes, R., McCullough, M., & Keltner, D. (2009). The

communication of emotion via touch. *Emotion*, *9*(4), 566–573. http://doi.org/10.1037/a0016108
Heslin, R., & Alper, T. (1983). Touch: A bonding gesture. In J. M. Wiemann & R. P. Harrison (Eds.), *Nonverbal Interaction* (pp. 47–75). Beverly Hills, CA: Sage.
Heslin, R., Nguyen, T. D., & Nguyen, M. L. (1983). Meaning of touch: The case of touch from a stranger or same sex person. *Journal of Nonverbal Behavior*, *7*(3), 147–157. http://doi.org/10.1007/BF00986945
Hoffmann, L., Krämer, N. C., Lam-Chi, A., & Kopp, S. (2009). Media equation revisited: Do users show polite reactions towards an embodied agent? In *International Workshop on Intelligent Virtual Agents* (Vol. 5773 LNAI, pp. 159–165). http://doi.org/10.1007/978-3-642-04380-2_19
Holt-Lunstad, J., Birmingham, W. a, & Light, K. C. (2008). Influence of a “warm touch” support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol. *Psychosomatic Medicine*, *70*(9), 976–985. http://doi.org/10.1097/PSY.0b013e318187aef7
Hornik, J. (1992a). Effects of physical contact on customers’ shopping time and behavior. *Marketing Letters*, *3*(1), 49–55.
Hornik, J. (1992b). Tactile stimulation and consumer response. *Journal of Consumer Research*, *19*(3), 449–458. http://doi.org/10.1086/209314
Jones, S. E., & Yarbrough, A. E. (1985). A naturalistic study of the meanings of touch. *Communications Monographs*, *52*(1), 19–52. http://doi.org/10.1080/03637758509376094
Jourard, S. (1966). An Exploratory Study of Body-Accessibility. *British Journal of Social and Clinical Psychology*, *5*(3), 221–231. http://doi.org/10.1111/j.2044-8260.1966.tb00978.x
Jung, Y., & Lee, K. M. (2004). Effects of physical embodiment on social presence of social robots. In *Proceedings of Presence, 2004* (pp. 80–87).
Kaufman, D., & Mahoney, J. M. (1999). The effect of waitresses’ touch on alcohol consumption in dyads. *The Journal of Social Psychology*, *139*(3), 261–267. http://doi.org/10.1080/00224549909598383
Kemper, N. (2009). *Effects of proactive behavior and physical interaction with a social robot*. Universiteit van Amsterdam. Retrieved from http://scriptiesonline.uba.uva.nl/document/147078
Kleinke, C. L. (1977). Compliance to requests made by gazing and touching experimenters in field settings. *Journal of Experimental Social Psychology*, *13*(3), 218–223. http://doi.org/10.1016/0022-1031(77)90044-0
Kleinke, C. L., Meeker, F., & La Fong, C. (1974). Effects of gaze, touch, and use of name on evaluation of “engaged” couples. *Journal of Research in Personality*, *7*(4), 368–373. http://doi.org/10.1016/0092-6566(74)90058-0
Knapp, M., & Hall, J. (2010). *Nonverbal communication in human interaction* (7th Editio). Boston: Wadsworth Cengage Learning.
Komatsu, T., Kurosawa, R., & Yamada, S. (2012). How does the difference between users’ expectations and perceptions about a robotic agent affect their behavior? *International Journal of Social Robotics*, *4*(2), 109–116.
Krämer, N., & Hoffmann, L. (2016). Media Equation. In N. Krämer, S. Schwan, D. Unz, & M. Suckfüll (Eds.), *Medienpsychologie: Schlüsselbegriffe und Konzepte* (2nd ed., pp. 404–411). Stuttgart: Kohlhammer.
Krämer, N., Hoffmann, L., Fuchslocher, A., Eimler, S., Szczuka, J., & Brand, M. (2013).

Do I need to belong? Development of a scale for measuring the need to belong and its predictive value for media usage. In *Paper presented at the Annual Conference of the International Communication Association,*. London, UK.
Krämer, N., Rosenthal-von der Pütten, A., & Hoffmann, L. (2015). Social Effects of Virtual and Robot Companions. In S. Shyam Sundar (Ed.), *The Handbook of the Psychology of Communication Technology* (pp. 137–159). Wiley Blackwell.
Kwon, M., Jung, M. F., & Knepper, R. A. (2016). Human expectations of social robots. In *ACM/IEEE International Conference on Human-Robot Interaction* (pp. 463–464). http://doi.org/10.1109/HRI.2016.7451807
Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174. http://doi.org/10.2307/2529310
Lee, K. M., Jung, Y., Kim, J., & Kim, S. R. (2006). Are physically embodied social agents better than disembodied social agents?: The effects of physical embodiment, tactile interaction, and people's loneliness in human-robot interaction. *International Journal of Human Computer Studies*, *64*(10), 962–973. http://doi.org/10.1016/j.ijhcs.2006.05.002
Levy, D. (2009). *Love and Sex with Robots: The Evolution of Human-Robot Relationships*. Harper Collins. http://doi.org/10.1017/CBO9781107415324.004
Lewis, R., & Derlega, V. (1997). Nonverbal correlates of confederates' touch: Confounds in touch research. *Journal of Social Behavior and Personality*, *12*(3), 821–830.
Libin, A., & Libin, E. (2004). Person-robot interactions from the robopsychologists' point of view: the robotic psychology and robotherapy approach. *Proceedings of the IEEE*, *92*(11), 1789–1803. http://doi.org/10.1109/JPROC.2004.835366
Major, B., & Heslin, R. (1982). Perceptions of cross-sex and same-sex nonreciprocal touch: It is better to give than to receive. *Journal of Nonverbal Behavior*, *6*(3), 148–162. http://doi.org/10.1007/BF00987064
Mayring, P. (2010). Qualitative inhaltsanalyse. In *Handbuch qualitative Forschung in der Psychologie* (pp. 601–613). VS Verlag für Sozialwissenschaften. http://doi.org/10.1007/978-3-531-92052-8_42
McCroskey, J., & McCain, T. (1974). The measurement of interpersonal attraction. *Speech Monographs*, *41*(3), 261–266. http://doi.org/10.1080/03637757409375845
Mori, M., MacDorman, K., & Kageki, N. (2012). The Uncanny Valley. *IEEE Robotics & Automation Magazine*, *19*(2), 98–100. http://doi.org/10.1109/MRA.2012.2192811
Mueller, F. F., Vetere, F., Gibbs, M. R., Kjeldskov, J., Pedell, S., & Howard, S. (2005). Hug over a distance. In *CHI 05 extended abstracts on Human factors in computing systems CHI 05* (pp. 1673–1676). ACM. http://doi.org/10.1145/1056808.1056994
Nakagawa, K., Shiomi, M., Shinozawa, K., Matsumura, R., Ishiguro, H., & Hagita, N. (2011). Effect of robot's active touch on people's motivation. In *Proceedings of the 6th international conference on Human-robot interaction* (pp. 465–472). ACM.
Nannberg, J. C., & Hansen, C. H. (1994). Post-compliance touch: an incentive for task performance. *The Journal of Social Psychology*, *134*(3), 301–307. http://doi.org/10.1080/00224545.1994.9711734
Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of Social Issues*, *56*(1), 81–103. http://doi.org/0.1111/0022-4537.00153
Nass, C., Moon, Y., & Carney, P. (1999). Are People Polite to Computers? Responses to Computer-Based Interviewing Systems. *Journal of Applied Social Psychology*, *29*(5), 1093–1109. http://doi.org/10.1111/j.1559-1816.1999.tb00142.x
Nass, C., Moon, Y., & Green, N. (1997). Are Machines Gender Neutral? Gender-

Stereotypic Responses to Computers With Voices. *Journal of Applied Social Psychology*, *27*(10), 864–876. http://doi.org/10.1111/j.1559-1816.1997.tb00275.x
Nass, C., & Steuer, J. (1993). Voices, boxes, and sources of messages. *Human Communication Research*, *19*(4), 504–527. http://doi.org/10.1111/j.1468-2958.1993.tb00311.x
Nass, C., Steuer, J., Henriksen, L., & Dryer, D. (1994). Machines, social attributions, and ethopoeia: performance assessments of computers subsequent to “self-” or “other-” evaluations. *International Journal of Human-Computer Studies*, *40*(3), 543–559. http://doi.org/http://dx.doi.org/10.1006/ijhc.1994.1025
Nass, C., Steuer, J., & Tauber, E. (1994). Computers are social actors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’94)* (pp. 72–78). http://doi.org/10.1145/191666.191703
Nass, C., Steuer, J., Tauber, E., & Reeder, H. (1993). Anthropomorphism, agency, and ethopoeia: computers as social actors. In *CHI ’93 INTERACT ’93 and CHI ’93 Conference Companion on Human Factors in Computing Systems* (pp. 111–112). New York, USA: ACM. http://doi.org/10.1145/259964.260137
Nguyen, T., Heslin, R., & Nguyen, M. L. (1975). The Meanings of Touch: Sex Differences. *Journal of Communication*, *25*(3), 92–103. http://doi.org/10.1111/j.1460-2466.1975.tb00610.x
Nie, J., Park, M., Marin, A. L., & Sundar, S. S. (2012). Can you hold my hand? Physical warmth in human-robot interaction. In *7th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2012)* (pp. 201–202). IEEE.
Nilsen, W., & Vrana, S. (1998). Some touching situations: The relationship between gender and contextual variables in cardiovascular responses to human touch. *Annals of Behavioral Medicine*, *20*(4), 270–276. http://doi.org/10.1007/BF02886376
Nomura, T. (2014). Influences of experiences of robots into Negative Attitudes toward Robots. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN 2014)* (pp. 460–464). http://doi.org/10.1109/ROMAN.2014.6926295
Nomura, T., & Kanda, T. (2008). Prediction of Human Behavior in Human--Robot Interaction Using Psychological Scales for Anxiety and Negative Attitudes Toward Robots. *IEEE Transactions on Robotics*, *24*(2), 442–451. http://doi.org/10.1109/TRO.2007.914004
Nomura, T., Kanda, T., & Suzuki, T. (2006). Experimental investigation into influence of negative attitudes toward robots on human–robot interaction. *Ai & Society*, *20*(2), 138–150. http://doi.org/10.1007/s00146-005-0012-7
Nomura, T., Kanda, T., Suzuki, T., & Kato, K. (2004). Psychology in human-robot communication: An attempt through investigation of negative attitudes and anxiety toward robots. In *13th IEEE International Workshop on Robot and Human Interactive Communication* (pp. 35–40).
Nomura, T., Shintani, T., Fujii, K., & Hokabe, K. (2007). Experimental investigation of relationships between anxiety, negative attitudes, and allowable distance of robots. In *2nd IASTED international conference on human computer interaction* (pp. 13–18). Chamonix, France: ACTA Press.
Nomura, T., Suzuki, T., Kanda, T., & Kato, K. (2006a). Altered attitudes of people toward robots: Investigation through the Negative Attitudes toward Robots Scale. In *AAAI Workshop on Human Implications of Human-Robot Interaction* (pp. 29–35).
Nomura, T., Suzuki, T., Kanda, T., & Kato, K. (2006b). Measurement of negative

attitudes toward robots. *Interaction Studies*, *7*(3), 437–454. http://doi.org/10.1075/is.7.3.14nom
Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. http://doi.org/10.1007/s10459-010-9222-y
Nuszbaum, M., Voss, A., & Klauer, K. C. (2014). Assessing individual differences in the need for interpersonal touch and need for touch. *Social Psychology*, *45*(1), 31–40. http://doi.org/10.1027/1864-9335/a000157
Okita, S. Y. (2013). Self-Other's Perspective Taking: The Use of Therapeutic Robot Companions as Social Agents for Reducing Pain and Anxiety in Pediatric Patients. *CyberPsychology, Behavior & Social Networking*, *16*(6), 436–441. http://doi.org/10.1089/cyber.2012.0513
Park, E., & Lee, J. (2014). I am a warm robot: the effects of temperature in physical human–robot interaction. *Robotica*, *32*(1), 133–142.
Patterson, M. L., Powell, J. L., & Lenihan, M. G. (1986). Touch, compliance, and interpersonal affect. *Journal of Nonverbal Behavior*, *10*(1), 41–50. http://doi.org/10.1007/BF00987204
Pattison, J. E. (1973). Effects of touch on self-exploration and the therapeutic relationship. *Journal of Consulting and Clinical Psychology*, *40*(2), 170–175. http://doi.org/10.1037/h0034573
Paulsell, S., & Goldman, M. (1984). The effect of touching different body areas on prosocial behavior. *The Journal of Social Psychology*, *122*(2), 269–273. http://doi.org/10.1080/00224545.1984.9713489
Peck, J., & Childers, T. L. (2006). If I touch it I have to have it: Individual and environmental influences on impulse purchasing. *Journal of Business Research*, *59*(6), 765–769. http://doi.org/10.1016/j.jbusres.2006.01.014
Peck, J., & Shu, S. B. (2009). The Effect of Mere Touch on Perceived Ownership. *Journal of Consumer Research*, *36*(3), 434–447. http://doi.org/10.1086/598614
Pfeifer, R., & Scheier, C. (2001). *Understanding intelligence*. London, UK: MIT Press.
Ray, C., Mondada, F., & Siegwart, R. (2008). What do people expect from robots? In *IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2008* (pp. 3816–3821). http://doi.org/10.1109/IROS.2008.4650714
Reeves, B., & Nass, C. (1996). *How people treat computers, television, and new media like real people and places*. CSLI Publications & Cambridge.
Register, & Henley, N. M. (1992). Phenomenology of Intimacy. *Journal of Social and Personal Relationships*, *9*(4), 467–481. http://doi.org/10.1177/0265407592094001
Reite. (1990). Touch, attachment, and health: is there a relationship? In K. E. Bernard & T. B. Brazelton (Eds.), *Touch: The Foundation of Experience* (pp. 195–228). Madison, WI: International Universities Press.
Robinson, H., MacDonald, B., & Broadbent, E. (2014). Physiological effects of a companion robot on blood pressure of older people in residential care facility: A pilot study. *Australasian Journal on Ageing*, *34*(1), 27–32. http://doi.org/10.1111/ajag.12099
Schreier, M. (2012). *Qualitative Content Analysis in Practice*. Sage Publications.
Sefidgar, Y. S., MacLean, K. E., Yohanan, S., Van der Loos, H. F. M., Croft, E. A., & Garland, E. J. (2016). Design and Evaluation of a Touch-Centered Calming Interaction with a Social Robot. *IEEE Transactions on Affective Computing*, *7*(2), 108–121. http://doi.org/10.1109/TAFFC.2015.2457893

Shibata, T., Mitsui, T., Wada, K., Touda, A., Kumasaka, T., Tagami, K., & Tanie, K. (2001). Mental commit robot and its application to therapy of children. In *Advanced Intelligent Mechatronics, 2001. Proceedings. 2001 IEEE/ASME International Conference on* (Vol. 2, pp. 1053–1058). IEEE.
Shibata, T., & Tanie, K. (2001). Physical and affective interaction between human and mental commit robot. In *IEEE International Conference on Robotics and Automation, (ICRA 2001)* (Vol. 3, pp. 2572–2577). IEEE.
Shibata, T., Tashima, T., & Tanie, K. (1999). Subjective interpretation of emotional behavior through physical interaction between human and robot. In *IEEE International Conference on Systems, Man, and Cybernetics (IEEE SMC'99)* (Vol. 2, pp. 1024–1029). IEEE.
Shibata, T., & Wada, K. (2010). Robot therapy: A new approach for mental healthcare of the elderly–A mini-review. *Gerontology*, *57*(4), 378–386.
Shiomi, M., Nakagawa, K., Shinozawa, K., Matsumura, R., Ishiguro, H., & Hagita, N. (2016). Does A Robot's Touch Encourage Human Effort? *International Journal of Social Robotics*, 1–11. http://doi.org/10.1007/s12369-016-0339-x
Sin, M., & Koole, S. (2013). That Human Touch That Means So Much: Exploring the Tactile Dimension of Social Life. *In Mind Magazine*, *2*(17). Retrieved from http://www.in-mind.org/article/that-human-touch-that-means-so-much-exploring-the-tactile-dimension-of-social-life
Sivadas, E., & Machleit, K. (1994). A scale to determine the extent of object incorporation in the extended self. *Marketing Theory and Applications*, *5*, 143–149.
Smith, D. E., Gier, J. A., & Willis, F. N. (1982). Interpersonal touch and compliance with a marketing request. *Basic and Applied Social Psychology*, *3*(1), 35–38.
Sorensen, G., & Beatty, M. J. (1988). The interactive effects of touch and touch avoidance on interpersonal evaluations. *Communication Research Reports*, *5*(1), 84–90. http://doi.org/10.1080/08824098809359805
Steward, A., & Lupfer, M. (1987). Touching as Teaching: The Effect of Touch on Students' Perceptions and Performance. *Journal of Applied Social Psychology*, *17*(9), 800–809. http://doi.org/10.1111/j.1559-1816.1987.tb00340.x
Stiehl, W. D., Lieberman, J., Breazeal, C., Basel, L., Cooper, R., Knight, H., … Purchase, S. (2006). The Huggable: A therapeutic robotic companion for relational, affective touch. In *2006 3rd IEEE Consumer Communications and Networking Conference, CCNC 2006* (Vol. 2, pp. 1290–1291). http://doi.org/10.1109/CCNC.2006.1593253
Stiehl, W., Lee, J., Breazeal, C., & Nalin, M. (2009). The huggable: a platform for research in robotic companions for pediatric care. In *Proceedings of the 8th International Conference on Interaction Design and Children* (pp. 317–320). http://doi.org/10.1145/1551788.1551872
Stiehl, W., Lieberman, J., Breazeal, C., & Basel, L. (2005). The design of the huggable: A therapeutic robotic companion for relational, affective touch. In *AAAI Fall Symposium on Caring Machines: AI in Eldercare*. AAAI.
Stiehl, W., Lieberman, J., Breazeal, C., Basel, L., Lalla, L., & Wolf, M. (2005). Design of a therapeutic robotic companion for relational, affective touch. In *IEEE International Workshop on Robots and Human Interactive Communication* (pp. 408–41).
Sussman, N., & Rosenfeld, H. (1978). Touch, justification, and sex: Influences on the aversiveness of spatial violations. *The Journal of Social Psychology*, *106*(2), 215–225. http://doi.org/10.1080/00224545.1978.9924173
Syrdal, D., Dautenhahn, K., & Walters, M. (2008). Sharing Spaces with Robots in a

Home Scenario-Anthropomorphic Attributions and their Effect on Proxemic Expectations and Evaluations in a Live HRI Trial. In *AAAI Fall Symposium: AI in Eldercare: New Solutions to Old Problems* (pp. 116–12).
Syrdal, D., Walters, M., Koay, K., & Dautenhahn, K. (2008). *The role of autonomy and interaction type on spatial comfort in an HRI scenario*. Retrieved from http://uhra.herts.ac.uk/handle/2299/1910
Tai, K., Zheng, X., & Narayanan, J. (2011). Touching a teddy bear mitigates negative effects of social exclusion to increase prosocial behavior. *Social Psychological and Personality Science*, *2*(6), 618–626. http://doi.org/10.1177/1948550611404707
Thayer, S. (1986). History and strategies of research on social touch. *Journal of Nonverbal Behavior*, *10*(1), 12–28. http://doi.org/10.1007/BF00987202
van Someren, M. W., Barnard, Y. F., & Sandberg, J. A. (1994). *The think aloud method: A practical guide to modelling cognitive processes. Department of Social Science Informatics, University of Amsterdam*. http://doi.org/10.1016/0306-4573(95)90031-4
Wada, K., & Shibata, T. (2006). Robot therapy in a care house-its sociopsychological and physiological effects on the residents. In *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on* (pp. 3966–3971). IEEE.
Wada, K., Shibata, T., Saito, T., Sakamoto, K., & Tanie, K. (2005). Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. In *Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on* (pp. 2785–2790). IEEE.
Wada, K., Shibata, T., Saito, T., & Tanie, K. (2002). Analysis of factors that bring mental effects to elderly people in robot assisted activity. In *Intelligent Robots and Systems, 2002. IEEE/RSJ International Conference on* (Vol. 2, pp. 1152–1157). IEEE.
Walker, R., & Bartneck, C. (2013). The pleasure of receiving a head massage from a robot. In *RO-MAN, 2013 IEEE* (pp. 807–813). http://doi.org/10.1109/ROMAN.2013.6628412
Walters, M., Koay, K., Syrdal, D., Dautenhahn, K., & Te Boekhorst, R. (2009). Preferences and perceptions of robot appearance and embodiment in human-robot interaction trials. In *New Frontiers in Human-Robot Interaction : Symposium at AISB09 Convention* (pp. 136–143).
Watson, D., Clark, L., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. http://doi.org/10.1037/0022-3514.54.6.1063
Watson, W. H. (1975). The meanings of touch: Geriatric nursing. *Journal of Communication*, *25*(3), 104–112. http://doi.org/10.1111/j.1460-2466.1975.tb00611.x
Weisband, S., & Kiesler, S. (1996). Self disclosure on computer forms: Meta analysis and implications. In *Conference on Human Factors in Computing Systems* (pp. 3–10). http://doi.org/10.1145/238386.238387
Whitcher, S. J., & Fisher, J. D. (1979). Multidimensional reaction to therapeutic touch in a hospital setting. *Journal of Personality and Social Psychology*, *37*(1), 87. http://doi.org/10.1037/0022-3514.37.1.87
Wilhelm, F. H., Kochar, A. S., Roth, W. T., & Gross, J. J. (2001). Social anxiety and response to touch: incongruence between self-evaluative and physiological reactions. *Biological Psychology*, *58*(3), 181–202. http://doi.org/10.1016/S0301-0511(01)00113-2
Willis, F. N., & Hamm, H. K. (1980). The use of interpersonal touch in securing

compliance. *Journal of Nonverbal Behavior*, *5*(1), 49–55. http://doi.org/10.1007/BF00987054
Wilson, J. H., Stadler, J. R., Schwartz, B. M., & Goff, D. M. (2009). Touching your students : the impact of a handshake on the first day of class. *Journal of the Scholarship of Teaching and Learning*, *9*(1), 108–117.
Wullenkord, R., Fraune, M., & Eyssel, F. (2016). Getting in Touch: How Imagined, Actual and Physical Contact affect Evaluations of Robots. In *25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN 2016)*. http://doi.org/10.1109/ROMAN.2016.7745228
Yohanan, S., Chan, M., Hopkins, J., Sun, H., & Maclean, K. (2005). Hapticat: exploration of affective touch. *7th International Conference on Multimodal Interfaces (ICMI '05)*, 222–229. http://doi.org/10.1145/1088463.1088502
Yohanan, S., & MacLean, K. (2008). The haptic creature project: Social human-robot interaction through affective touch. In *AISB 2008 Symposium on the Reign of Catz & Dogs: The Second AISB Symposium on the Role of Virtual Creatures in a Computerised Society* (pp. 7–11).
Yohanan, S., & MacLean, K. E. (2009). A tool to study affective touch. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems* (pp. 4153–4158). http://doi.org/http://doi.acm.org/10.1145/1520340.1520632
Yohanan, S., & MacLean, K. E. (2012). The Role of Affective Touch in Human-Robot Interaction: Human Intent and Expectations in Touching the Haptic Creature. *International Journal of Social Robotics*, *4*(2), 163–180. http://doi.org/10.1007/s12369-011-0126-7

APPENDIX

For the stimulus materials and questionnaires used in Study 1 – Study 4, please contact the author: laura.hoffmann@uni-due.de.