

# A Warm Touch of Affect?

Christian J.A.M. Willemse

Human Media Interaction, University of Twente, Enschede, The Netherlands

Perceptual and Cognitive Systems, TNO, Soesterberg, The Netherlands

Email: c.j.a.m.willemse@utwente.nl

**Abstract**—One of the research areas within affective Computer Mediated Communication currently under investigation is that of mediated social touch. A social touch is a complex composition of different physical parameters that can be simulated by haptic technologies. In this article we argue why we think it makes sense to incorporate warmth - and in particular simulations of one's body heat - in mediated communication devices; that is, physical warmth affects perceptions of social warmth, and our skin temperature can be considered a display of our socio-emotional state. Moreover, we outline specific research domains for the current PhD project.

**Keywords**—Affective Computer Mediated Communication; Social Touch; Body Temperature

## I. INTRODUCTION

Social connectedness and intimacy in interpersonal relationships are indispensable for our physical health and wellbeing [1]. It has been demonstrated that feeling alone can result in decreased happiness, increased depressive feelings, negative effects for the immune system, and even increased likelihood on early mortality (e.g., [2]). Over the years, many researchers and designers tried to facilitate the sense of being together when physically separated by means of Computer Mediated Communication (CMC) technologies. One of the intimate forms of face-to-face interaction currently under investigation for application in CMC is social touch [3]. Social touches - of which we speak whenever people intentionally touch another person in order to change the other's perceptions, thoughts, feelings, and/or behavior, in relation to the context in which it occurs [4] - are inherently intimate as the interactants need to be in each other's physical proximity [5]. Strangely enough, current forms of CMC are oftentimes only audiovisual.

Temperature is an important parameter in the complex physical composition of a social touch [4]. For newborns, the warmth provided by their caregivers during touch even is indispensable; without proper thermoregulation - i.e., the regulation of body temperature - normal physical development is not possible [6]. This social thermoregulation - i.e., *the warming of another agent by a supporter, either through touch or through a warming of the skin in the supporter above and beyond touch* [6] - also has consequences for the development of psychological mechanisms such as affect and social cognition. The early experiences we have with the warmth of our caregivers are considered the foundation of a recently discovered link between physical warmth and social behaviors and cognitions [7]. Perception of physical warmth can activate feelings of metaphorical interpersonal warmth (e.g., seeing someone as a warm person), and vice versa.

Since both perceptions are processed in the insular cortex area of the brain, the physical-metaphorical warmth link is bi-directional (e.g., [8]). This implies that our social perceptions also can affect our perception of the physical temperature. When socially excluded, people tend to perceive the environment as being colder and demonstrate more compensation behavior (e.g., more warm drinks or baths) [9]. Interestingly enough, people do not only experience an environment as being colder; their skin temperature also decreases [10]. In line with this, preliminary research suggests that as a function of social thermoregulation, one's skin temperature increases when one sees a loved one, but not a stranger, in distress [11]. Moreover, earlier research also suggests that changes in our skin temperature - albeit minor changes - can reflect our affective state: When in a positive mood, our skin temperature tends to be higher than when in a negative state [12], [13]. In other words: Our skin temperature can be considered a display of our socio-emotional state.

In the remainder of this paper, we will discuss related work, and we will explain why this work provides opportunities for the incorporation of thermal stimuli - either warm or cold - in affective CMC. Moreover, more specific research interests of the PhD project will be outlined.

## II. RESEARCH MOTIVATION AND AIMS

The core motivation of the current PhD project is a desire to better understand the implications of research on both the physical-metaphorical warmth link and skin temperature, for mediated communication. Since both research areas seem to find their origins in our earliest intimate experiences - i.e., the intimacy and social thermoregulation as experienced in the early childhood while being held by our loving caregivers - it seems appropriate to mainly focus on mediated social touch interactions. More concretely: We will carry out systematic empirical investigations, in which we apply and reconsider existing knowledge regarding temperature and possibly relevant psychological theories, in order to pinpoint the opportunities, but also the limitations, of physical warmth and coldness as means of affective CMC. Different wearable prototypes that physically simulate one's body temperature will be developed and applied; we thus will not specifically investigate representations of warmth in other sensory modalities. Considering the research on physical warmth and skin temperature, we identified two main research areas on which we will focus:

- *Affective feelings and behavior*: We will investigate whether feeling someone else's (mediated) body tem-

perature is perceived as an intimate cue. Moreover, we will investigate to what extent mediated body temperature can influence one's personal socio-emotional status, as well as one's perceptions of the interaction partner. These questions will be addressed at a physiological, cognitive, and behavioral level.

- *The meaning of warmth*: On the premise that skin temperature can be considered a display of one's social and/or emotional state, we will investigate to what extent people can actually interpret changes in (simulations of) someone else's body temperature, and how these interpretations interact with the mentioned affective feelings and behavior.

With a more thorough understanding of what the role of temperature can be in mediated interaction, we can provide guidelines with regard to the design of CMC devices, and for application of such devices within specific contexts.

### III. BACKGROUND AND RELATED WORK

In this section, we briefly introduce the research area of mediated social touch with an emphasis on simulated social touches that include thermal stimuli. Subsequently, we will discuss related work with regard to the two research areas: The social effects of warmth and coldness, and skin temperature as affective display.

#### A. Mediated Social Touch

In our daily interactions, social touches such as a comforting hug or a supporting pat on the back play an important role in the formation and maintenance of (intimate) relationships, social perceptions, and behavior (see for instance [14] for an extensive overview). Besides social effects, interpersonal touches can induce physiological responses as well, for instance a decrease of physiological stress symptoms (e.g., [15]). Moreover, recent research suggest that specific neurotransmitters (i.e., *C-Tactile afferents*), underly the concept of social touch, but not discriminative touch. The activity of the C-T afferents depends on the speed with which the (non-glabrous) skin is stroked (with ca 3-10 cm/s as optimum), and on the associated temperature (with ca 32°C - i.e., skin temperature - as optimum); this activity strongly correlates with subjective pleasantness ratings [16]. Since social touches do have such a vast influence on our daily interactions, it is strange that CMC mostly utilizes audio and/or visual communication. Research in the field of Mediated Social Touch investigates whether response similarities can be achieved between real human touch and touches mediated by haptic technologies. Initial results suggest that this is possible. It is for instance demonstrated that a mediated touch can result in pro-social effects of the same magnitude as those that are induced by real-life social touches [17]. The majority of the effort in the field has however been put in the development of a plethora of haptic interfaces, mainly aimed at recreating specific social touch actions. Several of these interfaces incorporate heat elements as well, for instance: The Hug [18], which is an anthropomorphic cushion that can convey hugs by means of

vibrotactile and thermal feedback, YourGloves, HotHands, and HotMits [19], which allow holding hands over a distance, and Huggy Pajama [20], which is a pajama that reproduces hugs by means of inflatable air pockets and heating elements. Although mediated touch devices seem promising with regard to affective CMC, they oftentimes lack a systematic investigation considering the relative (affective) qualities, and the social effects, of different haptic actuators. The specific qualities of for instance physical warmth (e.g., activating social cognitions and behavior) have not been investigated extensively.

Preliminary research on the affective qualities of thermal stimuli demonstrates - based on self-reports and skin conductance responses - that for instance warmer stimuli, presented to the hand, induce more arousal and higher dominance ratings than colder stimuli [21]. With regard to experiences of comfort and pleasantness, pre-adjusted stimuli were perceived as being more pleasant than dynamically changing stimuli, regardless of the absolute temperatures. In line with the finding that thermal stimuli can comprise affective qualities, Lee and Lim found that their communication device - which is capable of sending thermal messages by adjusting the intensity, rate of change, and duration - has most potential in the communication of emotionally charged messages [22]. A first attempt to actually investigate the social effects of thermal stimuli (i.e., *thermal hugs*) in mediated interaction, suggests that warmth increases social presence (i.e., the sense of *being there* with the other) [23]. During a mediated (i.e., instant messaging) collaborative task, one person of an intimate dyad could press a button and the other would then receive a thermal stimulus around the waist. Having this additional functionality thus resulted in an increased social presence. It remains however unclear whether this effect is caused by the presence of physical warmth (as warmth increases social cognitions [7]), by having an additional communication channel, or by the fact that someone intentionally discloses affect [24]. Related research concerning touch interactions with non-human entities also suggests promising effects of the incorporation of warmth. Users of a zoomorphic robot had a more positive attitude towards this robot when its skin was warmer [25]. In another study, participants were asked to watch a horror movie while holding the hand of an anthropomorphic robot. Participants perceived more trust towards the robot when the robot's hands were warm, rather than cold, and the robot was perceived as more human-like [26]. Moreover, in both robot studies, the perceived friendship with the robot increased as an effect of warmth. It remains unclear whether the physical warmth activated affective feelings, or that for instance the perceived human-likeness of the robot was a mediating factor.

To conclude, we can say that (affective) mediated social is a very promising research area, but the field requires systematic investigations with regard to potential social and physiological qualities of different actuators. Considering its preliminary results as means of affective CMC, as well as its function in social touch [4], [16], temperature (both warmth and coldness) seems a promising parameter for further investigation.

## B. Physical and Social Warmth

Recent research suggests that the perception of physical heat - either by means of physical contact with warm objects, or by increases in ambient temperature - activates perceptions of closeness and intimacy; abstract cognitions that seem to be associated with the physical contact experienced during our childhood [7], [8]. These implicit associations result in increases in specific social cognitions and behavior. Williams and Bargh [27] demonstrated that people - after briefly holding a cup with warm coffee (contrary to iced coffee) - tend to perceive an unknown person as being, metaphorically speaking, warmer (i.e., more friendly, helpful, sincere, trustworthy, and moral). Such differences in assessment did not apply for personality traits unrelated to this metaphorical warm-cold dimension. The same authors also found that priming with warmth - holding a warm pad - increased altruistic behavior: People were more willing to give a present to another person instead of keeping it themselves. Similarly, children were more willing to share stickers with an unseen peer when in a warm room, contrary to a colder environment [7]. Besides increased pro-social behavior, people focus - under the influence of warmth - more on relationships: They show more affiliate behavior (i.e., the need to belong) when sitting on a warm chair [28], and they use more language associated with relationships, categorize images based on their relations instead of attributes during a perceptual-motor task, and feel more social proximity (perceived interpersonal closeness in a non-physical sense) towards another [29]. Warmth also affects perceptions of physical proximity: After shortly holding a warm object, participants assessed the distance between themselves and this object as smaller than when the object was cold [28].

The relation between social and physical warmth is, due to the same brain region in which both are processed, bi-directional. This means that perceptions of social closeness can also affect perceptions of physical temperature. When socially excluded, people for instance perceive the environment as being colder and increasingly need warm drinks or baths [9].

As mentioned, the physical-metaphorical warmth link seems to find its origin in early child-mother interactions; interactions during which we also learn how to interact and form relationships with others on a higher order cognitive level (i.e., the formation of *attachment styles*). Since early experiences of infants with their caregivers can differ considerably, the strength of the physical-metaphorical warmth link is not equal amongst people. Preliminary research suggests that attachment style has a modulating role in the effects of warmth on social behavior: Only securely attached children were willing to share stickers [7] in a warm environment, and only people low in attachment avoidance and high in attachment anxiety perceived a warm cup as physically closer and demonstrated increased affiliative motives when sitting on a warm chair [28].

The conclusion that "*warmth serves as a symbolic cue signaling the close proximity of a source of affiliation*" [28] paraphrases the overarching argument in favor of the inclusion of warmth in affective CMC. However, we have to acknowl-

edge that research on the physical-metaphorical warmth link is still in its infancy. Moreover, the majority of the effects as were found are based on a direct comparison between additional warmth and coldness (i.e., colder than the regular room temperature). It could be the case that coldness, rather than warmth, is the determining factor with regard to the effects. When utilizing a similar economic trust game, it was demonstrated that people invested less with an anonymous partner when primed with cold, implying that coldness decreases interpersonal trust. Moreover, by using fMRI, the authors found increased activity in the insular cortex when holding a cold pack, but not when holding a warm pack, which suggests that particularly coldness affects subsequent trust decisions [30]. In order to apply thermal stimuli - either warm or cold - in affective CMC devices, a systematic evaluation of the opportunities and limitations of such stimuli is necessary. To do so, we will apply current knowledge on the physical-metaphorical warmth link in a context of affective CMC, and we will - when necessary - reconsider the mentioned findings.

## C. Skin Temperature as Affective Display

Over the years, research has demonstrated that physiological signals such as electrodermal activity and heart rate are good indicators of one's emotional state, and can be applied in human computer interaction [31]. Although not as often investigated and applied as other psychophysiological signals, skin temperature is also subject to changes in one's socio-emotional state. When we are in a positive affective state, our skin temperature tends to be higher than when we are in a negative state (e.g., stress, pain, fear). Emotional music can for instance induce changes in one's skin temperature [12]. After a short relaxing session in which the skin temperature increased, participants were presented with either arousing negative music, or positive music. The anticipated decrease in temperature after the relaxing session was perpetuated by the negative music, but attenuated by the positive sounds. After a stressful task, the results were comparable. More recent research, utilizing thermography techniques, also demonstrates that thermal changes are sensitive to emotionally valenced stimuli: With negative valence stimuli, the temperature in the face - and in particular in the nose - decreased, whereas it increased as response to positive valence stimuli [13].

It is interesting to note that the aforementioned perceptions of coldness and the increased need for physical warmth as associated with social exclusion [9], are also reflected in one's skin temperature [10]: When socially excluded, one's skin temperature, measured at the fingertip, decreases. Participants were to play an online ball tossing game with two (fictitious) other players, in which the participant would receive the virtual ball either regularly (inclusion condition), or never (exclusion). Over time, the finger temperatures of socially included participants slightly increased but not significantly, whereas the finger temperature of the excluded participants significantly decreased with nearly 0.4°C. Moreover, preliminary research found that our facial temperature increases when we see our romantic partner in distress, compared with seeing

our partner with neutral facial expression [11]. This effect did not occur when seeing strangers in distress, and suggests that we spontaneously increase our skin temperature in order to complement the (decreased) temperature of a partner in distress. The abovementioned effects support the theory of social thermoregulation [6], and suggest that skin temperature can be considered a display of social perceptions.

Psychophysiological signals such as heart beats and blood pressure are inherently personal as they usually cannot be perceived by other people without physical contact, or even without mediating technology. On this premise, it was investigated to what extent such physiological signals - i.e., audible heart beats - could serve as channel in affective CMC [32]. In a series of studies it was demonstrated that different heart beat sequences (varying on for instance heart rate and heart rate variability) are perceived as representing different emotional intensities. Moreover, hearing a heart beat was perceived as a cue with similar intimacy intensity as traditional non-verbal intimacy cues (mutual gaze, and interpersonal distance), and also resulted in specific behavior aimed at compensating for increased intimacy. Interestingly enough, these effects only applied when the heart beats were attributed to another person, rather than to a (non-social) audio recording [33]. These effects support the idea of applying cardiac signals in affective CMC, but as Janssen [32] suggest, other psychophysiological signals such as skin temperature could carry affective meaning as well.

Although preliminary steps were made with regard to research on both changes in skin temperature, and the potential of psychophysiological signals in CMC, many things are still unclear. More skin temperature studies, as well as replications, are necessary in order to determine the actual meaning of changes in skin temperature. In terms of the affective qualities of such signals in CMC, it is not yet clear what the underlying mechanism is. It could be that the effects are based on the idea that such signals are very personal and (almost) not perceivable without mediating technology, and that the mere fact that someone is willing to disclose this personal information makes it intimate [24]. Another explanation could be the fact that to actually perceive psychophysiological signals, one needs to be in physical contact with the other person, or even be in one's percutaneous space, which inherently is very intimate [5]. The associations with this intimacy could also be the underlying mechanism.

#### IV. RESEARCH PLAN

During the current PhD project, we aim to gain insights in the opportunities and limitations of thermal stimuli - both warm and cold - in affective mediated communication. We envision several experiments, outlined below, in which both the social effects and the meaning of thermal stimuli will be investigated; separately as well as intertwined, in order to reveal potential interplay between the two. Moreover, the effects of possible influencing factors (e.g., personal characteristics such as attachment style) will be explored throughout the studies, in order to gain more nuanced insights. Relatively simple wearable technology containing thermal stimuli has been, and

will be, developed in order to facilitate the studies. Since physical warmth, as well as social touches can induce different types of effects, we will investigate the potential of thermal stimuli in CMC on three levels: physiological responses, social perceptions, and behavior. A schematic overview of our intentions is provided in fig. 1

#### A. Temperature in Mediated Communication

1) *Social Touch*: Warmth as a parameter of a mediated social touch has not been studied extensively yet. We will investigate to what extent temperature, as an additional parameter in a mediated touch, affects the perceived hedonic qualities and naturalness of the touch, as well as one's emotional state. Since human stroking touches - when applied at specific speeds and (body) temperature - activate C-T afferents and thus pleasantness [16], we will particularly focus on this type of touch for mediated interactions. We expect that similar hedonic perceptions can be achieved when utilizing haptic technologies.

2) *Intimacy, Social Cognitions, and Behavior*: Warmth, as compared with coldness, seems to increase feelings of interpersonal warmth [27], social presence [23], the relational focus [29], perceptions of physical proximity [28], and pro-social behavior [7], [27], but it is unclear to what extent these effects apply in mediated communication. To gain insights in this, we will apply measures related to these concepts throughout different experimental settings. Moreover, we will follow the paradigm as was applied by Janssen in his work on mediated heart beats [33], to investigate whether people - as we expect - perceive feeling one's body heat as an intimate cue as well. In a virtual world, participants will interact with a confederate's avatar throughout different scenarios, while either feeling or not feeling the confederate's body heat. Traditional cues for intimacy (i.e., interpersonal distance, and mutual gaze) will be manipulated, and by measuring the perceived intimacy and compensation behavior of the participant (i.e., people tend to compensate for inappropriate increases in intimacy), the added value of mediated body temperature can be determined. The virtual reality setup will allow for a controlled environment, but also for repeated experiments in which for instance the parameters of the perceived temperature can be varied.

#### B. Interpretation of Temperature

1) *Meaning*: As described before, changes in skin temperature can reflect one's emotional state, as well as feelings of

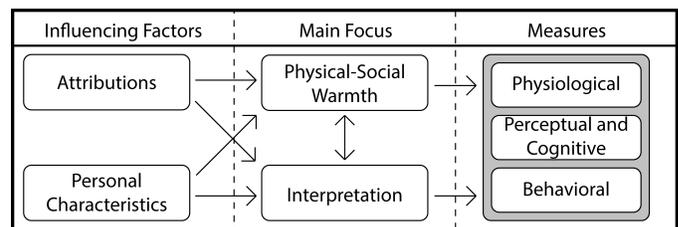


Fig. 1. A schematic overview of the proposed PhD research

social empathy. We will investigate whether people can also interpret these changes in someone else's skin temperature, for instance in terms of emotional intensity, valence, and/or arousal, but also on perceptions of the other person's social state (e.g., whether he or she feels socially in- or excluded). Initially, we will investigate this by means of simulations of body heat changes, utilizing wearable prototypes. We do so, in order to understand the potential of such body heat messages, but also to gain insights in the essential physical parameters of these messages. The absolute changes in skin temperature associated with social cognitions usually are very small and develop slowly (i.e., low rate of change), and may thus be difficult to perceive. Moreover, the other person's body temperature typically is in the perceptual neutral zone, in which temperature changes are hardly perceivable [34]. It thus seems appropriate to assume that some amplification of a body heat signal is indispensable.

2) *Self-Disclosure*: Following the interpersonal process model of intimacy, (emotional) self-disclosure (i.e., providing personal information to another by means of both verbal and non-verbal communication), determines the level of intimacy within an interaction [24]. The perceived amount of intimacy is however mediated by the attribution of the disclosure (in this context, attribution means *the receiver's interpretation of the reason why the information is disclosed*) [35]. These reasons for self-disclosure can be dispositional or situational (i.e., attributing the self-disclosure to the sender's personality, or to a specific context, respectively). The attribution can however also be interpersonal, meaning that the sender specifically chose the receiver to reveal personal information to. When the latter attribution type is the case, the intimacy is strengthened, because *"Disclosing to another communicates that we trust that person to respond appropriately, value his or her opinions and responses, and are interested in knowing them, and having them know us"* [36].

Based on these premises, we could say that revealing one's body heat is a form of self-disclosure, because it may display one's current socio-emotional state, and that mediated body heat could thus be considered a cue for intimacy (which will be verified in the abovementioned envisioned studies as well). However, it is interesting to investigate to what extent the type of attribution affects such perceptions. In line with the mediating effects of attribution on the self-disclosure-intimacy link, Janssen [32] demonstrated that an increased quantity of emotion communication positively affects the perceived intimacy, and that user-initiated (i.e., interpersonal attribution), rather than automatic communication of emotions (i.e. situational attribution) also positively affects perceived intimacy. We will investigate whether these findings also apply in a setting with mediated body heat, and we will particularly focus on whether and how these implications interact with the presumed social effects of warmth.

### C. Influencing Factors

Where applicable, we will investigate to what extent personal characteristics such as the earlier mentioned attachment

style [7], [28], influence the anticipated effects. Besides, we will pay specific attention to whom the warmth is attributed.

1) *Attribution - Social vs Non-social Warmth*: Literature thus suggests that physical warmth and coldness may affect social behavior. In order to better understand the implications of these findings for mediated social interaction, we aim to differentiate between the effects of non-social warmth (e.g., ambient temperature or warm of cold inanimate objects), and social warmth (i.e., one's body heat). Since research suggests that the origins of the social effects of physical warmth are in our earliest intimate experiences, we hypothesize that attribution of the warmth to another social entity, rather than to non-social heat sources, has a stronger social impact.

In a first experiment, we disentangled and compared different assumed heat sources. Participants were asked to form an impression of an unknown partner by means of textual instant messaging. After the conversation, a questionnaire regarding social cognitions was filled out in an adjacent room in which the interaction partner ostensibly just resided. The participant was either sitting on a neutral or heated chair, and in the latter case, the heat was either attributed to a non-social heat source (i.e., *an adaptive office chair*), or a social source (i.e., *'the other participant was sitting on this chair shortly before you'*). Moreover, the ambient temperature was manipulated (either warm, or neutral room temperature). Contrary to expectations, the results of this exploratory study did not support earlier findings on the social effects of warmth (although warmer ambient temperatures resulted in higher perceptions of interpersonal warmth). Moreover, the attribution of the heat source did not sort any effects either. These results demonstrate that it is not trivial to incorporate warmth in affective CMC technology, and that certain footnotes could be made regarding the literature on the social effects of physical warmth. The majority of these studies for instance relies on a paradigm in which additional warmth is compared with coldness; it could be that warmth does not *increase* social cognitions, but that coldness *decreases* these. A second possible explanation we identified, was the implicit reference to the heat source that was applied. In future studies, we will mention the warmth and the heat source to which it is attributed explicitly, in order to ensure that the distinction between social and non-social warmth is made correctly. Finally, we referred to the potential influence of the type of relation between the interactants.

2) *Attribution - Relationships*: The social effects of touches on the receiver are partly dependent on who is the initiator of the touch; holding hands from a loved one for instance resulted in a much higher decrease in stress than holding the hand of a stranger [15]. With regard to mediated communication, and in particular to the behavioral and cognitive effects of warmth, it is suggested that the type of relationship also plays a significant role [23]. Moreover, research on social thermoregulation suggests that one's skin temperature increases when seeing his or her partner in distress. These effects did not apply when one was seeing a stranger. These findings suggest that the pre-existing relationship may play a role in mediated interactions involving warmth, and may also (partly) explain

why no results were found in the abovementioned attribution experiment. We will therefore include the type and/or strength of a certain relationship throughout our studies; either as an independent variable, or as a covariate.

## V. CONCLUSION

Physical warmth and coldness seem to have an effect on our social cognitions and behavior. Moreover, some of our social and emotional feelings are represented by changes in our skin temperature. Based on these premises, this PhD project focuses on the opportunities and limitations of physical warmth as a means of affective mediated communication. By utilizing different prototypes containing warmth (and/or coldness), we will carry out experiments in which we will gain insights in the potential of warmth in mediated interaction on a physiological, cognitive, and behavioral level. Moreover, we will investigate the influence of several personal and contextual factors such as attachment style, but also the attribution of perceived warmth. Eventually, the knowledge as gained will be applicable in the fields of mediated social touch and affective CMC by means of psychophysiological signals. We believe that bringing together the relatively unexplored research areas of social thermoregulation and mediated social touch makes sense from an affective computing perspective, and we hope that our findings will help to advance the respective research areas, and inspire other researchers and designers to develop technologies that facilitate warm (or cold) interactions.

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