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What Effect Does Your Nonhuman Touch Have on Me? An Aesthetic Approach to Human-Robot Interaction

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To S.B., tireless breaker of things, forever blaming them for what she makes them do.

Abstract

This paper proposes an aesthetic approach to Human-Robot Interaction (HRI), focusing on the bodily dimension of human experience with social robots in tactile encounters. We resist cognitive-centered models, and value robotic materiality and affordances – particularly heat. Drawing from an experimental study with the NAO robot, we argue that thermoception, often neglected in HRI research, plays a critical role in shaping our emotional engagement with and acceptance of robotic agents. Their bodies, we thereby contend, are not just neutral tools but relational partners capable of altering our expectations and challenging our own bodily habits thanks to their material heterogeneity.

Keywords

Social robots; haptics; thermal HRI; material performative agency; bodily transparency.

1. *Too-Intelligent Robots*

Robotic systems are primarily conceived of as tools that replace or enhance our cognitive and bodily behaviors oriented toward a useful purpose. Their *raison d'être* is to satisfy objectives deemed advantageous. Advertisements for little vacuuming robots that clean the house while the family relaxes serve as an example of the widespread belief that intelligent machines must adapt to our needs. According to this logic, robots are simply subordinate and

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efficient things. The value of human-robot interaction (HRI) is thus discussed in terms of the level achieved by these nonhumans as to the comprehensibility of the information produced (Wang *et al.* 2025), their fluency in task execution (Ali, Green & Iqbal 2024), or the acceptability of their behavior in relation to the judgment of "non-artificial" agents (Kraus *et al.* 2022).

The point we wish to challenge here is the idea that semi-autonomous robots must act as we ourselves would if they are to meet our needs. This argument is deep-rooted. The epistemic forebear of all artificial intelligence is indeed the Turing machine, which in 1936 established our epistemic horizon of expectation: the simulation of human abilities, at least to the point of being indistinguishable from them, if not surpassing them. In our view, this authoritative tradition is fueled by an implicit theoretical assumption: that HRI is nothing but a contest between brainocentric agents, whose epic moment is represented by the chess match between Garry Kasparov, the Russian world champion who defeated Deep Blue in 1996, only to be beaten by IBM's supercomputer one year later.

This agonism between rivals, defined by their cognitive faculties – independent of any emotional dimension – is conservative both heuristically and epistemologically, and, as we will later see, socially as well. The idea that, to interact effectively, we need but train ourselves to use a machine that, in turn, is predisposed to be as user-friendly as possible, is reductive for understanding the nature not only of things but of ourselves. Its first result is a technophobia whereby we worry that the machine will rebel, just as we would. The 1927 film *Metropolis* by Fritz Lang tells the story masterfully. It is an unresolved fear.

The theoretical assumptions underlying the development of intelligent mechanical systems reproduce a logocentric epistemology in which HRI is primarily modeled as informational exchange between rational agents (Suchman 2007), where "reason" means calculation and prediction, neglecting the emotional capabilities of our embodied mind (Cavarero 2003; Gallese 2007). Framing the question in rationalistic terms not only affects how we design and treat robots but also reinforces a specific understanding of our own nature: if they are rational – that is, disembodied – because they replicate us, then we, as the ones replicated, are disembodied too. Mentalizing them means accepting as the model of an average human someone who has needs but no desires, is responsive to stimuli but insensitive, efficient but unambitious, without gender, age, ethnicity, social or educational characteristics, and free of flaws. Indeed, a robot.

Yet, a simple return to science fiction – from *I, Robot* by Isaac Asimov (1950) to *Klara and the Sun* by Kazuo Ishiguro (2021), from *2001: A Space Odyssey* by Stanley Kubrick (1968) to *Her* by Spike Jonze (2013) – might help us challenge this narrative and prompt us to ask if the rationalistic privilege of artificial intelligence is not in fact hallucinatory: don't robots show that what is actually human is our capacity for play, rebellion, and error? Doesn't HAL – a pure interface – start becoming like us the moment it stops calculating correctly and begins to aspire, object, kill, and fear? Above all: doesn't Dave, the astronaut who deactivates it, save himself by opening a hatch whose handle could only be turned manually?

We do not mean to suggest a technologically inflected alternative between (mortal) sensitivity and (superhuman) intellect, but to highlight the two defining behaviors of these artificial agents, based on their material specificity. On the one hand, we have "smart homes," in which computers control the lights and temperature, raise the shutters, and set cooking timers, thus functioning as intelligent and interactive systems, with their very body consisting of our entire house (Chan *et al.* 2008; Anderson & Anderson 2010; Telakivi 2022;). On the other, we increasingly deal in our daily lives with physical robots whose primary role is no longer task execution and that come into direct contact with us. In healthcare (Aymerich-Franch & Ferrer 2023), educational (Ceha *et al.* 2022), and entertainment contexts (Frieske *et al.* 2024) we rely on robots that are materially present in our surroundings, nearby, at hand. The relevant feature, in such cases, is their ability to be accepted by their living partners, whose subjective experience they affect and who are expected to want them around,[1] even in their most cherished spaces and in situations of vulnerability – for instance in assisted-living and caregiving contexts. In this second case, which is the one we will focus on, specific bodily habits are needed for both agents, potentially leading to a revision of the very principle of delegation, whereby the robot's ability to act on our behalf in sensible tasks is acknowledged (Latour 1992).

2. *Social Robots and Human Bodies*

NAO, PEPPER, Milo, Kaspar, and ZORA are some names for so-called social robots, also known as "so-bots" (Mobed *et*

[1] In the Usability, Social acceptance, User experience, and Societal impact (USUS) model proposed by Weiss *et al.* (2011), social acceptability is defined as an individual's willingness to interact with a robot in an everyday social environment.

al. 2024), already available on the market. They most often consist of materially extended hardware with which people engage in situations of physical proximity, if not direct contact. In both private and public sectors, they are procured to populate hospitals, schools, hotels, shopping centers, and nursing homes and interact with those who inhabit these spaces. Their design aims to foster an HRI in which the aforementioned imitative criterion extends beyond mimicry of our cognitive abilities (Ventre-Dominey *et al.* 2019) to include standards such as appropriateness and credibility of physical behaviors and adaptability in nonverbal communication through gestures, expressions, and the management of proper distance (Fong, Nourbakhsh & Dautenhahn 2003). Social robotics, therefore, focuses on intelligent systems built to collaborate with human beings – understood as relational bodies – within social, community, and intimate contexts (DeFalco & Dolezal 2023). It thus offers a way out of the rationalistic hallucination described above.

The minimum criteria for qualifying an intelligent mechanical system as "social" are neither clearly defined nor consistent in the literature (Jackson & Williams 2021). In many accounts, the degree to which it visually resembles us seems to be a key requirement for ensuring its sociality (Krägeloh *et al.* 2019). But the extent to which this effect depends on the morphological similarity of the mechanical body to ours and the extent to which it derives from other features beyond visual appearance is a highly debated question (MacDorman & Ishiguro 2006; Kätsyri *et al.* 2015). Moreover, in the case of social robots, humanization seems to produce an ontological leap: they are experienced as "social others" capable of sustaining interactions comparable to those that occur between people (Jones 2017).

Since the mid-2000s, some designers have argued that robots become social not based on how familiar they look but on how their living partners rate the quality of the encounter in real time (Hegel *et al.* 2009). The judgment entailed is not purely cognitive but includes experiential and emotional dimensions, such as the feeling of being understood, the perceived motor and expressive coherence of the robot's behavior, its responsiveness, and its ability to generate trust or empathy. The emotional responses of human subjects are indeed increasingly central to the design of today's social robots. As Ericka Johnson rightly points out, "it is our emotions that are at stake in the robot-emotion relation" (2025, 1). Robots' social character, then, is an interactive condition that emerges from how we evaluate the experience of dealing with them. Redefining it as a function of the encounter's impact on the partner means focusing on the construction of sociality as an emergent property of the engagement itself (Alač 2016).

If that is the case, robots' human-like somatic structure and their ability to replicate and/or enhance our cognitive and bodily skills no longer seem to be a sufficient or even necessary condition for them to socially engage with us. Indeed, we tend to respond favorably to mechanical partners that respect social etiquette, adapt their behavior to evolving situations, and act nicely. In this light, characterizing a robot as social means not only questioning the design choices privileged in building the artificial agent but also questioning the aesthetic conditions that make its acceptance possible – or problematic.

This becomes especially clear in situations, ranging from adolescent education to home care for the elderly, where these technologies manage complex dynamics. For example, an artificial agent in a nursing home must avoid intrusive gestures, unexpected movements, and sudden approaches and instead ensure clear and predictable motor patterns in order to be well-received by older individuals (Anderson & Anderson 2010). Similarly, a robot used as a teaching assistant must know how to stimulate student participation by capturing attention through multimodal strategies such as voice modulation, body orientation, or deictic gestures – while avoiding insistent or repetitive behaviors that could be perceived as invasive or annoying (Belpaeme *et al.* 2018).

However, this argument leads to the conclusion that robots have no actual social agency of their own, since it is humans who determine if their relational capacity is present and satisfactory. If they let us down, we can always turn them off. Are they not, after all, subordinate and performing things? This long relational detour, in the end, brings us back to the very place from where we started.

And yet, nonhuman others are increasingly required to operate in contexts where etiquette or predictability is challenged by the emotional complexity of the relationship in which they are implemented. From caregiving to companionship to mental health support, the partners often consist of individuals who, by definition, break with the idea of a statistically modeled "average" brain/body system. The evolution of social robotics thus requires us to rethink HRI not as a contest between disembodied intelligences, one of which is potentially embedded in well-trained and/or anthropomorphic mechanical structures, but as a process of relational co-construction, in which bodily, emotional, and experiential dimensions take precedence over instrumental ones and even reshape them.

3. *Tactile Feedback and New Possibilities for HRI*

Touch stands out as the sense most directly involved in interpersonal situations that prompts the co-emergence of affects, perceptions, expectations, and fears (Puig de la Bellacasa 2009; Tsirka, Velentza & Fachantidis 2024). Touch, as the relational sense *par excellence* (Merleau-Ponty 1945; Puig de la Bellacasa 2017), becomes the privileged channel for exploring new forms of coexistence and collaboration with nonliving agents, whose material constitution is aesthetically heterogeneous owing to their texture, shape, elasticity, size, humidity and weight. They produce feedback effects on the perceptual, semantic, and lived potential of tactility, which is a disposition to recognize one's own and others' bodies through the skin (Merleau-Ponty 1945). Human-robot tactile interaction (Tactile HRI) thus constitutes a growing research field within social robotics, aiming to understand how to engineer encounters that people consistently experience as pleasant, welcoming, and reassuring.

If HRI is configured as a space of negotiation in which human agents assess how much their counterpart's behavior aligns with the habits of interpersonal social life, do we expect a robot tasked with helping us up the stairs to know how to modulate the pressure of its grip the way a person would? To adjust its touch according to our sensitivity, eventually avoiding overstimulation, as would be important for some individuals with autism spectrum disorder, who register physical contact as a source of emotional stress? To have a gestural grammar like that of our bodies, which are made of bones, skin, muscles, and joints? And above all, what effect does its "sensitive know-how" have on each of us? It is once again our horizon of expectation that is called into question, here in a primarily corporeal sense, since perception is a form of first-person exploration of the environment through which we encounter material artifacts that invite us to use them in certain ways. This has important design implications, on the one hand, and heuristic and epistemic ones, on the other.

It is well-known that if tactile intimacy with a robot is deemed similar to that with a human, the exchange will be experienced positively, increasing parameters such as social presence, trust, and perceived friendship (Nie *et al.* 2012; Park & Lee 2014). However, can we be certain that a strong similarity to human touch will not reactivate that "uncanny" effect already well-documented in the case of visual resemblance, where design premises end up contradicting their own results? Masahiro Mori already showed in the 1970s that when the appearance of a nonliving body (here a robot) approximates our features almost completely, we react with strong disbelief (Mori 1970). Does the same apply to what our skin perceives?

The term "uncanny valley of haptics" (Berger *et al.* 2018) has already been used to refer to the threshold beyond which very realistic tactile feedback can generate a sense of dissonance and reduce the degree of acceptance in HRI.[2] Similarly, Conor McGinn and Dylan Dooley (2020) showed that the texture and stiffness of robotic surfaces influence our evaluation indexes for social presence, likability, and perceived safety and that higher levels of tactile realism do not always result in more "effective" interaction. A high degree of human-likeness can thus generate discomfort or rejection. The ambiguities and indeterminacies of tactile contacts between robots and people disprove the simplistic imitative assumption whereby anthropomorphizing the material eccentricity of the artificial agent effectively neutralizes it.

Insisting on such a camouflage risks, on the one hand, to reiterate a potential uncanny effect caused by an ambitious yet imperfect and therefore fragile resemblance, and on the other, to impoverish the agentive possibilities that stem precisely from the material specificities of robotic bodies. They, for example, could maintain prolonged physical contact without tiring, getting distracted, or feeling discomfort. This kind of stable, continuous, reliable attention is not typical of us but could be perceived as reassuring and function well in therapeutic contexts. In this sense, the material heterogeneity of the robotic body can become a resource for countering the imperative to humanize the nonhuman.

In this second perspective, the robot is no longer a flawed copy of us with awkward, slightly ridiculous gestures and a hard surface, or an upgraded version that vies with us on a cognitive and operational level, but rather an agent that brings forth a specific mode of presence linked to its own gestural and relational syntax. By valorizing its bodily unfamiliarity, we mean to suggest that its design needs not to be merely modeled on our standard bodily schemes and neurobiological processes, which would in turn reduce our physicality to repetitive and identical motor skills, but instead offers a chance to expand our capacities for engagement, both with intelligent artifacts and, potentially, with our fellow humans. Wherever there is matter, there are opportunities

[2] Affective haptics – the field of research focused on designing devices capable of influencing a subject's emotional state through the sense of touch (Paterson 2023) – is becoming an essential component in HRI studies.

for a sensory interplay.

A new aesthetic experience emerges, in which the robot, whose affordances contravene our habitual expectations, exerts a specific form of "material performative agency" whereby it interferes with bodily behaviors previously familiar to us, to the extent that it disrupts our bodily transparency (Calbi & Cappelletto 2024). Material artifacts, as nonliving agents, indeed have the capacity to intervene in the brain/body system of the people with whom they interact, breaking our pre-reflective and taken-for-granted bodily experience (Leder 1990; Damasio 1994; Blanke 2012; Damasio & Carvalho 2013) and disrupting our perceptual habits. We can then coevolve with the emergence of mechanical systems that mediate touch and generate new practices of contact. The design and engineering behind recent tactile interfaces (e.g., electro-tactile feedback systems or pressure sensors and actuators embedded in robotic "skin") establish new paths for articulating the possibilities inherent in this aesthetic domain, which is increasingly relevant, not only in the design of social robots, but also in studies of the human/nonhuman relation (Sartori 2026). What if, then, our horizon of expectation were disrupted by mechanical hands made of components that suggest coldness, while they are in fact warm?

4. *Warm Touch and Affective Disruption*

A robot brings with it not only its material and sensory otherness but also a peculiar relational pragmatics. How it engages with the environment and with us – detects our presence, calibrates its movements, gestures, and speech, and channels attention toward itself – affects our codes, systems of rules and conventions, and behaviors (Gemeinböck 2021; Abe 2022). While studies have addressed nociception, or sensitivity to pain, and kinesthesia, or awareness of body movement and position (Gibson 1986; Robles-De-La-Torre 2006; Paterson 2023), and some have emphasized issues such as surface texture, patterns of sensory activation, and vibrotactile feedback integrated into systems, thermoception – i.e. the perception of heat and cold – has been largely overlooked, with a few exceptions (Nie *et al.* 2012; Park & Lee 2014; Block & Kuchenbecker 2019; Borgstedt *et al.* 2022).

Thermoception is a determining factor in human exchange, affecting variables such as trust and prosocial attitudes (Williams & Bargh 2008), and the reduction of anxiety (Borgstedt *et al.* 2022). Heat and cold are capable of profoundly shaping how tactile interactions are experienced, suggesting that the thermal dimension of touch constitutes a privileged channel for affective communication. Studies such as those by Shetty *et al.* (2021) and Ooms *et al.* (2023) have shown that temperature variations induced by thermo-tactile stimuli can significantly influence how individuals emotionally interpret and evaluate all sort of experiences, including watching a film or listening to white noise.

Isn't it then paradoxical that an epistemological framework accustomed to anthropomorphizing machines forget that we are warm-blooded animals? Is human homeothermy not a part of the horizon of expectation in interpersonal relations? Not so, if we are thought of as disembodied. The primacy of cognitive simulation once again marginalizes and weakens the epistemic power of bodily co-presence between living and nonliving agents. The thermal dimension in tactile HRI is a blind spot in the understanding of the interpersonal capacities of our bodies. Making its omission explicit allows us to reconceive of interaction as a multisensory experience in which the exchange of heat between the two plays a regulatory role in emotional activation, behavioral choices, and the willingness to cooperate.

All matter, organic and inorganic, participates in a constant process of giving off, transmitting, absorbing, and emitting heat; agents involved in HRI are no exception. Stimulating physical contact between them through thermal exchange carries significant epistemic value in that it illustrates how our constitution – our capacity to carry out and receive actions, materialize intentions and thoughts, experience affect, and interact with people, artifacts, and environments – depends on our ability to distinguish between a mere tool and a partner, whether living or artificial. Heat is not simply a state of matter but a prereflective condition for the relationships in which we can engage.

The thermal component of tactile engagement becomes especially relevant when considering the affective dimension of HRI (Argall *et al.* 2010; Shildrick 2023). A particularly significant finding in this area concerns the role of a robot's surface temperature in shaping the first-person experience of interaction. Studies such as that of Park and Lee (2014) show that the simple fact that a robot is felt warm or cold to the touch can profoundly alter how it is perceived during physical contact. They suggest that a robot with a warmer surface temperature tends to foster a sense of greater closeness and a relationship perceived as more welcoming. Overall, these early results indicate that thermal stimuli act as powerful affective modulators, capable of shaping both the bond and the quality of HRI.

We conducted an experimental study focused on the thermal variable of robotic touch (Perpetuini *et al.* forthcoming), which implements the state of the art. We sought to examine how different hand temperatures of a NAO robot impacted the affective and physiological responses of participants during brief grasping encounters. NAO is medium-sized, has a humanoid morphology, is semi-autonomous and programmable, features jerky movements and is able to speak preprogrammed sentences in a metallic voice. Participants were asked to grasp both of its mechanical arms simultaneously, one with each hand, while it uttered short stories to sustain contact over time. (their contents were emotionally neutral and NAO's tone of voice was calm, to avoid adding extra experimental variables). Each grasping involved three different thermal conditions of NAO's arms, achieved by preheating or precooling the smooth gloves that it wore, which modified our experience of its limbs design and affordances. The study employed thermographic techniques to measure infrared (heat) emission from participants' facial skin[3] and used purpose-designed questionnaires to evaluate their subjective experience across the three thermal conditions.

The heat produced, dissipated, and absorbed by the robotic hand depended on its electromechanical properties that in turn determined specific qualities of touch. Moving beyond a purely thermometric conception of heat (Galimberti 2023) – which relies on the robot's temperature matching the human's – we focused on a more complex qualitative dimension whereby thermal exchange is interwoven with pressure, surface texture, moisture or dryness, and the material's thermal conductivity, absorption, and capacity. Our research hypothesis did not assume that robotic touch must reproduce the person's hand temperature in order to foster trust. In other words, we did not assume that participants necessarily preferred to experience a temperature equivalent to their own. Instead, we aimed to investigate the extent to which the thermal variable of touch influences the affective dynamics triggered during HRI, assessing the difference between living and robotic thermal conditions. The idea was that thermal touch provokes an aesthetic shock.

The study's results revealed that contact with a mechanical gloved hand warmer than the participant's own significantly increased the latter's willingness to engage with the robot. When the gloved hand was perceived as colder, the acceptance level was lower. Not so much isothermy, but rather a surplus of warmth, appears to be what people prefer to experience when grasping the partner's hand. Material and sensory discontinuities between agents are thus

[3] Infrared thermography (IRT) is a passive technology that assesses the spontaneous release of thermal energy from a body by estimating its surface temperature from a given distance. In particular, IRT allows for the evaluation of peripheral autonomic activity by analyzing variations in skin temperature (e.g. Merla 2014; Filippini *et al.* 2020).

the starting point for defining thermal encounters and highlighting their potential to affect human partners. A epistemically downcasted material variable such as heat can then perturb the affective configuration in HRI and shape modes of engagement without necessarily implying similarity or anthropomorphism. Engineered robotic heat introduces indeed elements of marked discontinuity with respect to the human body. Thermal properties in robots' interfaces could emerge as a key vector for rethinking affects and their disruptions in the human world. What matters is not only what humans seek in their interactive partners, but also how a sensory variable such as heat reorganizes our affective field of interaction.

Participants in HRI are not isolated entities but rather interdependent coagents within an "agentive situation" (Gallagher 2020) that involves both human perception and the affordances of the robotic interface, among which heat, with its constant variation over time, offers an opportunity to consider interaction in its processual and emergent dimension.

Concluding Notes on What HRI Can Teach Us

The thermal dimension of HRI is fundamental for understanding the impact robots have on our first-person lived experience of nonhuman partners, since heat plays a crucial role in modulating emotional responses. Such an understanding can be used for operational purposes – namely, to build more effective artificial agents for social contexts. However, emphasizing its profitability means favoring a technological determinism that the history of technology itself teaches us to distrust (Sartori 2024).

Let us then try to adopt a sidelong gaze. Instead of considering robots as tools that sometimes malfunction and must therefore be corrected, or that "go off-script," we might look at them as Jacques Carelman did at paradoxically designed objects in his *Catalogue d'objets introuvables* (Carelman 1969), which contains transparent parasols that do not obstruct the view of the landscape and coffee pots for masochists that pour hot liquid onto the hand of the person who grabs them. These are objects that offer the possibility of deactivating grasping habits and creating new gestures and new ways of thinking: a new aesthetic experience. If "covariations of gestures" (Malafouris 2014) are necessary to form alliances with the material world, then the surprises and disruptions of such collaborations are necessary to shed light on overlooked aspects of the brain/body/environment system in the overall human world.

While "most studies focus on using interactive systems intuitively and conveniently" based on the principle that "these achievements benefit our everyday life" (Ogawa & Ono 2008), we believe that the heterogeneity of a robot that disappoints or shocks our perceptual and relational habits – and the way our horizon of expectation adjusts to its unexpected affordances – is of great interest for research into the actual and often problematic exchange we undertake with artificial agents (with possible implications for the abovementioned principle of delegation).

Our bodily encounters with "social others" suggest the need for a renewed understanding of how we interact with them, one that leads us to "rethink material qualities in terms of their theoretical agency" (Cappelletto 2025). This, after all, is the task of aesthetics. Only at this point will the affordances of inorganic matter serve as orientation criteria within cognitive performances and social situations. On these grounds, it will then be possible to develop an education in contact with nonhuman agents.

Finally, robots allow for a deepening of our self-knowledge not because they imitate us – amplifying both our limits and our powers – but because they take us by surprise. Might such a nonliving other, in the end, remind us what it means to be a human in the world?

Authors' contributions:

Chiara Cappelletto wrote sections 1 and 2, and the concluding notes. Giulio Galimberti wrote sections 3 and 4. Both authors have substantially contributed to, seen, and approved the manuscript.

Samuel Fleck revised the paper.

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