Gentle Gestures *of* Control: On *the* Somatic Sensibilities *of an* IoT Remote App

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Jūra Miniotaitė
KTH Royal Institute of Technology

Vaida Pakulytė
Electrolux

Ylva Fernaeus
KTH Royal Institute of Technology

ABSTRACT

The design of user experiences for physical appliances increasingly involves connection, monitoring, and control via smartphone applications. Despite the rich possibilities for interaction provided by smartphones, the current standard mode of engagement with such apps is through graphical user interface manipulations. To explore new felt experiences for this use context, a remote-control app for a robotic vacuum cleaner was designed, enabling participants to have their gaze focused on the robot, while steering it by gently tilting the phone. This particular interaction is used as a case to emphasize the role of somatic sensibilities when designing smartphone applications in the context of IoT. Through a phenomenologically-inspired analysis, we describe the user experience in terms of physical manipulation, perception, effort, and utility, and through social and emotional engagement. An important attribute was how the interaction, through its subtleness, created a somatically connected experience.

Keywords
Domestic robots
Soma design
Embodied interaction
Gestures
IoT experiences

AUTHORS

Jūra Miniotaitė—BA in Media Technology, KTH Royal Institute of Technology. M.Sc. in Interactive Media Technology, KTH Royal Institute of Technology. She is a Doctoral student in Multimodal Machine Learning at KTH. As a researcher, she explores Human-robot Interaction, social robotics, and embodied interaction. She is the co-author of 'A Case Study of Deep Enculturation and Sensorimotor Synchronization to Real Music' (with O. Misgeld, T. Gulz, and A. Holzapfel; in *International Society for Music Information Retrieval Conference 2021*).

Vaida Pakulytė—BA in International Communication and Multimedia, Aarhus Universitet. MA in Digital Marketing & Social Media, London School of Business and Finance. She works on user experience and interaction design as part of the Consumer Experience Software team at Electrolux, specializing on applications related to robotic vacuum cleaners and air purifiers.

Ylva Fernaeus—BA in Computer and Systems Sciences, Stockholm University. M.Sc. in Interactive Multimedia, University of Westminster. Ph.D. in Human-Machine Interaction, Stockholm University. Associate Professor in the Department of Media Technology and Interaction Design at KTH and guest researcher at Umeå Institute of Design. Her research is focuses on physical interaction design, embodied programming, preciousness in interaction, and hybrid crafting. Her latest publications include 'Envisioning Arduino Action: A Collaborative Tool for Physical Computing in Educational Settings' (with G. J. Roumen, *International Journal of Child-Computer Interaction*, Vol. 29, Issue 100277); 'Co-watching 360-Films in Nursing Homes' (with A. Lundström and S. Ghebremikael; in *Proceedings of 13th IFIP Conference on Human-Computer Interaction*); and 'Troubling Care: Four Orientations for Wickedness in Design' (with K. Helms; in *Designing Interactive Systems Conference 2021*).

Gentle Gestures of Control: On the Somatic Sensibilities of an IoT Remote App

Jūra Miniotaitė
KTH Royal Institute of Technology
Department of Media Technology and Interaction Design
Stockholm, Sweden
jura@kth.se

Vaida Pakulytė
Electrolux
CX Software Team
Stockholm, Sweden
vaida.pakulyte@electrolux.com

Ylva Fernaeus
KTH Royal Institute of Technology
Department of Media Technology and Interaction Design
Stockholm, Sweden
fernaeus@kth.se

The present work focuses on the *somatic sensibilities* involved when designing movements on a smartphone for the remote control of a robotic device. With somatic sensibilities, we refer to detailed subjective sensory experiences as actively shaped by designers and experienced in use (see e.g., Loke & Núñez-Pacheco, 2018), in this case, for the specific purpose of controlling robotic vacuum cleaners. To delve into this topic a design exploration was conducted using the Electrolux robot vacuum cleaner Pure i9. The project was inspired by a user survey of 2,534 participants from around the world, reflecting perspectives on an existing robotic vacuum cleaner and its smartphone app. Some of the comments highlighted how users wanted to help the robot find its way around, and a few users explicitly requested control of the robot, e.g., "I want to be able to control the robot like a toy car". These suggestions, along with an interest in exploring new and alternative modes for interaction, informed the choice to design a new smartphone app, JoyTilt, which enables users to control the robot by gently tilting their phone. An envisioned use case is for more playful interaction, but also to temporarily be able to override the robot path. This suggestion for combining control of the robot with the robot being autonomous is also a theme recently discussed in terms of drone control (Eriksson et al., 2020; La Delfa et al., 2020).

The study was conducted at Electrolux in the Consumer Experience Software Team for air purifiers and robot vacuum cleaners. It highlights how JoyTilt enabled users to engage with the app through physical manipulation, directed perception, effort, and utility, as through social and emotional engagement. An important quality was how the design, through its subtleness, created a somatically connected experience (see Miniotaité, 2021).

BACKGROUND: APP DESIGN, SOCIAL CONTEXT, AND MOTION CONTROL

Smartphones are now integrated into almost all everyday settings and are, as such, integral parts of most human contexts that we design for. Mobile applications are often tightly interlinked to bodily engagements, ranging from location-based services to social interaction, connection to wearable devices, and various in-built sensor readings that very concretely imply and affect engagements of human senses. However, the felt sensations most typically associated with smartphones are still the ones associated with graphical interfaces on small screens: stiff necks, tingling sensations in fingertips, stretching of thumbs, and eye strain. In particular, when it comes to the increasingly common uses of smartphone apps for controlling and interacting with devices in IoT settings (Aloi et al., 2017), the bodily experience has, until now, been largely disregarded. A reason might be that development is still typically bound to desktop settings, resulting in a focus on graphical interfaces, clickable interaction and user flows (see e.g., Bentley & Barrett, 2012). The rich and varied experiences provided by motion sensors, light sensors, and sound detection, along with auditory and haptic feedback, are still not typically deployed for communicating with connected appliances using mobile applications.

As per definition, the mode of interaction fundamentally shapes the way people move and act with technology. It is for instance well known that graphical interfaces afford different modes of engagement than command-line interfaces (Norman, 1993), that further social and bodily engagement is offered by physical or tangible interfaces (e.g., Dourish, 2001), and that smartphones allow interaction far beyond the graphical interface (e.g., Benford et al., 2005). However, from the discourse of so-called 'soma design' (Höök, 2018), a term used to highlight design processes foregrounding so-called 'bodily experiences', there is still a lack of studies that investigate smartphone app affordances. Smartphone apps explored in this context are typically concerned with more artistic interactions or material add-ons, such as the tactile smartphone cushion cover Azalea (Hendriks et al., 2021), rather than the affordances of everyday apps and existing physical form-factors.

People's relationships and interactions with robotic vacuum cleaners are well investigated (e.g., Soma et al., 2018; Sung et al., 2010), highlighting how they affect existing cleaning behaviors and family dynamics around cleaning, e.g., from being performed mainly by a single person to concern everyone in the household (Forlizzi, 2007). Moreover, by naming them, talking to them and videotaping pets riding on them, and putting amusing covers on them (see e.g., Fernaeus & Jacobsson, 2009), these appliances take part in more playful and social activities in family settings. Thus, robot vacuum cleaners are tools for vacuuming our floors, but also for the social settings they are in — affecting everyday life in very direct ways.

The way in which owners feel about their appliances also affects how they treat them, and it has been suggested that human-robot collaboration and human control of robots facilitate empathy for robots (Vertesi, 2008). Ethical considerations and how to interact with autonomous appliances are studied by Eriksson *et al.* (2020), who examined an artists' process of learning how drones work, adapting their behavior to work with the artist, and designing drone behavior for an opera performance. Through closely analyzing recorded video of the choreographer, the dancer, and the drones, Eriksson and colleagues describe how important was that the drones followed the dancer's movements, while still retaining some autonomy, concluding that designers should consider how the design may impact users' movements in the space and also their behavior towards others.

Controlling mobile robots using gestures provides a natural separation, enabling users to keep their focus on the robot and its context when navigating. For instance, Coronado *et al.* (2017), used a 'steering wheel' gesture detected by a smartwatch for controlling a wheeled robot. Participants were asked to follow a path drawn on the floor, and although the researchers observed participants to be visibly struggling, they still reported that they had an easy time navigating using these gestures. Similarly, La Delfa *et al.* (2020) explored hand gestures for the control of drones, and here again, the multimodal feedback provided by the physical space was an important part of the interaction, e.g., that the mechanical sound from the propellers on the drone provided feedback on how smooth the user's movements were. The study also highlighted the importance of keeping the mappings of movements simple and to leave room for learning and skill development.

Starting with Nintendo Wii in 2006 (Nintendo, n.d.), tilting along with other motion controls is now standard in many game controllers. The latest Nintendo Switch released in 2020 (Nintendo, n.d.) has a built-in gyroscope and accelerometer for using tilting as user input. Tilting is also a well-known mode of interaction with smartphones, not least in gaming, but has also been used in various other contexts, e.g., for everyday tools such as carpenter's level apps or in research to explore alternative modes of interaction for people with disabilities (Ando et al., 2018; Wu et al., 2020), or more artistic or experimental explorations (e.g., Hung et al., 2016).

METHODS: MATERIAL EXPLORATIONS AND USER TRIALS

Below we provide an overview of the methods involved in our research process. Mapping of gestures with robot movements was informed by conducting hands-only inspired experiments (Buur et al., 2004), along with material explorations (Fernaeus & Sundström, 2012), and first-person analysis during development (Höök, 2018). After development, an experimental session was conducted with 10 participants (6 male, 4 female, ages ranging from 25 to 50), including testing as well as informal interviews. The experiment was recorded for video analysis. By closely studying the participants' interactions, as well as their verbal accounts, we are able to share some insights into the somatic experiences involved in the design.

The exploration was built on top of an existing interface that enabled remote control using on-screen buttons on a PC, enabling the robot to go forwards or backward and turn slightly left or right at the same time and spin on its own axis left or right. With this interface, an exploratory process began with the goal to use smartphone sensors for controlling the robot. This process is described further in "Analysis, Mappings of Gestures" Because of technical and legal regulations, we were not allowed to connect the app directly to the robot during the prototype and testing phases, instead, the phone had to be connected to the PC using a USB cord.

To explore the somatic aspects of the design, a test was set up comparing JoyTilt to an existing Spot Cleaning functionality, i.e., vacuuming an area of one square meter around the robot. This function is not accessed by the app, but by physically picking up the robot, putting it down where it should clean, and pressing a physical button. The test was conducted as an experimental, game-like setup, with artificial objects used to simulate features in a real context as seen in Figure 1.

The experimental test session was conducted during the COVID-19 pandemic, with 10 healthy volunteers wearing face masks. Coworkers at the company and students from our department were asked to volunteer because they were already exposed to contact with the experimenter. The experiment consisted of three parts. First, participants vacuumed rice off the floor using Spot Cleaning. Second, they used JoyTilt to achieve the same result. Third, they ranked both experiences on a five-point scale based on playfulness, easiness, efficiency, and enjoyment, followed by a discussion of these aspects of their user experiences. Overall, JoyTilt received better scoring in all aspects, except easiness, which we will discuss below. The scoring was used as a conversation point (similar to, e.g., Hardy & Rukzio, 2008), followed by a discussion on use cases for the two functionalities. Participants were also asked to reimagine JoyTilt and show how they would design the control of the robot, mimicking the hands-only experiment conducted prior to development.

Figure 1: The floor as staged for user testing. Framed as a playful navigation task, the tape represents walls to navigate the robot around, vacuuming rice thrown on the floor. Photograph: Jūra Miniotaitė.

ANALYSIS

The somatic experiences reflected in the user trial will be analyzed and discussed in this section. To guide the analysis, we took inspiration from the phenomenologically-inspired framework presented by Fernaeus *et al.* (2008), which foregrounded interactive experiences as performed by people through e.g., manipulation, perception, and social- and digitally-mediated actions. This framework was originally designed to help orient towards users' experiences and activity, in contrast to a data- or systems-oriented perspective. Grounded in pragmatic and phenomenological theory, it allows a concrete structure for reasoning around experiences involved in interactive artifacts. First, as illustrated in Figure 2, we explored how the design afforded a sense of gentleness in terms of *physical manipulation*. Second, we focused on *perception and attention*, as expressed, e.g., by gaze and posture. We then analyzed the digitally mediated action in terms of *effort and utility*; and finally, we explored how the app incited *social and emotional engagement*.

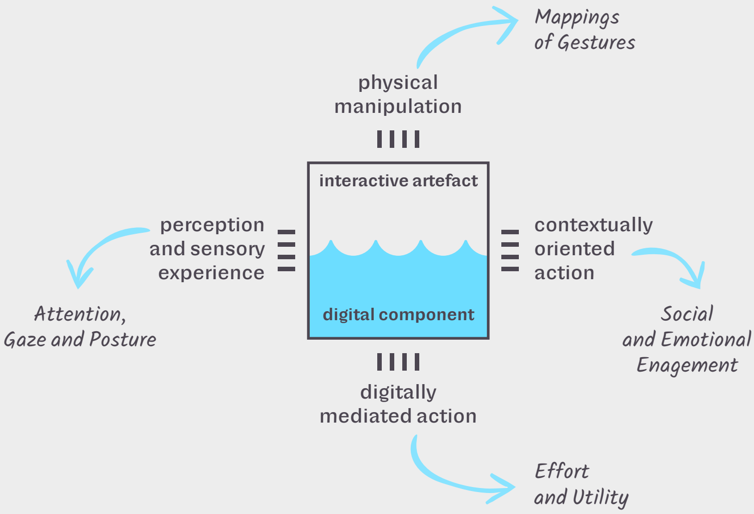

Figure 2: Map of how dimensions of the action-centric framework (Fernaeus et al., 2008) were used for the analysis of JoyTilt. This framework orients the analysis towards users' actions and experiences with an interactive artifact, rather than only its digital or electronic components. Illustration: Ylva Fernaeus.

Physical manipulation – Mappings of gestures

Prior to developing the gestures, three participants from a family-owning robotic vacuum cleaner were recruited to conduct a short and informal variant of a hands-only experiment (Buur et al., 2004). The participants were asked to use their phones, in standby mode, to show how they would make a robot go in different directions if it were able to sense their phone. An insight was that these users would expect the robot to sense and follow the direction that the phone is pointing to. Two of the participants used large sweeping motions using their whole arm to send the robot in different directions (see Figure 3).

The sweeping gesture was tested and implemented in an iterative design process. In developing the gesture, an objective was to keep the acceleration required to move the robot to a minimum. This metric was leveraged against the acceleration that was generated by moving the phone back to the starting position. A first-person perspective by the developer heavily informed the design choices, as reflected in the below quotes from the process: "When the gesture was fully implemented using accelerometer data from the phone and tested with the robot, the movement felt strained. It didn't match to the slowness and character of how the robot was moving."

This first-person experience involved the cultivation of *kinaesthetic awareness* (Candau et al., 2017) with respect to the design intentions, which guided a change in the mapping to involve an easier, gentler movement. The mapping was modified to involve the gyroscope to allow for a more subtle tilting motion instead. As expressed by the developer, this interaction "felt casual compared to the more physically taxing almost aggressive motion using accelerometers." This also relates to the notion of slow technology (Hallnäs & Redström, 2001), although it became a factor to design *with* here, rather than a broader use quality originally aimed for:

> Because there was some time to get to know the robot, a sense of how it behaved and what its aesthetics were obtained. This robot's movements are slow and systematic when it goes around cleaning. It vacuums the corners very carefully and it puts care into the decision to go into another room. By pausing, 'looking around', and when it is decided, speeding up to make it over the doorsill, it gives a sense of care for its job. It can be described as a gentle robot. The aesthetics of the robot are reflected in JoyTilt because tilting is a gentle interaction. (Designer, 1st author)

Thus, although a larger and more intense gesture intuitively had seemed more appropriate, and also had similarities to the gestures explored by e.g., Eriksson *et al.* (2020), a more gentle approach, using smaller gestures, was considered more appropriate here. These qualities are further investigated in the user trial, with several images below emphasizing the very subtle manipulations conducted by participants.

Attention, gaze, and posture

Interpreting someone's gaze is an important social skill used to understand each other, and an important indicator of attention, perception, intention, and emotion (Frischen et al., 2007). All participants had their gaze focused on the robot when testing JoyTilt, except for some short glances to the phone. Due to the preservation of anonymity, it is not possible to show images of this, however, you can tell by the way the phone is positioned in relation to the participants' bodies in the photographs shown in Figure 3, that they are not looking at the phone, except for the moment captured in the final snapshot in the sequence. During the entire experiment, the participants were focused on the interaction with JoyTilt and were looking at the robot, even while answering the experimenter's questions. Sometimes they would pause in the middle of a sentence to change the robot's direction before continuing to talk about their experience.

Five participants had a relaxed stance (Figure 3) and used small movements in their wrists to control the robot. Notice how only the hands are moving and the body stays in the same position. These participants stood completely still during the experiment, with their gaze focused on the robot. Three of them reported that they perceived controlling the robot to be easy, while the other two said it was hard.

Figure 3: Participant during the experiment using JoyTilt with a relaxed posture, their gaze on the robot vacuum cleaner and moving only his hand to control the robot vacuum cleaner. Photographs: Jūra Miniotaitė.

Three of the participants had a tenser stance and looked less comfortable while controlling the robot (Figure 4). This group also stood still and made small movements with their hands to control the robot while the rest of the body was still and the gaze focused on the robot. The tense stance made it look like the participants put a lot of effort into controlling the robot, almost as if they were ready to perform a high-intensity bodily movement. Below is a quote from one of these participants talking about the experience:

> I'm forced to be in a certain position with my hand. I'm adjusting my posture to where the phone is. If I could do this in a more relaxed mode where I choose the angle, then that would be better. Right now, I feel a little cramped. (...) It is the technology telling me what to do rather than me using the technology.

However, despite this, they still said that they thought controlling the robot was easy, though with suggestions for improving interaction.

Figure 4: Participant during the experiment using JoyTilt with a tense posture, their gaze on the robot vacuum cleaner and moving only their hand to control it. Photographs: Jūra Miniotaitė.

Two of the participants used more of their whole bodies to control the robot. They both reported that they would be walking around while controlling it if it were not for the cord that was plugged into the phone. One of these participants looked tense at the beginning, but relaxed and started making larger movements as they became more comfortable with using JoyTilt (Figure 5). These participants also gave a high score in easiness and said they found JoyTilt easy to use.

In Figure 5, you can tell by the position of the shoulders and feet that the participant was changing stance and body position when controlling the robot. One of these participants had expressed skepticism towards mobile interaction with a physical product like the robot vacuum cleaner. When asked to describe interaction after the experiment this person said it was so physical "you forget that you use the mobile phone."

This highlights the often-neglected aesthetic quality in designing a connected experience with a physical appliance to be focusing on the physical manipulations of the device itself, rather than the standard of interaction using mostly a graphical interface.

Figure 5: Participant being slightly more mobile while using JoyTilt. Photographs: Jūra Miniotaitė.

When asked how to map gestures to robot movement, almost all participants had a unique design suggestion. However, some common themes were discerned. The participants that used their whole body when controlling the robot suggested ways of controlling the robot that did not involve a phone. One suggested placing the phone on the body and to map movements from tilting their whole body. Four of the participants were either happy with the design and would not change it or suggested some variation of tilting the phone. Three participants suggested using a joystick instead of a phone in different ways. Nobody expressed the same large and rapid movements expressed prior to development.

Effort and utility

The phenomenology of effort, in relation to utility, is a recently highlighted aspect of experience (Székely & Michael, 2020). In this respect, JoyTilt was tested as an app alternative to Spot Cleaning. Seven participants agreed that JoyTilt would make a good alternative to that function, as a quicker way to clean a spot. However, six participants said that navigating from the station to the spot was impractical and would prefer to either carry the robot to the spot and then use JoyTilt, or to be able to increase the speed for getting to the spot. It should be noted that the station was only a few meters away from the spot during the experiments, meaning that this might be even more of an issue in a typical home setting. Thus, rather than an alternative, a better view of the use case would be as a nudge or to temporarily take control during autonomous movement.

All participants were able to use JoyTilt and collect all the rice without any visible problems. However, two participants took longer and appeared to make more of an effort to get all grains of rice off the floor, and two other participants described the interaction as 'mentally taxing' in a negative way. The remaining four participants described the interaction as easy.

Five of the participants had issues with overcompensation when they perceived the robot did not obey their gestures, e.g., tilting the phone beyond the threshold where the phone recognizes it. Some participants would proceed to speak to the robot when it did not do what they expected. One participant commented on the backward motion when using JoyTilt: "It is ok for the backward motion to be awkward because I don't think I would use it a lot."

While some expressed enthusiasm about being so immersed they developed connections with the robot, others reported a more negative feeling. They looked as immersed during the experiment but said that the interaction was mentally taxing. What might be the difference between the felt experiences? Is it the mindset? As expressed in the below quote, it also depends on what moment in the experience we are referring to: "Once you get the hang of it, it's pretty easy." All this highlights the challenges of analyzing the user experiences of others.

While all participants graded the interaction as playful, novelty might be contributing to this, a well-known aspect of new technology. Investigating this further would require a long-term study, and a more varied group of testers (i.e., children), which could not be carried out at this time. Previous long-term studies show that using robot vacuum cleaners becomes routine and that it serves more as a tool when the novelty wears off (Sung et al., 2010). This might indicate that long-term engagement with JoyTilt would be perceived as just another utility, rather than a playful experience.

Similar to the study by Coronado *et al.* (2017), we noted a discrepancy between the self-reported effort and the way it looked to us as observers, emphasizing the importance of using triangulation when evaluating somatic experience, using data from different perspectives to validate results and expose contradictions. The struggling reflected in the self-reporting ties in with the feelings of mental strain or immersiveness that were expressed during the experiments.

Social and emotional engagement

Two of the participants reflected on their relationship with the robot. One said that normally the robot would do its own thing and that they would be frustrated with the robot if it did not do what they expected or wanted. If it would miss a spot, they would even shout at it. During the experiment, they said that it felt like they were collaborating with the robot and that they felt responsible for its actions because they were in control, or like the cleaning was a collaboration between them and the robot. One reflected on the relationship with the vacuum as not being good during the times when they are at home during the day.

> —Sometimes I shout at it (the robot at home): "Why don't you go to the sofa!" (...) This feels quite nice because usually it's doing its thing and I'm doing my thing and I just shout at it. But now I feel like I can get in there, I feel responsible for it, I guess.
> —You feel responsible for it?
> —Yea, yea! I feel responsible because now I'm directing it, right!

This suggests that JoyTilt may provide a more intimate connection, facilitating some of the responsibility that makes a person bond with an inanimate object (Vertesi, 2008). For further development of JoyTilt, more nuanced controls could be introduced so that there is a possibility to get more control, but also develop mastery in controlling the robot (La Delfa et al., 2020). There is also room for letting the robot be more independent, in line with the sentiment expressed in Eriksson *et al.* (2020), so that the robot does not become a 'slave'. However, this should be investigated further before deciding that independence is a desired feature, since a robot vacuum cleaner is first and foremost a tool.

Future studies should explore how multiple users would collaboratively control the robot, a topic also brought up by three of our participants. A multi-user scenario would facilitate other types of interactions and provide other perspectives on appliances as social players, as well as new somatic sensibilities.

CONCLUSION

We presented some of the somaesthetic considerations of designing a tilt-based remote-control app for a robot vacuum cleaner, allowing users the freedom to choose when they wanted control and when they wanted the robot to work by itself. The somatic experience was explored through an experimental setup combined with video analysis and interviews, using a phenomenologically-inspired mode of analysis.

All participants kept their gaze on the robot and remained relatively static while controlling it, with their stances varying from tense to more relaxed. Most participants expressed satisfaction with the gestures, but also new ideas for controlling the robot in playful ways. Engagements in terms of users' feelings towards the robot were also expressed, in which the gentle gestures of control provided by JoyTilt appeared to have a positive effect. Through this analysis, we hope to inspire and provide input for investigations on the felt experiences of interactive systems more broadly, in which the subtle and simple is sometimes preferred to the rich and expressive.

On a meta-level, our contribution is to broaden the discourse of somatically oriented design work in the context of IoT, by directing our attention to everyday engagements, such as the small maneuvers with a smartphone app. Our impression is that, until now, these types of interactions have been dismissed as 'less' embodied, and perhaps therefore also less relevant to this discourse. We argue that by inviting the design of smartphone apps into the discussions around somatically oriented design, without prioritizing some experiences over others, we create a more inclusive and better philosophical match with the theories upon which the field is founded.

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