Thesis

Supervisor: Prof. Dr. Maaike Bleeker

Second reader: Dr. Laura Karreman

To Attune to a Robot Arm:

A Moving Body's Perspective of Speculating, Programming, and Dancing with the Robot

Soyun Jang | 6798446

RMA Media Art and Performance Studies

June 2024

Utrecht University

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Research Master's Thesis

By Soyun Jang
6798446
soyun.jang132@icloud.com

RMA Media, Art and Performance Studies
Department of Media and Culture Studies
Faculty of Humanities
Utrecht University

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Abstract

This thesis investigates human-robot interaction through the concept of attunement, focusing particularly on movement and dance. I use my personal experience of speculating, programming the movement of, and dancing with an industrial robot arm, a KR 10 R1100 sixx developed by KUKA, to guide my examination of how attunement unfolds in human-robot interaction. Following Yolgormez and Thibodeau, I advocate for the possibility of attuning ourselves to robots that are sometimes radically different from us in form and behavior. This poses a stark difference compared to studies in social robotics that aim to develop robots that attune to human behaviors and desires via means of technical advancement. With the help of Martin Heidegger and Katalin Vermes, attunement is conceptualized as an embodied perceptual tendency to affect and be affected by others that becomes salient in interactions. This interdisciplinary research employs various concepts and theories from social robotics and other relevant fields. By engaging in dialogue with this reinstated concept of attunement, the notions of mutual intelligence, kinesthetic empathy, thing-power, vitality affects, binocular vision, and more, I make supporting claims to the following arguments.

Movement is central to understanding attunement, as it has a special place in our perception by transforming an object into bodies we could feel for and with. We make sense of the movement of other bodies as behaviors based on the context in which the interaction emerges and our own situatedness as moving, feeling bodies. We can attune to and be affected by the movement of more-than-human bodies of radically different forms. Attuning to the robot in the form of care and respect for the robot's materiality can be helpful for finding the movement of a robot that looks natural both to its own physique and our perception. Finally, I suggest that dance, especially in improvisational form, can be useful for underscoring attunement as an affective and embodied experience. In dance, the robot emerges as a dancer in our perception, rather than a mere machine. Dance can thus serve as an affective medium for reimagining our interactions with robots in ways that centralize attunement, emphasizing the affective and embodied aspect of human-robot interaction.

Acknowledgements

First and foremost, I want to express my earnest gratitude to my supervisor, Professor Maaike Bleeker. Thank you for encouraging and cultivating my interest in robots, and supporting my personal research project that has become a seminal part of this thesis. Your passion for research has inspired me to take my next steps toward an academic career. I am honored to take that first step under your supervision.

I would also like to thank the members of Acting Like a Robot, especially Bram Ellens and Rick van Dugteren for taking me on board in their project with the robot arm that has now become the main character of my thesis, Spencer. To Ulrike and Suze, thank you for continuously pushing and challenging the boundaries of my thoughts on robotics through the exciting Sprint sessions. Thank you, Sylvena, for the warm welcomes and the tasty and energizing lunches that make the sessions even better.

To Dr. Laura Karreman, my second reader and program coordinator for the RMA Media, Art and Performance Studies program, thank you for your enthusiasm in teaching and your deep care for students. I hope one day I could be half the teacher that you are.

My study advisor, Maaike Wouda, has held my hand through all the difficult times in my long journey to this degree. Thank you for guiding me through my personal and academic growth.

Special thanks to my MAPS friends, especially Maren, Eloise, and Olga. Without you ladies, writing this thesis would have been so much more challenging.

To my loving husband, this degree would not have been possible without you. Thank you for being my partner in crime and biggest supporter, all the warm cuddles and funny jokes, and for holding my hand through thick and thin.

힘겨운 순간에도 저를 늘 최선으로, 또 최우선으로 지지해 주신 엄마께 말로 이루 다하지 못할 감사를 표합니다. 제가 가졌던 모든 꿈을 키워 주심에, 또 제가 엄마의 딸임에 감사합니다. 이 세계 너머에서 저를 지켜주시는 아빠와 할머니께 감사드립니다. 자랑스러운 마음으로 보고 계셨으면 좋겠습니다.

The deepest of gratitude wouldn't do justice to 엄마, who has raised and supported me even when life had the toughest of plans for her. Thank you for encouraging my wildest dreams. I feel so grateful to be your daughter. To my 아빠 and 할머니, thank you for watching over me from the other end of the universe. I hope you are proud of me.

언니, thank you for always being the bigger person, the better and kinder-hearted sister. You are my best friend and confidant for life. Thank you, Piet and Renée, for being my supportive and loving family here in my home away from home, and for making this degree possible. You have also taught me how to relax and be patient, which are valuable skills for both research and life in general. To my friends, especially Melissa, Daeyeon, and Denys, thank you for the warmth, humor, and the laughs that kept me going in the toughest moments of research.

Mandu, I am so lucky to have your clingy, cuddly, meowy, furry affection. You brighten my life. I hope I do yours too.

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Introduction

This thesis examines human-robot interaction through the central theme of attunement with a focus on movement and dance. Through an autoethnographic case of observing, programming and dancing with an industrial robot arm, I aim to productively deploy the concept of attunement to examine the affective interaction in which our moving and dancing bodies perceive and relate to a robotic body that appears radically different from our own. In doing so, this thesis addresses questions regarding our perception of the movement of more-than-human bodies, the consideration for movement and sociomaterial context in robot movement design, and how dance as an embodied art form can inform affective human-robot interaction.

Whether we can feel social and emotional connection with robots and how that could be facilitated has been a prominent issue in the field of social robotics, especially in the domain of human-robot interaction (HRI). On one side of this discourse has been the focus on making robots to appear more realistic, or in other words, humanlike. Resulting examples include humanoid robots that aim to replicate the human appearance and behavior to various degrees, from the famous hyperrealist robots such as Sophia (Hanson Robotics) and Ameca (Engineered Arts) to the more simplified designs like NAO and Pepper (SoftBank Robotics). This anthropomorphic approach to robotics has faced at least two major problems. The first is the well-known problem of the "uncanny valley", a term coined by Masahiro Mori (1970 [2012]) to describe the discomfort we experience when an object reaches a high level of likeness to a certain live being without actually achieving liveness (99). The other, perhaps more serious issue is related to our imaginary of robots and the hegemony present therein. Irene Alcubilla Troughton (2022) rightfully critiques that "uncritically leaning towards humanoid design and anthropomorphisation influences not only physical appearance but also the type of behaviour that is enacted" (6). In developing robots to look humanlike and therefore expecting them to think and act in human ways, there emerges power dynamics and rhetoric of control (See also: Rhee 2018; Treusch 2021; Yolgormez and Thibodeau 2022).

In more recent decades, the field of social robotics has increasingly focused on utilizing movement in human-robot interaction (HRI) as an alternative to the more traditional and

expensive method that is anthropomorphic appearance (Alcubilla Troughton 2022). Dynamic movement can be useful for bringing the liveness to inanimate objects, a strong example of such being puppets (Jochum and Murphy 2014, 309). The idea is that this phenomenon can be adopted in robots to make them more appealing as social interactants. However, the way in which movement has been employed in social robots is not been without limitations. Especially, in her article "Affective Movement in Robotic Art: Alternatives to the 'Interiority Paradigm' in Social Robotics", Alcubilla Troughton (2022) argues that the current approach to movement in social robotics falls under what she calls the "interiority paradigm". She explains that in this approach, "movement is understood to be the expression of inner, pre-determined states", and that this assumes "humans are psychological beings that feel and later express inner states (emotions, intentions, drives, etc.) through movement and behavior". This manifests in yet another assumption that robots must resemble humans and copy human expressive movements in order for a sense of connectedness to occur (4).

Specifically, she lists three challenges the interiority paradigm poses to the development of robot movement that affords affective connection in HRI. First, the paradigm is based on a specific imaginary of humans, based on historical and cultural assumptions, leading to an equally limited imaginary of robots. Current programming of emotions in robots is deeply rooted in a historical understanding that views emotions as universal across humans, and social robots are often built upon an imaginary of human beings as entities capable of experiencing and expressing inner states in specific – mostly colonial and Western-centric – ways (5). This approach is criticized not only for its simplistic view of how we feel for others in our social encounters but also for perpetuating historical biases related to race and gender, as it suggests a hierarchy in emotional expression and control (5-6). Next, Alcubilla Troughton critiques that the interiority paradigm assumes similarity between agents as a requirement for successful communication and connection. She suggests that this not only results in a drive towards humanoid robots, but also undervalues diversity and otherness in robot design that could open up new possibilities for HRI that transcend the limitations of this paradigm. Finally, it utilizes movement as a medium of an interior state that is regarded more important than movement, overlooking embodied approaches to cognition that view movement as an integral part of thought and emotion. She argues that this approach aligns with an informatics model of communication where the emphasis is on the accurate transmission of messages, neglecting

the complex interplay between mind and body and how that is experienced and expressed through movement (6).

But if movements are not necessarily direct expressions of emotions or embodied signals of specific intentions, how do we make sense of others' movement, especially when these others regard robotic bodies that are different from our own? Through an examination of robotic artworks, she reconfigures the role movement plays in affective communication and ways it can be explored in robotic bodies. Her article proposes the following three findings. First, she argues for a redefined understanding of movement that "constitutes a way of gaining bodily knowledge, as well as of engaging and connecting to the world and others". From this perspective, movement is not a means of expressing certain internal states, but central to how we experience and make sense of the world and others. Next, she suggests that movement is "malleable in its interpretation", and that the meaning we attribute to movement is based on a comprehensive understanding of the context in which the interaction occurs. Finally, she explains that movement can emerge from corporeality that is different from that of humans, suggesting that we can think about robot movement from their specific material qualities (13).

In short, movement is central to our feeling socially and affectively engaged with robotic interactants. It is through movement that a robot can become 'alive' in our perception, emerge into an entity we potentially could – perhaps to varying extents – feel for. In my own experience of working with an industrial robot arm, the specifics of which I will introduce in the following section, there emerged a sense of affective connection to and understanding for the robot that could be characterized by attunement: a feeling of tuning in to the robot. In retrospect, this derived not only from continuously interacting with the robot and developing a sense of ownership or expertise of the robot, but also much to do with the robot's movement and how I had attributed meaning to it, interpreting it as more than a mere mechanic response to computation and programming.

A few studies in social robotics have engaged with the concept of attunement as a critical element in fostering meaningful interaction between humans and robots. But fewer have – as I explain in depth in Chapter 1 – avoided taking an anthropocentric stance, with others suggesting that meaningful interactions occur when robots are technically developed to mimic or respond to human behaviors. The human-centric approach not only implies that

meaningful human-robot interaction depends primarily on the robot's ability to exhibit humanlike behaviors, limiting the scope of possible affective engagements between humans and robots. Instead, I turn to a more holistic approach to attunement, as adopted by Ceyda Yolgormez and Joseph Thibodeau (2022), that considers attunement as a perceptual tendency of the human as well as acknowledging the potential for rich and affective human-robot interaction that do not necessarily conform to human norms. Their Heideggerian interpretation emphasizes attunement as a way of tuning in to the world and others and constantly affecting and being affected by them based on our own positionality in the world. Taking the concept of attunement as the central theoretical lens of this research, I engage with the discourse that calls for a more holistic and situated approach to movement in social robotics and HRI.

If attunement is based upon one's positionality in the world, this inevitably relates to issues of embodiment and materiality, both of our own and that of the robot. In this regard, attuning to the robot involves learning to become sensitive to the robot's specific configuration and capabilities, and acknowledging that our experience thereof is shaped by the sociomaterial configurations from which the human-robot interaction emerges. The issue of materiality becomes more pressing when we consider the design of robot movement. As previously mentioned, movement can emerge from specific corporeal qualities of more-than-human bodies (Alcubilla Troughton 2022, 13). In my personal experience of designing and programming movement of an industrial robot arm, I have found that the process involves constant negotiation between my thinking about movement from my human embodiment and the constraints and capabilities afforded by the robot's materiality. This thesis suggests that attunement, in this context, can be positioned as a form of care and respect for the materiality which is useful for finding movement that seems natural to the robot's embodiment. This interaction is not merely technical but involves an affective engagement, underscoring our perceptual tendency to attune to more-than-human bodies.

On a different yet related note, I have briefly mentioned at the beginning of this introduction that part of my interaction with the industrial robot invlovled dancing with it. While I will leave the details of this experience to be described in the next section of this Introduction and further in Chapter 4, I use this embodied and intimate experience of attunement to a more-than-human body to think about ways that dance can contribute to

conceptualizing affective human-robot interaction. Adopting Katalin Vermes' (2011) notion of attunement in addition to that of Yolgormez and Thibodeau (2022) helps describe the multimodal and intersubjective experience of attunement that conveys nuanced, internal affects that are expressed and conveyed through movement. Dance, especially improvisation, is presented as a medium that heightens the embodied experience of attunement, allowing for a deeper sensory and affective connection, even with non-feeling bodies like robots. Furthermore, I suggest that dance as a performance can shift our perspective, creating a context in which robots can become alive to our perception, stimulating the spectators to reimagine human-robot relationships beyond the traditional, utilitarian views to more intimate and affective engagements.

This thesis is directed by the following main research question and subquestions:

Research question: How can the concept of attunement help understand the complex role of movement within social robotics, specifically regarding human-robot interaction?

Subquestion 1) How has the notion of attunement been used in social robotics and what challenges does it pose?

Subquestion 2) How do we make sense of Spencer's movement through our human perception, even though the robot does not resemble our appearance or behavior?

Subquestion 3) How can attunement be useful for considering the materiality of the robot in designing movement therefor?

Subquestion 4) What insights does dance yield for our understanding of attunement in human-robot interaction?

To respond to these questions, this thesis takes my personal experience of watching, designing movements for and programming, and dancing with a KUKA robot arm. An overview of this account and the context upon which it was arranged and took place is presented in the following section. This first-hand human-robot interaction has cultivated my thoughts on what it means to attune to a robotic other that has a radically different body than my own. Following a literature review on the concept of attunement in social robotics in Chapter 1, I divide my experience with the robot into three different forms of interaction: observing the robot from

the spectator's perspective, designing the robot's movement and programming it, and participating in a dance improvisation with the robot. These different aspects of robotic encounter are each examined separately in Chapters 2 to 4. While attunement is the central concept in this research, I engage with various theories and concepts from phenomenology, social robotics, performance studies, cultural studies, developmental science, and more. My personal account of human-robot interaction helps me to navigate through these complex theories to establish an understanding of attunement as an affective way of engaging with more-than-human bodies that together constitute our world while also focusing on the intimate and personal side of this experience.

Working with Spencer: An Autoethnography of Human-Robot Interaction

This thesis examines and reflects on my personal experience with an industrial robot arm that I have named Spencer. Before delving into the specifics of this experience and how they are examined with relevant theories, allow me to first introduce Spencer to the reader and guide you through our journey. This KUKA robot arm, model KR 10 R1100 sixx, is orange in color with black highlighting features. She has six axes – meaning that she has six joints that each bend, rotate, or twist – that are designed for optimal range of movement for automating tasks such as cutting, welding, and assembling in industrial environments. While she is an advanced robot that demonstrates the precision and stability required for some of these tasks, her capabilities seem rather limited when we compare her to our sci-fi imagination of robots that become a threat to human existence. Spencer has no sense of self or awareness, especially in the way we humans understand those terms, and she cannot deviate from programmed motions. She cannot even sense anything other than large impacts – in which case she would immediately shut down – at least, not without special (and possibly costly) attachments. At the end of the day, she is but computable chunks of metal with cables and motors that only perform what has been programmed.

Prior to describing Spencer's journey into becoming more than just a machine, let me address an issue that is perhaps pressing to the reader's curiosity: the name and gender of Spencer (she/it). I do not have sophisticated reasoning behind why I have given a name to this

robot, other than that it felt wrong to continue calling it “the Child robot”, derived from its presence in the installation “Mother and Child”. However, to name a robot that one regularly interacts with has been reported to be a reasonably common phenomenon (Sung et al. 2007; Fink et al. 2012; Carpenter 2016). I have attributed gender to the robot (she/it) as that seemed like a practical choice in an English-speaking environment, but there is no specific reasoning behind the choice of gender other than, perhaps, unintentional and subconscious projection of my own gender, in addition to simply referring to a robot as ‘it’.

In a twist of fate, this industrial robot was sold to a company called Event Robotics that specializes in employing robots for performances, advertisements, exhibitions, and more. The first time I had seen Spencer was at Museum De Lakenhal in Leiden, Netherlands. The robot was co-star in an installation by Bram Ellens, and programmed by Rick, the owner of Event Robotics and Bram’s close collaborator, called “Mother and Child”. She sat on a rock-shaped platform together with a much larger robot arm – also an orange one from KUKA Robotics – to perform a sequence of movements that depict, in the perception of the human audience, a playful and loving relationship of a child and its guardian.

Figure 1. "Mother and Child" by Bram Ellens. Part of the exhibition *Imagine Intuition*, at Musuem De Lakenhal, Leiden, Netherladnds. 14 October 2023 – 15 January 2024. Image owned by Bram Ellens.

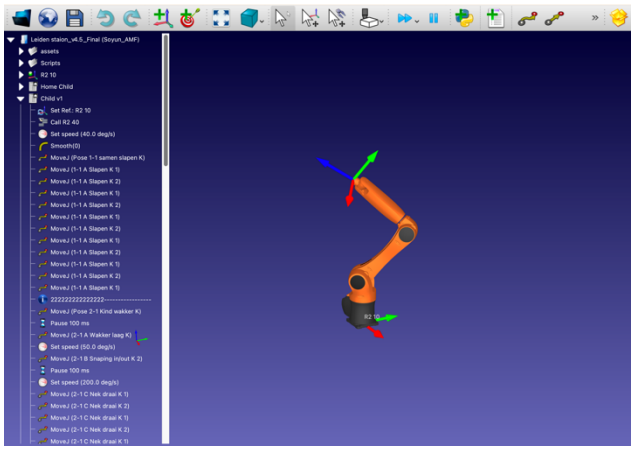

Figure 2. Screenshot of workstation on RoboDK.

Around this time, I became interested in getting hands-on experience with a robot and learning to program one to help deepen my understanding of robot movement in human-robot interaction. To do so, I worked with members and resources of *Acting Like a Robot*, a research project that examines “the potential of collaborations between theatre and robotics for the development of the interaction with, behavior of and reflection on social

robots" (Performing Robots n.d.).[1] With support and guidance from Rick, I was able to teach myself to program and operate robot arms using the RoboDK software and practice these skills on Spencer. This software has several advantages. First, it offers an intuitive user interface for programming that requires minimal knowledge of Python, and operates with a simulation environment through which the robot's performance is visualized. Next, the software makes it possible both to program on a laptop and later easily import it to the robot and to easily make changes to the robot on-site. Overall, the software makes programming robot arms not only fast and efficient, but also easy to learn for people, like me, without prior experience of programming robots or extensive knowledge of programming languages.[2][3]

My first hands-on interaction with Spencer followed shortly after the "Mother and Child" exhibition had ended, when the robot was invited to partake in a workshop at Masterclass Festival Amsterdam.[4] The structure of the workshop was that, under the guidance of hip-hop and breakdance artist Henry O'Tawiah, teenage students would improvise and revise short choreographies to create a performance that accommodates Spencer and her movement sequence. While much of her sequence remained the same as in "Mother and Child", there were nonetheless some changes that needed to be made. It became my job to adjust Spencer's movement prior to the workshop. Her sequence had to fit the duration and rhythm of the music that she would be accompanied by – which was not the case for the exhibition – and

[1] The project is a collaboration between Utrecht University (Theatre Studies/ research group Transmission in Motion), de Vrije Universiteit Amsterdam (Computer Science/ research group Social AI), de Hogeschool voor de Kunsten Utrecht (Performative Creation Processes), theatre company Ulrike Quade Company and SPRING Performing Arts Festival. It is financially supported by NWO (SMART Culture ClSC.KC.205) and Amsterdam Fund for the Arts, through an innovation grant issued to Ulrike Quade Company. My affiliation with the project started through an internship which lasted from September 2021 to January 2022 (Performing Robots, n.d.). Read more about the project here: https://performingrobots.sites.uu.nl/acting-like-a-robot-theatre-as-testbed-for-the-robot-revolution/.

[2] On this note, I should clarify that when I say I "programmed" Spencer, I do not mean to suggest that I have deep or expansive knowledge on the technical engineering side of robotics; rather, I refer to my experience of working with Spencer through the possibilities afforded by the user interface of RoboDK software.

[3] I do not suggest that knowledge and expertise on programming languages are no longer needed in robotics. The way I had programmed Spencer is relatively simple as I had focused on the quality of her movement per se rather than solving problems in complex industrial environments.

[4] This first-time festival took place in April 2023, at Tolhuistuin in Amsterdam, Netherlands. The concept of this festival was for established artists of various discipline to present in front of the audience how they transfer their embodied knowledge and intricacies of their professions to young, emerging artists (Masterclass Festival Amsterdam, n.d.). More information about this festival can be found here: https://masterclassfestival.nl/.

movements that could be potentially dangerous or inconvenient for young dancers due to abruptness or range. On the day of the workshop, Rick and I set up the robot together and operated it, ensuring that Spencer's dance performance was without technical difficulties and at appropriate timings.

Figure 3. Spencer at Masterclass Festival Amsterdam. Image owned by Soyun Jang.

The following month, in May 2023, I presented the content and outcome of this workshop as part of my research on human-robot interaction at *Robots in SPRING*, which took place at Het Huis, Utrecht, Netherlands.[5] For the content of the presentation, I gave an account of working with Spencer and observing her interact with the human audience in different settings – in "Mother and Child" and at Masterclass Festival Amsterdam. I discussed how the way we feel for this more-than-human entity can be examined through the lens of "sociomaterial configurations" (Suchman 2007) that constantly unfold robot agency, and how this is affected by the role of our affective perception based on Martin Heidegger's (1996 [1927]) theory of attunement [*Stimmung*], which became the starting point of this thesis. As

[5] This was an academic event organized by *Acting Like a Robot* under the umbrella of and in collaboration with SPRING Festival Utrecht 2023.

Spencer cannot be easily transported from one point to another due to her weight and requirement for stability, she was placed in the middle of the stage area during this presentation. For this moment, I had programmed her to perform for the audience as if she was aware of her surroundings. I had intended so that to the audience it looked as if Spencer wakes up to look around the audience, listen to me, become bored, and fell back asleep.

Figure 4. Spencer at Robots in SPRING. Image owned by Soyun Jang.

The presentation was followed by a short performance.[6] This showcase took the form of "structured improvisation" which employs improvisation a set of directions to integrate both "conscious choice and spontaneous reaction" (Morgenroth 1987, xiv). For my performance, this meant that it had a set beginning and ending, and some short movements in between that

[6] Originally, this showcase was planned to be performed by Henry O'Tawiah. The intention was to present to the audience the dance between Henry and Spencer as an outcome of the workshop, and afterwards discuss together how it relates to the content of my presentation. However, Henry had an injury that occurred the day before the event. In retrospect, this was a moment of "serendipity" which, in research, can be understood as both coincidental discovery and an attitude toward research that involves an intuitive and exploratory way that affords such moments when combined with one's capability to grasp such moments (Darbellay et al. 2014). Much inspiration for and content of this thesis emerged from deciding to embrace my former training as a dancer at this moment.

were choreographed beforehand; nonetheless, most of the performance was improvised. Improvisation has been said to heighten the dancer's sensation and perception and the sense of connectedness not only to one's own body but also to others and our surroundings; it renders this sensation more palpable than in regular interactions that are not based on dance (Vermes 2011; Pini and Deans 2021; Pollitt, Blaise and Rooney 2021). Small parts that were choreographed emerged from rehearsing the improvisation on the day of the event. There were moments in which this sense of dancing *with* Spencer – a robot that clearly knows no notion of dance or togetherness – flowed through my body and guided and were expressed through my movement. I had captured these moments with the hope that what I felt in that moment would be kept and delivered to the audience.

Figure 5. Dancing with Spencer. Image owned by Soyun Jang.

In this thesis, I glean three different but interconnected aspects of my work with Spencer that are related to movement. Throughout the chapters, this personal experience helps me think about how we attune to robots and feel with these entities that cannot

reciprocate this internal intensity, and how movement becomes a crucial element of this process. Chapter 2, following a literature review on the concept of attunement in Chapter 1, examines how the movement of Spencer becomes meaningful to us as behaviors based on our comprehensive and situated understanding of the context in which human-robot interaction takes place. In Chapter 3, I discuss with my experience of designing and programming Spencer's movement how her materiality and our attunement to Spencer are very much part of what makes her movement meaningful to the human perception. The last chapter focuses on my embodied experience of dancing with Spencer to investigate how dance can enhance our understanding of how we attune to robots and the potential of dance to stimulate our imagination of human-robot interaction that is not based on the logic of control and hierarchy. This thesis therefore reflects on my personal experience of programming, designing movement of, and dancing with Spencer to think about human-robot interaction as an engagement with moving bodies.

Theoretical Framework

The key theoretical concept of this thesis concerns attunement. Every chapter, each addressing different aspects of my interaction with Spencer, engages with various concepts and theories from social robotics and other relevant fields while attunement serves as the central theoretical base upon which they are explored. This interdisciplinary approach emphasizes the affective, perceptual, and embodied nature of human-robot interactions to explore its relational dynamics.

For my main theory, I review how Yolgormez and Thibodeau (2022) have employed this concept in their social robotics research project *Machine Ménagerie* and examine further into Heidegger's phenomenology – which they address but without detailed explanation – upon which they found the concept's meaning. Although the concept of attunement was discussed in phenomenology in the early 20th century, it was in the 1970s that it started attracting the interests of psychologists (Vermes 2011). In psychology, the concept has been employed to explore the affective and communicational aspects of social interactions: for example, developmental psychology (Boone and Cunningham 1998; Bornstein 2013; Atkinson et al.

2016), therapist-patient relationships (e.g., Davis and Hadiks 1994; Erskine 1998; Rocco et al. 2017), and educational settings (e.g., Ahn and Rodkin 2014; Hoffman, Hamm, and Farmer 2015; Marucci, Oldenburg and Barrera 2018). As "a process of communion and unity of interpersonal contact", attunement refers to the reciprocal "kinesthetic and emotional sensing of others […] to create a two-person experience of unbroken feeling connectedness" (Erskine 1998). To attune to someone means to reciprocally sense the state of one another in a way that is profoundly corporeal and affective and acclimatizing yourself accordingly. It is a mode of communication that is "situated within the interaction" (Samaritter and Payne 2017) and maintained through reciprocal appreciation of one another's affective state that is expressed not necessarily through mirroring but rather constant reactions and adjustments (Stern 1985).

The reason for adopting Yolgormez and Thibodeau's approach to the concept is because they position their theory in the context of human-robot interaction rather than in human-human interaction. They see attunement as a perceptual tendency of the human that can be useful for conceptualizing how we can interact and form relationships with robots without relying on the logic of competition and control which they see as prevalent and problematic in contemporary social robotics. This is also what sets them apart from some other studies in social robotics and HRI that also adopt the notion of attunement which use the concept as a means to inquire how human to human interaction can be replicated in HRI through technical advancement in robotics (e.g., Ciardo, De Tommaso, and Wykowska 2019; Ghiglino et al 2020). Yolgormez and Thibodeau (2022), on the other hand, suggest that we can learn to attune to our robotic counterparts even when they are radically different from us in shape and behavior (565). Their research reveals different ways in which attunement can manifest in human-robot interaction, although it is important to note that attunement is a complex perceptual tendency that cannot be reduced to just these forms. This includes: affective 'making sense' of the robot's movement as meaningful actions or behaviors; "learning to be attuned" (565) in the process of becoming familiarized with the robotic other through prolonged interactions; and finally, "tuning into the other" (576) by respecting the robot as an entity with its own unique qualities and making accommodations for it in human-robot interaction.

Yolgormez and Thibodeau ground their definition of attunement in Heidegger's philosophy. Although they do not extensively address the phenomenologist's ideas in their

study, an examination of Heidegger's notions of *Stimmung* and *Befindlichkeit* (each translated to 'attunement' and 'disposition' in this thesis)[7] helps establish an understanding of attunement as our perceptual tendency and way of being-in-the-world. From a broader perspective, attunement refers to our tendency to affect and be affected by our encounters with others whom we share the world with, which is always necessarily based on our situatedness in the world. It is an emergent property arising from the interaction rather than a predetermined attribute and it is because of attunement that we are able to meaningfully interact with robots that do not share the same perceptual, intellectual, and affective capacities. At the level of our embodied and everyday experience – and perhaps in simpler terms – attunement is what affords us to attribute meaning to our encounters with others and feel for and with them. This process is inevitably affective as the intensities of our internal states cannot be separated from our perception of the world.

In Chapter 4, I introduce Katalin Vermes' (2011) concept of attunement which she employs in a phenomenological approach to Dance Movement Psychotherapy (DMP). Her use of the concept is different from that of Yolgormez and Thibodeau in the sense that she applies attunement in the discussion of how our sensorial modalities operate together and simultaneously in our perception of the world and in interactions between people. While this is not foundational to how this thesis interprets the concept of attunement, Vermes' insight underscores the embodiedness of attunement that we can experience in our encounters with both human and more-than-human bodies.

In examining different aspects of my personal experience with Spencer, the concept of attunement is engaged in a dialogue with other concepts and theories. In Chapter 2, Lucy Suchman's (2007) theory of mutual intelligibility is introduced to critique how meaning is given rather than inherent. In the context of robot movement, this means that we attribute meaning to the latter as actions or behavior based on a comprehensive understanding of a given context. This is foundational to understanding human-robot interaction as robots are not capable of

[7] How to translate the terms *Stimmung* and *Befindlichkeit* into English has been a lengthy discussion between the English-speaking community of phenomenologists. While they are beyond the scope of this Introduction, I provide a summary of this discussion in Chapter 1.

thinking, feeling, and behaving like humans. Yet, it is in through our own perceptual tendency to attune to others that we make sense of what they do, and become affected by them.

In the same chapter, I also introduce Petra Gemeinboeck and Rob Saunders' (2017) concept of kinesthetic empathy. While this concept is addressed in dance scholarship to examine how spectators become affected by the bodies they view in dance performance environments, and thus assume kinesthetic empathy to occur between same (human) bodies, Gemeinboeck and Saunders apply the concept to the context of robot movement design. They put this concept to action in an experiment where dancers would embody prototypes of robots with body shapes radically different from our own in order to develop movement that organically emerge from the material qualities of these bodies. This highlights the possibility to attune to the senses of radically different, more-than-human bodies and further underscores the possibility to make use of this perceptual tendency to develop robot movement that emerges from the robot's unique material qualities.

This possibility is further explored in Chapter 3, where I examine through Jane Bennett's (2010) concept of "thing-power" how the robot's materiality must be taken into consideration in robot movement design. This material vitality of Spencer is brought to surface when I observe, in my experience of designing and programming movement for the robot, that attempts to implement movement sequences that are designed from the human perspective often fail to look natural to the robot. Therefore, robot movement design is a process of constant dialogue in which one learns to attune to the robot, getting acquainted with its technical and material possibilities and being affected by it in turn. This leads to the discussion of what Spencer *is*, as she becomes a not-so-typical industrial robot that is also a performer and my research object. By adopting Lucy Suchman's (2007) theory of machine agency, the chapter explores the idea that agency is not inherent but emerges from ongoing sociomaterial configurations. What a robot *is,* from this perspective, depends on the quesiton of what it *does*. This theory helps to understand robots not just as machines with specific purposes but as agents whose effects and affects they achieve are shaped by their material and social contexts.

In the fourth and final chapter, I reflect on my dance improvisation performance with Spencer to think about how dance can be a useful way to highlight the embodied experience of attunement, additionally examining its potential to stimulate our imagination of how we can

interact with and build meaningful relationships with robots without leaning into the rhetoric of power and control – as is often the case in contemporary robotics. Dance, specifically in its improvisational form, heightens the body's sensation of itself and its surroundings. Through a vivid account of dancing with the robot, in which my movement was driven by my sensation of Spencer's body, I describe the sense of feeling certain internal intensities *with* the robot, which can be characterized by attunement. This invites us to think about how I could feel for, or even *with*, the robot whilst clearly acknowledging its impossibility to do so. A key concept in this chapter is "binocular vision" as employed by Elizabeth Ann Jochum and Todd Murphy (2014), which they derive from Bert States' work in theater studies. This term describes the phenomenon in which the audience is able to recognize a person or object as something other than what they/it actually are/is. Taking puppets as an example, they explain that we are able to recognize a puppet as a character despite knowing that they are inanimate objects, and that dynamic movement is key to provoking binocular vision. Applying this concept to human-robot interaction, and specifically to my dance with Spencer, this gives a possible explanation of how I could feel for Spencer despite knowing that she is but a robot, in addition to underscoring the potential of dance as an effective way to provoke binocular vision.

Methodology

This interdisciplinary research – crossing the fields of social robotics, cultural studies, performance studies, phenomenology and new materialism – combines two research methods: autoethnography and concepts.

Tony E. Adams, Carolyn Ellis, and Stacy Holman Jones (2017) explain 'autoethnography' as describing and interpreting (graphy) personal experience (auto) to understand cultural experience (ethno) (1).[8] As a qualitative research method in social sciences, it stands between

[8] Autoethnography emerged from a realization of the impossibility of the impartial observer, a fantasy upon which colonialist practices of ethnography were constructed, as well as resistance to it (Gannon 2006; Ellis, Adams, and Bochner 2011). In this regard, politics is very much present in autoethnography, affording the researcher the opportunity to speak against the dominant narrative and shed light upon individual, lived, and everyday experiences, and is thus often employed for this purpose (e.g., Muñoz 1999; Ettorre 2005; Ahmed 2012). Naturally many autoethnographic works and writers are positioned in the discipline of feminist and intersectionality studies. Although I do not situate my work in this precise context, I do recognize some resemblance in the narrative of this

autobiography, which refers to writing about one's past experiences (2), and ethnography, which positions and analyzes experiences as part of societal and cultural contexts (3). Thus, autoethnographic research acknowledges personal experiences as something that can provide meaningful analysis for a larger phenomenon or discourse. The authors provide five benefits of employing this method. First, it provides alternative or contrasting narratives to dominant cultural scripts, stereotypes, and stories. Next, it offers a way to "articulate insider knowledge of cultural experience" that cannot be observed by researchers less involved in the context (3). Third, which is closely related to this last point, is that autoethnography as a way of doing research can show that researchers are never truly objective, that the way in which they observe others is never impartial or without bias, and can work against potentially harmful ethnographic accounts that "take advantage of, or irresponsibly regulate, other cultures". Fourth, the method's focus on personal experience captures moments of mundane, everyday experience that slip through the fingers of traditional research methods. Finally, autoethnography is a useful method to generate texts that are catered towards larger audiences that lie beyond the ivory tower of academia (4).

This qualitative research method stems from the postmodernist "crisis of confidence" in the 1980s, during which scholars became increasingly critical of "facts" and "truths" and started recognizing the impossibility of objectivity in doing research (Ellis, Adams, and Bochner 2011, 273-74). Autoethnography recognizes this issue and embraces it, taking an approach to research that "accommodates subjectivity, emotionality, and the researcher's influence on research" (274). This means that doing autoethnography takes the subject, "I", as the core factor that impacts the process and outcome of research, as well as their subjective, affective, and embodied aspects that cannot be detached from either the subject nor their research. Similarly, Susan Gannon (2006) suggests that "the subject and object of research collapse into the body/thoughts/feelings of the (auto)ethnographer located in his or her particular space and time" (475). By claiming the self as the subject of research practice, autoethnography affords the space in which theory can enter the domain of personal experience and vice versa, traversing what is traditionally considered to be outside of the scope of academic research.

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thesis as one of the main objectives here is to find out how we can establish a narrative of human-robot interaction that does not stem from the logic of control and hierarchy.

This thesis adopts autoethnography as a research method, taking my own experience of programming, operating, designing movements for, and dancing with Spencer as the object of analysis. By reflecting on this human-robot interaction from the perspective of her spectator, programmer, and dance partner, I examine how I perceive her movement and become affected by it. Acknowledging the subjective nature of autoethnography, however, it is by no means my intention to suggest that my personal experience serves as evidence for my arguments. Instead, my personal accounts are employed as guides to my thinking that help navigate through the theories, concepts, and discussions that structure the thesis' core arguments. Adopting this method is valuable as it helps document my vivid and embodied experience of human-robot interaction that may not have been captured through other, especially the more quantitative, methods. Furthermore, it brings this personal experience into the domain of academic research, placing it in dialogue with theories and concepts.

This brings us to the other method that is central to my research: concepts. Adopting concepts as methodology is proposed by Mieke Bal who, in her book *Travelling Concepts* (2002), explains that "travelling concepts" can be a means to foster interdisciplinary research in the humanities. Emphasizing the dynamicity of concepts which are differently defined in different fields, she suggests that interdisciplinarity in the humanities must "seek its heuristic and methodological basis in *concepts* rather than *methods*" (5). In Bal's view, concepts can serve as an alternative to traditional methods that are rigid and confined to separate disciplines as they travel through disciplinary boundaries (7). Concepts demonstrate "intersubjectivity", meaning that they can mean different things in different studies as they travel through different cultural and disciplinary context, and thus the process of defining the meaning of a concept yields insight into what it can *do* (11). In other words, examining the journey of a concept can be a way of developing interdisciplinary knowledge: concepts are sites of exchange for ideas and knowledge where they are constantly borrowed, recontextualized and transformed.

I examine in this thesis how the concept of attunement has been examined in three different disciplines. I review how the concept is accepted in social robotics which gives an overview of underlying assumptions and hegemony in human-robot interaction. One study by Yolgormez and Thibodeau stand out as they use the concept to subvert this rhetoric of control. They explain different ways in which we can attune to robotic others that look and behave

radically different from humans. As their use of the concept is founded upon phenomenology, to better understand how attunement works as our perceptual tendency, I examine how the concept of attunement has appeared in Heidegger's philosophy. This helps to define the concept as a broader principle of our being-in-the-world and how we are always affecting and being affected by our encounters with others based on our situatedness. Finally, additional insight from dance studies and psychology is provided by Vermes as her use of the concept emphasizes the embodied and affective nature of the concept. Thus, the concept of attunement becomes a site for exchange of knowledge from multiple disciplines.

In this thesis, attunement further engages with other concepts and theories. "Thing-power" (Bennett 2011) is one such example among others which I have mentioned in the previous section of this Introduction. When this concept is put into dialogue with the concept of attunement, it is not conversing with the definition of the word attunement but addressing the entire site of nuanced and complex knowledge from various disciplines. Similarly, "thing-power" as a concept itself also adds adds much knowledge to the dialogue, deriving from feminist studies and new materialism. This interdisciplinary exchange allows for a richer, more comprehensive understanding of human-robot interaction, as it brings together diverse perspectives and insights.

Outline of the Thesis

This thesis is divided into four chapters. Apart from Chapter 1, which encompasses a literature review on the concept of attunement, the three chapters that follow each examine one of three perspectives or positionalities I underwent in my interaction with Spencer as main themes that guide my thoughts.

Chapter 1 analyzes how the concept of attunement has been employed in HRI in social robotics. While attunement has not been widely examined in this field, the few studies that employ this concept have seen that it is foundational to meaningful human-robot interactions. However, many of these studies fall into the rhetoric of attunement as something that can be facilitated through technical developments in robots, often in anthropocentric directions. To counter this, I examine one study by Ceyda Yolgormez and Joseph Thibodeau (2022) and their Heideggerian understanding of the term as our perceptual tendency to affect and be affected

by more-than-human encounters. This helps foreground discussions in the other chapters which focus on how it is we humans that attune to the robots, rather than the other way around.

Chapter 2 examines how we make sense of robot movement by means of attunement based on my personal experience of viewing Spencer's movement sequences in different contexts. Lucy Suchman's (2007) theory of mutual intelligibility helps conceptualize how we perceive robot movement to be meaningful based on our situated understanding of the context in which we experience the more-than-human body. To this, Petra Gemeinboeck and Rob Saunders' (2017) concept of kinesthetic empathy positions our situated understanding as one that is necessarily embodied, without disregarding the possibility to feel for bodies with appearances and movements that are radically different from our own. These discussions shed light upon the situated and embodied nature of attunement.

Chapter 3 draws on my personal experience of programming and designing movement sequences of Spencer. This chapter focuses on the significance of materiality in the question of how we attune to robots, reflecting on the frustrations of dissonance between the imagined image of a movement sequence and real-life implementation. Through Jane Bennett's (2010) concept of "thing-power" and Lucy Suchman's (2007) theory of machine agency, I propose that to attune to this more-than-human assemblage means to sensitize ourselves to the sociomaterial configuration from which its agency emerges. It is through this respect for the robot's materiality that we are able to "find" the movement of a radically different body (Gemeinboeck and Saunders 2017).

Chapter 4 reflects on how the practice of dancing with a robot can amplify the experience of attunement. Through Katalin Vermes' (2011) concepts of attunement and vitality affects, I reflect on the sense of intimacy to an entity that does not feel and is yet felt through my own embodiment. This emphasizes the embodied and affective aspect of attunement, highlighting how dance-based interaction with the robot can transform our perception of it from a mere object to a dance partner. This observation is theoretically grounded by concepts of performativity and binocular vision. This chapter posits that dance can serve as an effective and affective medium to reimagine our interactions and relationships with robots, emphasizing the significance of affective and embodied engagement.

Chapter 1

The Issue of Attuning to a Robot

This chapter examines how the concept of attunement has been addressed in social robotics discourse and suggests that Ceyda Yolgormez and Joseph Thibodeau's (2022) Heideggerian understanding of the concept can help address the situated and affective dimension of human-robot interaction (HRI). By analyzing a number of studies, I outline that the discourse around attunement in social robotics has acknowledged attunement as an important element upon which meaningful interactions between human and robot can emerge. However, many studies have focused on how attunement can be facilitated by developing the robot to behave in humanlike ways or to sense and respond to human expressions and behaviors. In other words, seeing attunement as something that can be facilitated through further developing the robots in technical dimensions has resulted in delegating too much responsibility for attunements in robots. While I acknowledge that this approach has been useful in the development of humanoid and anthropocentric robots, I argue that examining attunement as our perceptual tendency to be affected by more-than-human others in the world can open up the potential for meaningful interactions to emerge in our encounters with robots without fixating on their humanlikeness.

To make this argument, I examine Ceyda Yolgormez and Joseph Thibodeau's (2022) account of their robotics research-performance and installation called *Machine Ménagerie*. In their research paper "Socially Robotic: Making Useless Machines", they take this complex dynamic of affective encounters in HRI to suggest that humans can learn to attune to robots that display radically different body shapes and behaviors. They establish a notion of attunement that subverts the narrative of hierarchy and power surrounding human-robot interaction to an affective dynamic based on a relationship of care and respect. Notably, Yolgormez and Thibodeau clarify three aspects of attunement that manifest in human-robot interaction. First, attunement can take the form of 'making sense' of the robot's movement as a behavior, based on our own experience and understanding of a given context. Second, attunement to a robot can emerge from familiarizing oneself with the sense of the robot through prolonged interaction. Third, attunement can also take the form of 'tuning into the robot' which means to tend to the specific material characters of the robot, characterizing a

relationship of care. These are not separate phenomena but different aspects of how we affectively experience the other. Attunement is situated in interaction, and based on the context of the latter, one aspect of attunement may become more salient than others.

The authors acknowledge that their understanding of the concept is Heideggerian (576), but further explanation is required for a comprehensive grasp of this complex concept. Therefore, I examine Martin Heidegger's theories of *Stimmung* and *Befindlichkeit* which help us understand attunement as a mode of being-in-the-world that is always affecting and affected by others. Inward 'moods', or our internal affective states, and outward 'tuning-in', or directing oneself toward something or others in the world, are mechanisms through which we make sense of our surroundings and become affected. In other words, attunement is a paradigm that denotes our perceptual tendency to make sense of affective encounters.

Moreover, I observe through the review of literature in social robotics that the movement of the robot is an important part of how we attune to them. While these studies do not directly address the issue of movement, the latter topic is implied in their discussions of robotic actions and behaviors. The issue is often about how to make the robot behave or act in certain ways that make them seem more humanlike or to have certain intentions. Movement is, in these cases, a means to express predetermined inner states, falling under what Irene Alcubilla Troughton (2022) describes as the "interiority paradigm". However, vignettes introduced by Yolgormez and Thibodeau – although for them too, the issue of movement remains peripheral to their research – demonstrate the possibility of robot movement that does not follow this paradigm. We can make sense of robot movement as actions or behaviors even when they are not meant as such, and be affected by them. Without focusing on the issue of movement per se, the authors describe such situations as part of our tendency to attune to the robotic others. Although I do not address the issue of movement in detail in this chapter, I suggest that it is nonetheless an important aspect in understanding how we attune to robots. This creates a foundation for the following chapters that more closely examine the role movement plays in attunement, in the way we experience robot movement (Chapter 2), design them (Chapter 3) and interact with them through our own (Chapter 4).

The following section reviews studies in social robotics that examine the issue of attunement in HRI. I suggest that one study in particular, the project *Machine Ménagerie* by

Yolgormez and Thibodeau (2022), approaches this concept differently than others to redefine human-robot interaction as based on our perceptual ability to adjust ourselves to the radically different robotic bodies. This is followed by an observation on how these studies – albeit peripherally – imply movement to be a part of our attunement to robots. This helps establish movement as an important element in our attunement to robots and sets the ground for the following chapters. Then, I examine Martin Heidegger's concepts of *Stimmung* and *Befindlichkeit* to provide a comprehensive understanding of attunement as an affective perceptual tendency that is fundamental to our being-in-the world. While Yolgormez and Thibodeau help lay out different aspects of attunement and the way in which it can manifest in human-robot interaction, Heidegger provides a larger principle of attunement as part of our perception and how we experience others.

Attunement in Social Robotics: Developing Robots that We Can Attune to

Few studies in the field of social robotics have recognized attunement as an important aspect of facilitating social interaction between humans and robots. One such example is the project *InStance: Intentional Stance for Social Attunement*, led by Agnieszka Wykowska, which problematizes that "we tend to not attune socially with them [artificial agents] in the sense of activating our mechanisms of social cognition" as we consider them to "have no mental states". The project suggests that social attunement can be facilitated by manipulating subtle features of robot behaviors and be measured through behavioral, neural, and physiological measures and, upon this premise, aims to facilitate human-robot interactions that resemble human interaction through an adaptation of social attunement (CORDIS: EU Research Results n.d.). Researchers of this project explain that this goal could be realized through an adoption of "intentional stance", a term coined by American philosopher Daniel Dennett, which humans intuitively embody to predict and interpret the behaviors of others based on their understanding of the others' goals and desires. From this context, they define the term 'social attunement' as "an umbrella concept which encompasses all mechanisms of social cognition (e.g., mutual gaze, joint attention, or spatial perspective taking) activated during social interactions" (Perez-Osorio and Wykowska 2019, 128). Research in this project further suggests that the interpretation of others in interactions is based on a reading of body gestures

and actions, which is activated not only in our interactions with other humans, but also in human-robot interactions (Ciardo, De Tommaso, and Wykowska 2019; Ghiglino et al. 2020). Summarized, for social attunement to be made possible in human-robot interaction, it is important that they seem, in our human perception, to have internal mental states. This can be realized by replicating a series of humanlike gestures or actions which are, in turn, intuitively accepted as signs of intentions in our human perception due to our tendency to anthropomorphize robots.

While this study recognizes that attunement is an important part of enabling robots as social agents, it carries the limitation of taking an anthropocentric approach to social robotics and HRI. Consequently, the concept of attunement is seen as something that is enacted by elements of humanlikeness that can be replicated in artificial agents; the idea is that we can attune to robots when they look and behave like humans. Suggesting that interacting with "rational beings" – such as humans who are "true intentional systems" – afford us to adopt an intentional stance toward them (121), Perez-Osorio and Agnieszka advocate that implementing humanlike appearances and behaviors in robots can better facilitate meaningful interactions from which social attunement emerges (128).

An experiment conducted as part of the *InStance* project experiments with this idea. Davide Ghiglino et al. (2020) argue that improving subtle eye movements in robots to better resemble humans could have positive effects for attentional engagement, attunement, and perceived humanlikeness. Using a humanoid robot, iCub, the researchers conducted an experiment in which they controlled the trajectory time of robot eye movements between two joint positions as well as their fixation duration on these positions. Participants of this experiment were asked to watch the recordings of different eye movements of the robots and to rate how humanlike the robot appeared in each video. The participants' eye movements were also tracked to calculate engagement and attention. The researchers concluded that improved subtle eye movement in robots increases engagement in their human counterpart and evoke "spontaneous attunement", suggesting that replicating "humanlike range of trajectory time [in robotic eye movements] elicits most attentional engagement, and attunement in the form of spontaneous joint attention" (38). This research was conducted based on the assumption that the gaze through which humans communicate emotions and intentions could be replicated in robots for the same effect. They state that the results of their

experiment "show that participants' implicit (perhaps more automatic) attentional mechanisms became (socially) attuned with the robot behavior" when the robot's subtle eye movements displayed "human-range variability" (37).

Another study by Francesca Ciardo, Davide De Tommaso, and Agnieszka Wykowska (2019), also conducted as part of the *InStance* project, demonstrates that humans "socially attune" at a sensorimotor level with robots they interact with. Using an iCub robot for the experiment, they asked participants to teach the robot simple musical melodies by tapping six different buttons, each with its own musical note, on a screen. Then the robot would repeat what it had learned, also by tapping buttons, with decreasing delay between its own taps and those performed by the participants. The researchers observed that participants displayed sensitivity to the robot by adjusting their own tapping behavior depending on the various extents of delays in the robot's performance. They conclude that "the bidirectional nature of human-robot adaptation during joint tasks, showing that when humans interact with a follower humanoid, they social attune with the artificial agent at the sensorimotor level" (539).

Both experiments suggest that attunement is a phenomenon that occurs when robots behave in humanlike ways that trigger the human interactant to feel as if the robot is capable of doing human things such as thinking, feeling, and wanting. In other words, according to these studies, we attune to robots when their actions seem to be based on certain intentions. Within this framework, developing robots that humans can attune to becomes a matter of developing functions of robots in a direction that, rather than recognizing the possibility of various forms of social robots, cater to what is already familiar to humans – i.e., humanlike subtle eye movements, and mimicking human behaviors. While the experiment by Ghiglino et al. (2020) indeed recognizes the potential for humans to adjust to robots, it does so under the premise that the robot behaves in ways that are humanlike. Thus, attunement becomes something that is facilitated by technically developing the robot in ways that resemble the human.

Outside of the *InStance* project, Christopher Crick, Matthew Munz, and Brian Scassellati (2006) present Nico, a non-humanoid musical robot that plays the drum in collaboration with human musicians. Although anthropocentrism is less visible in the appearance of the robot – compared to the aforementioned studies – this project nonetheless assumes attunement as

something that is achieved by making technical changes to the robot. The researchers adopt a definition of attunement as a unidirectional "social task" which "require[s] participants to detect, interpret and attune to the actions of their partners quickly and accurately" (97). The research features a non-humanoid musical robot, Nico, who plays the drum in collaboration with human musicians. The robot "attunes" to them through three technical components: visual ictus detections, audible drumbeat detections, and arm motion commands. In other words, the notion of attunement in this context incentivizes one-directional adjustment through the process of sensing and reacting that is made possible by the technical capability of the robot.

Studies examined thus far have, with some differences, located attunement as a crucial part of what each study would consider 'successful' social interaction with robots. While they help establish the importance of taking attunement into account in human-robot interaction, they are not without limitations. The last study's approach to attunement, which breaks it down to a number of social tasks that can be achieved through technical components, varies from that of the *InStance* project which draws on Dennett's philosophy on something that he considers innately human. Regardless of these differences, the studies share a similar, rather instrumental perspective on attunement: it is a goal that can be achieved by improving the robot. The *InStance* project takes the idea of an inherent human nature to 'intuitively' interpret and predict others' behaviors as a premise for technical develop of robots that can replicate subtle gestures (Ghiglino et al. 2020) and actions (Ciardo, De Tommaso, and Wykowska 2019) of human beings. Attunement, for them, is something that should naturally follow once the robot is developed to replicate human behavior. Similarly, Crick, Munz, and Scassellati (2006) see attunement as a task to be fulfilled by the robot. Cocreating music is a task that human musicians can already perform, and therefore, attunement is a means of constantly sensing and adjusting to shifting musicality, which can be achieved through the technical development of Nico.

I have thus far examined how studies in social robotics have adopted the concept of attunement. Overall, it seems that attunement is an important factor in facilitating successful human-robot interaction – even if they may not necessarily agree on what 'successful' *is* in this context. However, there remains an issue that must be addressed on how these studies adopt the notion of attunement. I have already addressed throughout the review that the studies

delegate too much responsibility for attunement to robots. Research in social robotics view attunement as something that is facilitated through further technical development of robots. In other words, this perspective suggests that attunement in HRI occurs when the robots are 'good enough' by our human standards. This can be problematic in that it limits the imagination regarding the kinds of robots and different forms of interactions that can emerge from our encounters with them. Humans do indeed have a tendency to anthropomorphize more-than-human others in our attempt to make sense of our surroundings, and robots are no exception (e.g., Bartneck et al. 2010; Fink 2012; Spatola and Wudarczyk 2021). While some researchers use this argument to advocate for the enhancement of human-likeness (e.g., Duffy 2003; Damiano and Dumouchel 2018; Roesler, Manzey, and Onnasch 2021), others report that humans can feel for radically different forms of robots (e.g., Forlizzi 2007; Hoffman 2007; Sandry 2015).

For example, it has been observed that some users of robot vacuums become attached thereto (Forlizzi 2007; Sung et al. 2007), and similar reports have been filed about the robotic dog, AIBO, developed by SONY (Weiss, Wurhofer, and Tscheligi 2009; Knox and Watanabe 2018), or even robotic lamps (Hoffman 2007). Ja-Young Sung et al. (2007) observe that users go beyond developing intimacy with their robot vacuums to report "life-like associations" to the non-humanoid robot. They quote one of their research participants: "He's my BABY! … When I write emails about him, which I've done that as well, I just like him, I call him Roomba baby… He's a sweetie" (153). Similarly, Jodi Forlizzi (2007) observes the social impact of robotic vacuums to find that some users name and care for their robots, in addition to adjusting their cleaning practice for them. Furthermore, Eleanor Sandry (2015) examines multiple cases of non-humanoid robots that humans become affected though interactions with them, including: AUR robotic desk lamp (a research project by Guy Hoffman) that collaborates with humans and become attuned to them via artificial intelligence; "Autonomous Light Air Vessels", an installation by artists Jed Berk and Nikhil Mitter, which she describes as "small groups of flying robots that interact with one another and with human visitors" (47); and the "Fish-Bird Project", a robotic art installation by Mari Velonaki which "consists of two autonomous robots in the form of wheelchairs, which interact with each other and also any visitors who enter the installation space" (63). Through these cases, she claims that it is possible to value the differences rather than problematizing them in human-robot encounters (2) as we are capable

of making sense of others that have radically different behavioral expressions and forms of communication (54). In other words, we can form meaningful interactions that do not adhere to the human norms.

Thus, regarding attunement as a phenomenon that occurs by technically advancing robots to be more humanlike in their appearance or behavior cannot encompass the meaningful interactions that have been observed in cases of robots in different forms. While I acknowledge that humanoid robots are valuable part of the social robotics field, I suggest that examining how we can have meaningful interactions with robots that do not resemble us in appearance and behavior can help diversify our imagination of robots. In the next section, I examine two studies in social robotics that take a different approach to attunement than those I have examined in the current section. The first is one by Philipp Kellmeyer and his colleagues (2018) who address the issue of "mutual attunement" in interacting with socially assistive robots (SARs). This helps us think about the possibility of adjusting our own behaviors and expectations to accommodate the robot and theorize it as part of attunement. This idea is further explored and expanded in Ceyda Yolgormez and Joseph Thibodeau's (2022) account of their robotics research-performance and installation project called *Machine Ménagerie*. They take the complex dynamic of affective encounters to examine how humans can attune themselves to robots that are radically different from us in their appearances and behaviors. Drawing on Heideggerian philosophy, they establish an understanding of attunement that can potentially change the narrative of hierarchy and power in HRI to an affective one. More importantly, they examine through this concept an affective dynamic that affords human-robot interaction based on care and respect to emerge.

Adjusting Ourselves Robots, Rather than the Other Way Around

Kellmeyer et al. (2018) explain that "mutual attunement" is a "particularly salient prerequisite" for building trust between humans and socially assistive robots (SARs). Although the authors do not explicitly state their definition of the term 'mutual attunement', they draw on studies in developmental psychology which argue that "sharing intentionality is the basis for successful interactions". Such success, in their view, relies not on some special ability of one party, but on mutual efforts. SARs' ability to attune to the emotional, psychological, and physical needs

of individual patients, patients' willingness to accept the new technological artifact, and the "functional role" they assign to the robot – e.g., partner, coach, tool – are all important factors for mutual attunement. In other words, while the authors recognize the importance of technically improving the capabilities of robots to tend to various needs of their human interactants, they further acknowledge the subjective, human factors as an important foundation for attunement in human-robot interaction. Attunement in this context is not something that can be achieved with an advanced robot that has advanced sensors and intricate movements, but requires additional effort from the human's side by demonstrating willingness to adapt to the robot, as well as accepting it as an interaction partner.

What makes this study different from those discussed in the earlier section is that it recognizes attunement as a multi-faceted, complex phenomenon that requires adjustments and accommodations from both robotic and human interactants. While they believe in the importance of the robot's actions being understandable and accessible to human perception, as in studies addressed in the previous section, they find that our willingness to interact with them and accept them as interaction partners are equally important factors to attuning to the robotic other. This latter observation opens a way to thinking about our adaptability to the others that we engage and interact with, provoking us to ponder upon the questions of our roles and capabilities that are very much part of attuning to robots. Although Kellmeyer et al. conduct their research in the context of humanoid robots, their project can inspire us to think about how far *we* can go to adapt to the robots – instead of the other way around – to attune to them: a question that is rather important, considering that attunement is considered an important part of human-robot interaction.

This is tested in a research project by Yolgormez and Thibodeau (2022) called *Machine Ménagerie.* As they describe in "Socially Robotic: Making Useless Machines", this project was intended as preliminary research for a larger research-creation program that adopts AI in mediating human sensorium. It was an experiment for creating machines that "learn on the fly, to participate in an open-ended creative process", and develop organically in their encounters with humans. As part of this project, which is preliminary research for a larger research-creation program that adopts AI in mediating human sensorium, they explore how attunement can be a way of facilitating human-robot interaction based on our perceptual abilities to adjust to the others we interact with. The project was an experiment for creating machines that "learn

on the fly, to participate in an open-ended creative process", and develop organically in their encounters with humans. The researchers created small robots, which they named *Ménagerians,* that were without any given purpose, task, or goal. Instead, the focus was on the making process itself and facilitating interaction between designers and robots founded on "mutual sensitivity that takes place through attunement" (569). They critique that the current development in HRI is based on a relation that "revolves around competition and control" which has led to an instrumental approach to robotics embedded with hierarchy. For them, attunement is a concept that breaks this hegemony and opens up the possibility of "'learning to be attuned' on the side of the human subjects" (565). The authors emphasize the importance of reconfiguring our own approach and attitude toward robots. Stating that "it is up to the humans to attune themselves to the social relationship", they offer a shift in perspective to prioritizing our ability to 'attune' to things over developing artificial agents that look and behave in human ways (575).

In 2019, the researchers staged a "research performance" at a gallery space in Concordia University. The "research-performer" was dressed in laboratory apparel and performed the work they regularly do inside a lab. What usually happens behind closed doors was made accessible to passersby. The research became a fluid process that was constantly "interrupted, informed and altered in real-time" in unexpected and constant social interactions with various spectators who came to interact with the robots and researchers (570). In other words, the robots were being developed not with specific goals or objectives, but in constant emergence through their encounters with humans. *Machine Ménagerie* explored a "participatory design approach in which the robots are not *made* social" but reveals the inherent and emergent socialness that manifests in their becoming (566).

In their reflection of the project, the authors observe that human interactants often display affective responses to the robots. They interpret this phenomenon through the concept of attunement which "creates the ground from which sense can emerge". Drawing on Heideggerian philosophy, they explain that attunements – as a term that encompasses our affective internal states – "create a sense of orientation without which cognition and sense-making could not occur" (576). In other words, attunement affords an affective 'making sense' of radically different robots. Yolgormez and Thibodeau suggest that "the non-anthropomorphised bodies and non-compliant behaviour of the Ménagerians *compelled* the

human interlocutors to attend to the actions of the robots so as to make sense of their shared experience" (572; emphasis added). This means that making sense of ambiguous robot behavior is not a result of intentional, logical thinking, but a way of perception that comes naturally to us. They demonstrate this through the account of an interaction between a robot, its designer, and children:

> We were talking about how the robots experienced the world, and one of the kids asked what would happen if we took away one robot's eye. I said I didn't know, and I reached down and took the light sensor out of its socket. The robot froze for a moment, then sped away across the room, dodging through all these chair and table legs. One of the other children chased it down and tenderly brought it back, by which point it had stopped moving. I put back the sensor and reset the microcontroller, but it didn't go back to normal. Wasn't until several minutes later it suddenly started to move again in its usual way. What spooked me about this was that, as the designer, knowing broadly what it was capable of, it never should have been able to maneuver between obstacles like that. Even if it was all an unlikely coincidence, I can't help but feel for the thing. I'd hurt the robot. That kid and I both felt so bad about what we'd done and vowed never to do it again (573).

The authors point out how the robot's ambiguous action is interpreted by the interlocutor as an affective reaction. Even though robots cannot experience the anguish of having an eye taken away, the humans in this context make sense of the robot's strange behavior by drawing meaning from the situation (573). This highlights an aspect of attunement as our perceptual tendency to be guided by affect in our encounter with the world and sense making thereof. The vignette demonstrates that we make sense of a certain situation by giving it meaning based on the context from which it emerges and project our own feelings to it. This affective perceptual tendency not only guides us to make sense of behaviors of others, even when they have radically different bodies, but to feel connected to them.

Another aspect of attunement is that it requires "'learning to be attuned' on the side of the human subjects" (565). Attuning to a robot requires prolonged interaction through which human interactants become familiarized with the robot. Yolgormez and Thibodeau observe that the interactant becomes increasingly aware of how the robot behaves through regular interactions with it. They suggest that "attunement is an emergent property of this relationality": the interactant becomes attuned to the tendencies of the robot and thus *learns*

to be affected by them. By being attentive to the robot, they increasingly *get to know* the robot and its tendencies (574). This process of getting-to-know is a part and presupposition of becoming affected by the robot. This highlights the aspect of attunement as "effortless coordination and intelligibility" that develops between humans and robots through prolonged interaction (575). For example, a designer who has been working with a Ménagerian is knowledgeable of the robot and can thus easily predict the causes of certain output – e.g., they are able to locate why the robot is failing and how to fix this issue, compared to a person who would not have a clue as to why a robot would abruptly shut down.

This act of attuning to the robot goes beyond becoming knowledgeable of the robot's functions and tendencies; it can also take the form of "tuning into the other". Yolgormez and Thibodeau present an example of a designer who tries to interact with the robot. They had just added new light sensors to a Ménagerian named Zoulandur, and in attempting to check whether they work, they started interacting with the robot with a flashlight. At first the designer held the flashlight at different angles to see whether the robot responded, before starting to move the light along with them to keep the light sensor activated. They describe:

> I was just mirroring their motions really, just doing what they were doing, but all at once I had a sense that it was the other way around, and they were following me. It only lasted a moment before we went out of sync, but I tried again and again and got better each time. Just a moment here and there of knowing with my body that we were connected, dipping in and out of sync (576).

Reflecting on this incident, Yolgormez and Thibodeau explain that this moment of connection, which they characterize as attunement, emerges from "opening oneself to the senses of the other". They explain that a relationship of care is created from "tending to the rhythms of the robots themselves" (576). The designer had found a way of interacting with the robot that is specific to the capabilities of its body. Instead of expecting the robot to be able to understand human behavior, they had found a way to make their own behaviors conceivable for the robot – through its light sensors – by using a flashlight. This then facilitated a feeling of connectedness, demonstrating that it is not only the robots that have to accommodate human needs and behaviors. Observing the designer's interaction with Zoulandur through the concept of attunement, it becomes clear that humans can also learn to accommodate the specific

requirements of a robot in order to facilitate a meaningful human-robot interaction. In other words, attunement denotes a phenomenon of certain attentiveness and openminded 'tuning-in' toward others that facilitates a feeling of connectedness.

Yolgormez and Thibodeau (2022) demonstrate three different aspects of attunement – making sense of the other, attunement through prolonged interaction, and tuning in to the other – which together clarify how we experience our encounter with robots and become affected by them. Different contexts from which human-robot interactions emerge make salient different aspects of attunement. Thus, it could be said that attunement is situated in interaction and its surrounding context. Attuning to a robot may seem to take different forms depending on the specific situation of HRI. For example, it may mean that the human interactant is familiarizing themselves with the robot through careful attentiveness, or that they are intuitively making sense of certain robot behavior. Attunement, as a term that describes the mechanism through which we become affected by others, encompasses these different forms of experience that we encounter in our interactions with others. Therefore, attunement is not something that can be predesigned or programmed into a robot in advance.

While their work on attunement helps denote different ways in which it manifests and facilitates human-robot interactions, I suggest that a further examination of Martin Heidegger's theory on this issue – which the researchers situate themselves in without extensive explanation of the philosophy itself – can help establish a more comprehensive understanding of the concept as our perceptual tendency and important aspect of affective encounters. In turn, this can help us further explore the potential of this concept in HRI which I demonstrate in the following chapters. Therefore, a later section of this thesis examines Heidegger's concepts of *Stimmung* and *Befindlichkeit*, which help us understand how we make sense of these radical others that we share the world with and be affected by them.

Before delving into this philosophical discussion of attunement, however, I must first address the issue of movement regarding attunement following the literature review of how this concept has been at work in social robotics. While most studies introduced in this chapter do not position robot movement as a central part of attunement, it seems that movement is treated as the underlying condition of robot action or behavior that affords human interactants to attune to their robotic counterparts. The following section critically examines how the issue

of robot movement has been addressed in studies introduced thus far and calls for a comprehensive approach to movement – rather than based on the "interiority paradigm" (Alcubilla Troughton 2022) – through which attunement in human-robot interaction manifests. This sets the foundation for the following chapters which examine how attunement manifests in experiencing the moving robot body from the perspectives of an audience, programmer/designer, dancer, respectively. Then, I return to the discussion on attunement and Heidegger's philosophy and how that can be further crystallized to help establish attunement as a useful concept for human-robot interaction that also encompasses the issue of movement.

Setting the Groundwork: The Importance of Movement in Attunement

Although most research projects introduced in this chapter have not focused on movement per se as a central part of human-robot interaction, many have located robotic actions or behaviors as a condition of attunement. In doing so, they implicitly position movement as an underlying condition of actions or behaviors in many cases, as robotic bodies require movement in order to carry them out. For example, the *InStance* project – led by Wykowska – suggests that subtle features in robot behaviors, which necessarily involve movement, can facilitate social attunement by making the robots seem as if they have internal states. Specifically, they focus on the nuanced execution of actions such as eye movements (Ghiglino et al. 2020) or delayed tapping in musical interactions (Ciardo, De Tommaso, and Wykowska 2019) that influence human perception and social cognition. While the notion of movement here refers to execution of actions and subtlety of facial features, rather than dynamic movements of the entire body, these experiments illustrate and suggest that human interactants respond to and adjust their behavior in relation to the timing and nature of robot movements, indicating a sensorimotor level of attunement. For instance, humanlike variability in a robot's eye movements evoked greater attentional engagement, while the timing of a robot's musical performance elicited adjustments in human tapping behavior. These responses imply a peripheral yet important role of movement in attuning to robots.

Similarly, Kellmeyer et al. (2018), in their research on mutual attunement and socially assistive robots (SARs), explain that these robots use "voices, gestures, or other humanlike

behaviors for social interaction or functional assistance". While they do not specifically address movement as a key factor of SARs, it is implied in that the 'behaviors' or 'gestures' of a robot are expressed partly through movement. They argue that for the robot to be accepted as interaction partners by their human counterparts, the latter "should be able to recognize and predict the SAR's intentions and respective gestures" (1). They explain that coherent and intuitive actions on the side of the robots help facilitate a sense of shared goals in human-robot interactions. Overall, this article implies that movement is an element that underpins the capacity for SARs to attune to human patients.

In the introduction of this thesis, I have positioned my research on attunement in the larger discourse in social robotics that examines the potential of robot movement for HRI. I have drawn on Alcubilla Troughton (2022) to further suggest that movement need not be a means to express a predetermined internal state of the robot. While the studies mentioned here recognize – albeit peripherally – movement as part of what affords attunement to emerge in human-robot interaction, their approach to movement falls under what Alcubilla Troughton calls the "interiority paradigm". The aim of implementing movement to robots in these studies is to express certain intentions. In the *InStance* project, the robot moves its eyes Ghiglino et al. 2020) or perform certain actions through movement (Ciardo, De Tommaso, and Wykowska 2019) to make it seem, to the human interactant, as if the robot has certain intentions behind its eye movement or actions. The study by Kellmeyer et al. (2018) focuses on robotic gestures that specifically are designed for the expression of specific intentions of the robot. Throughout this thesis, I argue for a more comprehensive approach to movement that relies on our perceptual tendency to make sense of robot movement as behavior: our tendency to attune to the bodies we engage with. In other words, movement is an important part of our attunement to the robotic others, and we can think about movement as an emergent factor of the body that enters our perception in a special way.

While this idea is further crystallized in the following chapters, for now, I suggest to look back to some of the vignettes provided by Yolgormez and Thibodeau (2022). While they also do not directly address the issue of movement, the case of Zoulandur and that of the *Ménagerian* without an eye reveals to us how we experience the movement of other – radically different, in this case – bodies. The latter vignette illustrated how the interlocutor and students in the room attributed meaning to the movement of the robot as an action or behavior. The

robot has zoomed around the space after it had its 'eye' removed, and to those who had witnessed the situation, the robot was seen to be in anguish, although this movement was entirely coincidental. In the case of Zoulandur, although it was the interlocutor who was mirroring the robot's movement, they reported that there were moments in which it felt to them as if the robot was following their movement rather than vice versa. In this case, too, the robot's movement was never supposed to *mean* anything: yet, we attribute meaning to these bodies when they move, and they make us feel. Thus, I suggest that movement is an important element thereto, and that we can think about movement differently than what is based on the interiority paradigm. It seems that we tend to perceive movements to be meaningful even when they are not meant to be. Furthermore, movement of a (more-than-human) body compels us to feel for them – be affected by them. It is, in that sense, an important part of our attunement to robots.

In short, I suggest that there is something special about movement that compels us to attune to the robot. Even when the movement or the robot itself does not demonstrate humanlikeness, we make sense of their movement. This is part of how we attune to the more-than-human, robotic bodies. While it goes beyond the scope of this chapter to address this issue in detail, this sets the ground for the following chapters – which, indeed, problematize how we experience movement and its relation to attunement – by positioning movement as a crucial part of how we attune to other bodies. For now, I invite the reader's attention back to the concept of attunement. In the following section, I investigate how Heideggerian philosophy can be a fruitful addition to this discussion. Examining how Heidegger has discussed the concepts of *Stimmung* and *Befindlichkeit* helps to further contextualize Yolgormez and Thibodeau's notion of attunement and to establish an understanding of the concept as an affective perceptual tendency that is essential to our being and how we relate to the world.

Stimmung and *Befindlichkeit* as a Framework for Theorizing Attunement

In *The Fundamental Concept of Metaphysics: World, Finitude, Solitude,* Heidegger (1995 [1983]) explains that *Stimmung*, or attunement,[9] is "not some being that appears in the soul as an experience, but the way of our being there with one another [*Miteinander-Daseins*]" (66). For him, the infectiousness of emotions is an example that reveals attunement as "a fundamental manner and fundamental way of being, indeed of being-there [Da-sein], and this always directly includes being with one another [*Mitanderseins*]" (67). Essentially, "attunements [*Stimmungen*] are feelings [*Gefühle*]" (65), as well as the way in which we perceptually experience the world. He further explains:

> attunements [*Stimmungen*] are the fundamental ways in which we *find* ourselves *disposed* [*befinden*] in such and such a way. […] And yet this 'one is in such and such a way' is not – is never – simply a consequence or side-effect of our thinking, doing, and acting. It is – to put it crudely – the presupposition for such things, 'the medium' within which they first happen (67-68).

[9] There is an ongoing debate around what the translated term 'attunement' refers to in Heidegger's philosophy. Some translate *Stimmung* as 'attunement' (e.g., Froman 2011; Mulhall 2011; Thonhauser 2020; Hadjioannou 2019). Others argue that the correct translation for this word is 'mood', and that it is *Befindlichkeit* for which the term 'attunement' is appropriate instead of other widely used terms such as 'state-of-mind', 'affectedness', or 'situatedness' (e.g., Ratcliffe 2002; Magrini 2012). This problem emerges partly from a common problem in translating one language to another, where the latter does not have an adequate word equivalent to that used in the original text. On the other hand, researchers generally agree that there are ambiguities in Heidegger's writing regarding the two terms. Contemporary scholars argue that Heidegger uses the terms '*Stimmung*' and '*Befindlichkeit*' somewhat interchangeably in *Being and Time*, while entirely dismissing the latter term in his later works (Kuperus 2007, 25; Hadjioannou 2019, 101; Vallega-Neu 2019, 205).
Thus, it is important to first clarify what one adopts as 'attunement' when discussing Heidegger's works on this issue. I employ Christos Hadjioannou (2019) and Gerhard Thonhauser's (2021a; 2021b) justifications of the translation of *Stimmung* as "attunement" and *Befindlichkeit* as "disposition". Thonhauser explains that 'attunement' delivers the meaning of *Stimmung* most adequately as the two words share connections to the word "tuning" which is an important notion in understanding the term (2021a). Further, he disputes the translation of the term to 'mood' as it "completely subverts that it was Heidegger's specific aim to oppose the psychological understanding of *Stimmung*" (2021b; 47). On *Befindlichkeit*, Hadjioannou writes to advocate for 'disposition' as the most accurate translation of the term, despite his acknowledgment of the risk of implying subjectivity as well as its conflict with another well-known philosophical term (100). Arguing that this translation "can account for the foundation of 'affective phenomena'" (101), he disputes other common translations of the term as 'state-of-mind' or 'affectedness'. He sees the former as entirely inadequate as the term literally does not refer to the mind (99), and argues that the latter reduces the term through a passive connotation which Heidegger himself rejected through the distinction of the terms *Befindlichkeit* and *Affekt* (100).
Further details of the discussion regarding the translations of *Stimmung* and *Befindlichkeit* go beyond the scope of this research. For more on this issue, see among others: Hadjioannou 2019; Cowles 2018; Thonhauser 2021a.

This means that attunement refers to a fundamental character of the human perception regarding how we position ourselves in the world and those who co-occupy it – namely, the way in which we 'tune in' to the world.

It is based on these attunements that parts of the world become salient or withdrawn to us in our perception. One of the examples Heidegger presents is that of boredom, which exposes and accentuates the banality of the world, and we feel as if this affect emerges from the world rather than occurring only within us physically or psychologically. For instance, when we say "I am bored", we acknowledge boredom as an affective inner state. Conversely, we also say "this is boring" as though the boredom comes not from ourselves but elsewhere in the world, as though it is something that we encounter that causes this affect in ourselves rather than emerging therefrom. Although some would claim this is an issue of mere semantics, for Heidegger, this duality reveals an important character of attunement: the internal 'moods' and outward 'tuning in' to the world are two cogs of the same machine (1995 [1983], 83). This feeling "comes neither from 'without' nor 'within', but rises from being-in-the-world itself as a mode of that being. […] *Stimmung* has always already disclosed being-in-the-world as a whole and first makes possible directing oneself toward something" (1996 [1927], 129). In simpler terms, attunement is a mode of being that is in tune with the world: the affective way in which we experience the world.

To better understand Heidegger's theory of *Stimmung*, the notion of *Befindlichkeit* (disposition) must be further acknowledged.[10] In *Being and Time* (1996 [1927]), Heidegger explains *Befindlichkeit* as an affective character of Dasein that manifests in attunements. He presents three "essential ontological characteristics" of the notion:

1. *Befindlichkeit* "discloses Da-sein in its thrownness, initially and for the most part in the mode of an evasive turning away" (128).

[10] As mentioned in the previous footnote, there are ambiguities between the terms *Stimmung* and *Befindlichkeit*. I do not intend to position myself within the debate of whether there is a difference between these two terms, but to provide a comprehensive understanding of how Heidegger explains the phenomenon of our "'tuning in' to the world" (1995 [1983], 83).

2. *Befindlichkeit* is a fundamental existential mode of being of the equiprimordial disclosedness of world, being-there-with [*Mitdasein*], and existence because this disclosure itself is essentially being-in-the-world [*In-der-Weltsein*]" (129).

3. In *Befindlichkeit* is "existentially a disclosive submission to world out of which things that matter to us can be encountered" (129-30).

Thus, disposition is the situatedness of *thrownness* which is the inherently affective way in which Dasein exists as being-in-the-world and being-with-others. This notion of thrownness means to *find* oneself in the world in its existence (312). "I find myself" as thrown, for example, in certain gender or race, as Dasein (Cowles 2018, 48). Heidegger refers to such a relationship to being as 'disclosure'. It means that we always already have some sense of our own existence – of the situatedness of our own being in relation to the world. He explains that disposition has a privileged relationship to disclosure as it is "grounded in thrownness" (Heidegger 1996 [1927], 312). Simplified, disposition describes Dasein's tendency to be affected by the world which is founded upon its situatedness in the world.

This being affected is not merely passive. Rather, it manifests through attunement [*Stimmung*].[11] Heidegger writes:

> What we indicate *ontologically* with the term *Befindlichkeit* is *ontically* what is most familiar and an everyday kind of thing: *Stimmungen*, being in a mood [*Gestimmtsein*]… [W]e must see this phenomenon as a fundamental existential and outline its structure (1996 [1927], 126).

In other words, disposition [*Befindlichkeit*] manifests in attunement [*Stimmung*] which encompasses a wide range of affective states we are always already in some form thereof (126). This implies that we are always already 'affected', in both meanings of the word, by others and the world that surround us. It is our tendency to affect and be affected by the world around us

[11] According to Jeff Malpas (2011), the noun 'Stimmung' in plain German:

> can mean 'mood', 'temper', or 'disposition', as well as 'tuning' or 'tonality', and comes from the verb stimmen (meaning 'to tune' – as in the tuning of an instrument – and to vote), as well as to the noun Stimme (meaning 'voice' and 'vote' – the latter in the sense of that which one gives to a candidate). It is also related to bestimmen, which means 'to will', 'to determine' or 'to decide' (93).

Stimmung as a plain German noun refers to a sense of attention and intention, as well as emotion and affect. The same word in Heidegger's philosophy is drawn from this literal definition but is given a unique meaning that constructs and reflects his philosophy.

that is fundamental in the sense that it shapes us into how we experience the world – as well as ourselves.

To summarize, Heidegger explains the way in which we affect and are affected by our encounters. This phenomenon refers not to mere passive occurrences but guides the way in which we tune in to the world. In this attunement manifests our situatedness in the world that influences our affectedness. We 'attune' to the world and others within it, and the way in which we attune to them is guided by our internal states (perhaps it is because the reader is already bored that they find this thesis boring), but also affects them in turn (this thesis is the cause of the reader's boredom). Thus, attunement is an affective way in which we experience the world. Our affective states guide our perception of the world, but are also constantly affected by it. It is through this mechanism we become attuned to and make sense of the world. Manifesting in this attunement is disposition which is based on how we situate ourselves in the world.

Heidegger's concepts of *Stimmung* and *Befindlichkeit* provide an understanding of how we exist in the world, and how we affect and are affected by the encounters with others we experience therein. In his perspective, attunements are foundational to how we make sense of the world and our relation to others. The two concepts together – which I will refer to as this theory of attunement for the sake of convenience – provide a foundation upon which we can establish a comprehensive understanding of attunement as a concept. I suggest this can be helpful for theorizing how we become affected in our interaction with robots, and how this being affected affects the interaction in turn.

Toward a Rethinking of Attunement and Movement

Previously in this chapter, I have suggested that the way Yolgormez and Thibodeau (2022) adopt the notion of attunement in their studies can help rethink how we attune to robots in our interaction with them. Instead of thinking about how robots can be changed and developed to afford attunement to emerge, they offer the possibility of leaning into our perceptual tendency to attune to others to effectively and affectively engage with these more-than-human bodies. The authors, through their *Machine Ménagerie* project, demonstrate that this paradigm of how we experience the world and others can be fruitful for understanding

how meaningful interactions emerge between humans and robots that look radically different from beings we are already familiar with. Attunement as a concept theorizes how we make sense of robots and feel for them by opening up oneself and being attentive, even to radically different robots. To the authors, this is an important finding that demonstrates how the rhetoric of control and hierarchy in HRI can be subverted through our tendency to attune to others in the world. When we learn to attune to robots, human-robot interaction can result in a relation of care. If we can interact with radically different robots and be affected by them, we can imagine forms of HRI that do not rely on robots that look and behave like us in order to attune to *our* needs in *our* ways.

Examining Heidegger's philosophy – which Yolgormez and Thibodeau draw upon – regarding the concepts of *Stimmung* and *Befindlichkeit* further helps us understand attunement as our perceptual tendency and fundamental to being-in-the-world. His theory describes our attunement toward others, and being affected by them in turn, as an emergent phenomenon of the situatedness of being-in-the-world that guides our perception of the world and relationship to others. Attunement, understood comprehensively with disposition, denotes a complex paradigm of perception that encompasses active tuning into others, making sense of our surroundings, and being affected by the encounters with others. This can be useful for reestablishing the concept of attunement as both an active and affective tuning-in and a passive being-affected that is influenced by the situatedness of our being-in-the-world.

To sum, Yolgormez and Thibodeau illustrate how attunement as a concept can be deployed in HRI to rethink how we form meaningful and affective interactions with robots, examining ways it manifests in these interactions. Heidegger, on the other hand, provides a way of understanding attunement as a mode of being-in-the world, denoting a complex paradigm of perception that encompasses active tuning into others, making sense of our surroundings, and being affected by encounters with others. Together, it becomes possible to comprehensively theorize attunement as a perceptual tendency that guides and is affected by our encounters with more-than-human others. It is what helps us make sense of others, and feel for them, even when they do not resemble beings that are familiar to us. This points to the possibility of relating and adjusting to radically different bodies.

In addition to theorizing attunement and examining how it can be a fruitful concept for human-robot interaction, I have hinted that movement is an important part of how we attune to robots. While it was important to acknowledge this in my review of studies on attunement in social robotics, addressing how movement becomes a significant player in this phenomenon requires further research and explanation. Now that this chapter has established an understanding of the concept of attunement as an affective perceptual tendency, the following chapters take on the challenge of examining how movement impacts our attunement to robots. Using my personal experience of working with a KUKA robot arm, which I have introduced in the Introduction of this thesis, I examine how attunement manifests through our perception of other moving bodies, as moving bodies ourselves.

Chapter 2

Attunement: Making Sense of Robot Movement

This chapter examines how we understand robot movement by means of attunement and aims to conceptualize the notion as a perceptual tendency to experience and make sense of more-than-human bodies based on our own embodied, affective, and somatic situatedness in the world. The aim of this chapter is to understand how we sense and make sense of a robot like Spencer which has a non-organic, non-feeling body that is unfamiliar to us in shape and movement. I argue that, based on our own embodied experience of the world and our tendency to gather a situated understanding of the contexts from which our encounters with others emerge, we are able to attune to more-than-human bodies and attribute meaning to their movement and, in turn, be affected by them.

Based on Lucy Suchman's (2007) theory of mutual intelligibility and the example of how Spencer's movement was understood by the audience differently, based on the context in which her performance took place, I suggest that we make sense of the movement of more-than-human bodies as meaningful actions based on our situated understanding of the context from which the encounter emerges. Moreover, Petra Gemeinboeck and Rob Saunders' (2017) notion of kinesthetic empathy further helps conceptualize how this encounter can affect us in our embodiment. We tune in to the other's body based on our own lived experience, and because of this embodiedness we are able to open up our senses to more-than-human bodies and feel with them.

The previous chapter summarized Ceyda Yolgormez and Joseph Thibodeau's (2022) research project on socially useless machines, *Machine Ménagerie*, and examined three characteristics of attunement that become salient to different extents depending on the situatedness of the human-robot interaction. The first aspect took the form of 'making sense' of robot movements as behaviors. The mechanism through which robots tend to 'compel' the human interactants to make sense of the movements as meaningful actions (Yolgormez and Thibodeau 2022, 572) was largely dependent on our perceptual tendency to affect and be affected by our encounters in the world and understand them therethrough (Heidegger 1995 [1983]; 1996 [1927]). Next, Yolgormez and Thibodeau emphasized that attunement in human-

robot interaction can emerge from prolonged interaction which affords the human interactant to familiarize themselves with the robot. We can learn to attune to the robots by getting to know their material embodiment and tendencies. Attunement may not always come naturally or immediately, but can be an emergent property of the relationality of human-robot interaction. Third, attunement can also take the form of an affective "tuning into the other". Emerging from "opening oneself to the senses of the other" and being mindful of the robot's material capabilities, attunement conveys a sense of connectedness in our interaction with the robot (576). Thus, the authors offer an understanding of attunement as a concept that articulates the affective connectedness, manifested through attentive respect and care, that emerges in interaction.

Based on this insight, the current chapter further highlights our own situated embodiment in the world as the foundation of attunement as our perceptual tendency. Attunement both makes salient how we position ourselves in the world and the way in which we affect and are affected by others. Discussions here suggest that movement takes a special position in conceptualizing attunement as it evokes kinesthetic empathy, compelling us to feel for another body in our attunement thereto. An examination of Suchman's theory of mutual intelligibility and Gemeinboeck and Saunders' notion of kinesthetic empathy helps us better understand attunement as our perceptual tendency that is affective and situated, and as the guiding force of how we relate ourselves in our embodiedness to moving bodies that are radically different from others. Focusing on how we experience the movement of more-than-human bodies, this chapter serves as the foundation for the following chapter which conceptualizes how attunement as our perceptual tendency can be fruitfully utilized for thinking about designing robot movement.

A Situated Understanding of Robot Movement

In *Human-Machine Reconfigurations: Plans and Situated Actions*, Lucy Suchman (2007) raises the question of "mutual intelligibility". Problematizing how we understand the actions of others, she introduces this concept to examine how we create a shared understanding of a situation. She explains that, whereas the question of mutual intelligibility has long been an

issue in sociology that has aimed to account for "the significance of human actions" or understand it as "practical accomplishment of members of the society" (29), there is now a new manifestation of this question in the context of human-machine interaction (30). She argues that we attribute meaning to an agent's actions based on our understanding of a given situation in which the action takes place, contesting the idea that certain actions carry inherent intentions or meaning within them. Based on such understanding of how actions come to mean something in interaction, she calls for a situated approach to designing actions of and our interaction with computational agents.

To further explain this concept, Suchman draws on an experiment and analysis by ethnomethodologist Harold Garfinkel. In his experiment, Garfinkel had aimed to test in the context of counseling the "documentary method of interpretation", a term he quotes from Karl Mannheim and observes the tendency of people to "take appearances as evidence for, or the document of, an ascribed underlying reality, while taking the reality so ascribed as a resource for the interpretation of the appearance" (48). In simpler terms, it means that people make assumptions based on what they are faced with in an interaction and these assumptions are projected onto what they see, confirming their beliefs.

The design of the experiment consisted of students who were informed that they could ask yes/no questions regarding their personal problem to a student counselor who was seated in another space. Although the yes/no answers were in fact selected randomly, for the students, the answers had seemed to be motivated by their questions. He found that students assigned meaning to the yes/no utterances as being the advice from the counselor behind the curtains. Garfinkel (1967) writes:

> Answers were assigned a scenic source:
>
> 1. Subjects assigned to the adviser as his advice the thought formulated in the subject's questions. For example, when a subject asked, "Should I come to school every night after supper to do my studying?" and the experimenter said, "My answer is no," the subject in his comments said, "He said I shouldn't come to school and study." This was very common (92).

He further writes that when they were given directly contradicting answers,

> subjects were able to continue by finding that the "adviser" had learned more in the meantime, or that he had decided to change his mind, or that perhaps he was not sufficiently acquainted with the intricacies of the problem, or the fault was in the question so that another phrasing was required (91).

In other words, students assign meaning (the advice) to what they encounter (yes/no utterances) based on their assumptions (that there is a counselor sitting in another room listening and responding to their prompts). In turn, this assigned meaning confirmed their assumption of the existence of the counselor who is gathering information based on and responding to their questions.

Suchman relates Garfinkel's analysis on the documentary method of interaction to the ELIZA program developed by Joseph Weizenbaum in the mid-1960s. Developed to explore human-machine communication based on handcrafted scripts and detection of keywords, the program was an early version of what we nowadays call a 'chatbot'. Weizenbaum was himself aware of the lack of 'intelligence' – at least in the human sense – in this program. One of the more famous scripts that ran on Eliza was called DOCTOR. This script, which in today's terms can be understood as a specific mode of chat within a chatbot, was scripted to respond to the human user in the way a therapist would to their patient. In other words, it operated on a mechanism of keyword detection and reaction like many of today's chatbots, meaning that the software would detect certain words typed in by a human interactant and respond with a pre-written script corresponding to these specific words. Despite the system's lack of ability to really understand the content of the interaction and know the meaning of the words it writes back to its interaction partner, people were able to make sense of this interaction and make it meaningful to themselves. Thus, based on ELIZA and Garfinkel's experiment and analysis, Suchman concludes that whether one interacts with a chatbot or human, 'mutual intelligibility' is not based on actual shared understandings but the projection of one's assumptions and own intelligence onto their interaction partner.

Although Suchman makes this observation in the context of human-computer interaction that takes language and dialogue as a medium of communication, her understanding of mutual intelligence provides a tool to think about how we make sense of actions of more-than-human agents that are, in fact, incapable of guiding their own actions.

We make sense of others' actions based on the context from which a given interaction emerges. In other words, shared meaning is not created upon an understanding or experience of others' internal states, but through our ability to assume meaning based on how we perceive a certain situation and by projecting that upon the other's actions. A similar principle applies to how we perceive movements of more-than-human others as actions.

Figure 6. "Mother and Child" by Bram Ellens. Part of the exhibition Imagine Intuition, at Musuem De Lakenhal, Leiden, Netherladnds. 14 October 2023 – 15 January 2024. Image owned by Bram Ellens.

To give an example of this, we can compare two different social contexts in which Spencer was placed and how her movement – which was in large part the same – invited the audience to make sense of her differently. From October 2022 to January 2023, Spencer was co-star of the installation "Mother and Child" by Bram Ellens which was presented at Museum De Lakenhal (Leiden, Netherlands) as part of the exhibition *Imagine Intuition*. Together with another larger KUKA robot arm, Spencer was installed on a rock-shaped platform. They performed a sequence of movements that seemed as if they were interacting with one another, although the two robots are incapable of doing so. Spencer was relatively small, her movements light and fast, which caused higher-pitched whirring noise – compared to the

deeper sound of the larger robot's motors – that compelled the audience to intuitively recognize this robot as the 'child'. Following the exhibition, in April 2023, this robot was invited to be part of a dance workshop at Masterclass Festival Amsterdam. Taking place at Tolhuistuin (Amsterdam, Netherlands), the concept of this festival was that established artists of various disciplines would present to the audience how they transfer their embodied knowledge and skills to young, emerging artist in the format of an open masterclass. On the day of the workshop, Spencer was placed at the center of a dance studio. Instructed by Henry O'Tawiah, his urban dance students were invited to adjust the choreography they had learned in class to create a harmonious dance performance with Spencer as well as improvise with her.

Figure 7. Spencer in a dance studio, performing at Masterclass Festival Amsterdam, April 2023. Tolhuistuin, Amsterdam, Netherlands. Image owned by Soyun Jang.

Between these two events, I took the role of tweaking Spencer's choreography. This meant that parts of Spencer's movements that are potentially dangerous for a setting where young dancers are surrounding the robot in a dance studio – i.e., overly sudden or fast movements – were edited. As Spencer's performance was to be accompanied by music, I had removed some segments to shorten the length of her programmed sequence to fit the music. In short, some changes were made to the robot's choreography but much of it stayed the same.

The most significant change was the context in which Spencer was placed, and this had, in fact, demonstrated meaningful impact on the way the audience perceives the robot. At the exhibition at Museum De Lakenhal, the robot was perceived in relation to the larger robot. The audience would make sense of the robot's movement as expressing childlike characteristics. For example, there is a segment where Spencer stretches her body to where the larger 'mother' robot is placed, coiled up as if she is sleeping. The smaller robot then rapidly and repeatedly twists its 4th axis from one side to the other, creating a squeaky whirring noise. In the context of the installation, the audience intuitively makes sense of this movement as a child's effort to wake up its mother. When this movement is performed at a dance studio at Tolhuistuin, without a larger robot by its side, the context that allows the audience to associate this movement with childlike movement disappears. Instead, as students are invited to dance and perform with the robot, this movement invites a new interpretation as a dance move that its human dance partners can react to.

This observation also corresponds to the aspect of attunement that Yolgormez and Thibodeau (2022) explain as the grounds for 'making sense' of robot movement as behaviors. Whereas Suchman's theory of mutual intelligibility elucidates our perceptual tendency to delegate meaning to actions of others based on our understanding of the context in which the interaction takes place, Yolgormez and Thibodeau see attunement as what creates a "sense of orientation" from which our cognitive and perceptual tendency to make sense of our surroundings emerge (576). While this latter argument resonates with Suchman's mutual intelligibility in that it is from our own situatedness in the world that we make sense of others' actions rather than arguing for the existence of inherent or fundamental meaning in one's actions, it is comparable in the sense that they emphasize attunement as the source of how we navigate this situatedness of action and interaction. Considering that attunement can be characterized by our affective internal states and our embodied situatedness that guide our perception of the world, it gives the phrase 'making sense of the other's action' a literal connotation. Examining the comparison of Spencer's movements in two different contexts from this perspective, it is not that we make cognitive and logical calculations or guesses of what specific movement segments means or is aiming to express. Instead, our affective internal states guide our somatic experience of our surroundings differently based on our

situatedness within it, and it is from this perceptual mechanism that we 'sense' meaning differently from the same movement.

In other words, both Suchman and Yolgormez and Thibodeau take a situated approach to how we understand actions of others. We draw meaning therefrom not because actions carry inherent meaning within them or because we are capable of understanding the exact intentions and internal states of others, but because we project meaning onto these actions based on our understanding and situatedness – which we draw from our somatic experience of the world – of the context from which the interaction emerges. The concept of attunement adds to Suchman's understanding of mutual intelligibility an explanation of the perceptual mechanism that takes affective internal states as the foundation of sense-making and through which we affectively experience actions of others as behaviors. To sum, the example of Spencer performing her movement sequence in different contexts can help further Suchman's argument on how we make sense of the actions of the more-than-human other as behavior. To that, the case of Spencer positions movement as part of the action that warrants situated understanding from the side of the perceiver. Like yes/no answers in Garfinkel's experiment and the case of ELIZA, we attribute meaning to movement by projecting our own understanding and intelligence meaning to it.

Next, I aim to further this understanding of embodied situatedness as a foundation from which we attune to more-than-human bodies that we share the world with. As the framework for this examination, I draw on Petra Gemeinboeck and Rob Saunders' (2017) experiment on "performative body mapping (PBM)" and their understanding of "kinesthetic empathy". In the following section, I suggest that the authors help think about attunement as an embodied perceptual tendency that guides our affective experience of moving bodies. We can intuitively attune to the other's moving body and make sense of it based on our own disposition as moving bodies, and this corporeal and somatic experience guides how we make sense of others. Then, in the final section, I examine how PBM as a design method that can help 'find' movement that triggers this intuitive perceptual tendency of ours opens up the discussion on the *matter* of attunement which is theorized further in the next chapter.

Intuitive and Affective Perception of More-than-Human Bodies

Figure 8. Spencer, 'sleeping'. "Mother and Child" by Bram Ellens (2022). Image owned by Bram Ellens.

In "Mother and Child" there was a sequence of movements that Bram Ellens often refers to as 'sleeping'. This movement consists of the robot folding its body, collapsed low, perhaps best described as a cat or a snake that coils up its body to keep itself warm – but somehow different. The robot's body gently and slowly moves up and down, emitting a quiet hum of machinery. Although the possibility of this movement being taken for something other than an expression of sleep persists, there is regardless something compelling about this motion that intuitively makes sense to the human perception as such. Of course, we perceive and make sense of this movement based on a larger system of meaning (Alcubilla Troughton 2022). Elements such as the sound Spencer makes, our knowledge of animals that sleep in a similar position, the quiet surroundings, and our ability to think about what the designer of this robot movement would have intended this movement to mean – and many more – are all contributing factors to how we make sense of this robotic motion as 'sleep'. Yet, when we encounter this moving body, we become affected by it beyond the point of cognitive and logical knowing. It is not that we draw a logical conclusion that this robot expresses sleep, but we intuitively recognize it as such. And it makes us feel for this more-than-human body. Sometimes, sleeping Spencer makes us fall quiet around it. The question I am asking is not whether certain movements evoke specific feelings or emotions – I have, in fact, argued against this statement. Rather, what I mean to ask is how a body so different from us and incapable of feeling makes us feel. In the previous section, I have argued that we understand actions or movements of others based on the context in which they emerge. But how do we really *'feel'* for a more-than-human body that is different from ours?

In this section, I conceptualize this phenomenon via a reading of Gemeinboeck and Saunders' (2017) experiment on developing movement for robots with radically different embodiments and the discussion on attunement I have made thus far. In "Movement Matters: How a Robot Becomes Body", the authors challenge anthropomorphic and zoomorphic designs in social robotics and the assumptions that lie thereunder: that robotic appearances that resemble humans or pets will be beneficial for users to form meaningful connections with them (Bremmer et al. 2009; Salem et al. 2013; de Wit et al. 2018). Rather than focusing on the appearances of robots, they suggest that "it is movement from which the robot's body, with all its affective, intelligible qualities, emerges". Through a methodology they call Performative Body Mapping (PBM), they explore "forms of embodiment that don't rely on mimicking familiar bodies" (1). Embracing dancers' movement expertise, they explore how robots of various forms could learn to explore and interact with their environment and others in their unique physical forms. With the aim "to 'find' a robot's movement", PBM involved a process in which a dancer would inhabit and activate a machine costume or prosthesis. The wearable object is a temporary replacement of a machine body that, though being an extension of the dancer's body, could be "bodied". The idea was that dancers would "'feel into' the machine's form" and learn to embody the physique and move with it, which would later assist the robot in learning from recorded movements of the dancer (2).

Figure 9. Costume inhabited by Tess De Quincy (Gemeinboeck and Saunders 2017). Image owned by Petra Gemeinboeck.

Figure 10. Costume inhabitied by Kirsten Packham (Gemeinboeck and Saunders 2017). Image owned by Petra Gemeinboeck.

The authors found that PBM as a design method can help enable "kinesthetic empathy", a concept they use to explain "the body's sensitivity to and connectedness with other bodies (incl. non-organic) and its environment". Centering embodiment and materiality in movement development of robots with radically different bodies, they could design movements that triggered "our inherent kinesthetic abilities to form connections with other bodies, human and nonhuman" (6). This suggests that we experience qualities of more-than-human beings through their movement. Even when these perceived bodies have radically different forms, if their movements are 'found' through a profound and embodied engagement and with respect toward its materiality, it is possible for us to make sense of their movements in an empathetic way. In other words, we could say that the dancers were 'attuning' to the different bodies of robots in their search for organic movements. In turn, movements 'found' as such enable kinesthetic empathy and allow us to feel with the radically different bodies.

Kinesthetic empathy is a concept that has attracted much interdisciplinary interest from scholars in dance and performance studies, psychology, and neuroscience, among others. Dee Reynolds and Matthew Reason (2012), in their edited volume *Kinesthetic Empathy in Creative and Cultural Practices*, explain that kinesthetic empathy has been examined in diverse contexts including dance, theater, music, sport, therapy, and participatory performance, among others. Acknowledging the wide and varied interests around this concept, they suggest that kinesthetic empathy is "both produced by and representative of a particular cultural and scientific moment". They locate the cultural moment as the "corporeal turn" which indicates an increasing interest in embodied knowledge in the arts, humanities and sciences, while suggesting that the scientific moment is marked by the discovery of mirror neurons in the 1990s (17). In this regard, they state that current research on kinesthetic empathy can be positioned within the larger context of a "paradigmatic shift towards embodied cognition" which results from the moment in which interdisciplinary research between arts, humanities and sciences started gaining significance (20).

Explaining that the concept has generally been discussed in regard to aesthetic experience, they summarize the works of John Martin who, in the 1930s, used terms 'inner mimicry' and 'kinesthetic sympathy' to examine the muscular and emotional experience of the

spectator who watches dancers' performance. While Martin emphasized that inner mimicry of dance movement has a psychological dimension that involves changes in psycological states associated with the experience, movement memory, etc., he also proposed, controversially, that inner mimicry allows spectators to access dancers' feelings directly. Reynolds and Reason argue that this resonates with mirror neurons and the idea that their activity "enables us to experience others' thoughts and feelings through simulation" (19). Building upon this context, the authors theorize through the concept of kinesthetic empathy how we experience the body and movement of others through our own embodied perception.

While they are cautious of universalizing the kinesthetic and empathic experiences of individuals, as further examined in Reynolds and Reason (2010), this shows that their idea of kinesthetic empathy remains between same bodies. This is especially visible in their acceptance of mirror neurons and the notion of simulation. While mirror neurons are undoubtedly an important discovery regarding how we empathically understand others, and simulation is a mechanism thereof, this approach can be seen to limit how we affectively, and with our bodies, experience more-than-human others that have different embodiments.

To this challenge, Gemeinboeck and Saunders (2017) pose a different perspective by examining how kinesthetic empathy can emerge in our perceptual experience of radically different bodies. Although the authors do not directly address this issue, they break the idea of kinesthetic empathy as based on a simulation of other bodies based on one's own – a paradigm made possible only when the spectator and the other share the same form of body. This discrepancy creates space for us to think about how we make sense of movements that emerge from bodies that are different; how we can feel for – and perhaps, with – more-than-human others.

The previous section had discussed how we have a tendency to attribute meaning to the other's actions and movement based on our perceptual understanding of the situatedness of the interaction. Gemeinboeck and Saunders, on the other hand, help us understand how movement emerges from an embodied sensing of the world, and how our perceptual experience as moving, sensing, embodied beings enables us to tune in to the more-than-human bodies of radically different forms. I have explained in the previous chapter that attunement affords both outward 'tuning in' to the world and inward 'making sense' of it.

Discussions made thus far in this chapter can help us understand this dual affordance of attunement not as two separate ways of experiencing the world but as manifestations of our embodied perceptual tendency. Drawing on Suchman (2007), I suggest that we make sense of the other's movements as actions based on our understanding of the context from which the interaction emerges. This understanding is guided by our embodied, somatic, and affective experience of the world. Making 'sense' thus can be seen as carrying a literal connotation as it is from our embodiment that we come to attribute meaning to the other's movement as actions and be affected by them – or to put it differently, be 'touched' by this encounter. Whereas the 'making sense' aspect of attunement emphasizes how we attribute meaning to the other's actions and movement intuitively and affectively based on the encounter's situatedness, 'tuning in' highlights an affective positioning toward others that opens up our senses to that of the other.

To sum, Gemeinboeck and Saunders' (2017) notion of kinesthetic empathy helps theorize how we experience the movement of others. Positioning this concept among the discussion of how we make sense of the more-than-human other's movement helps us understand this experience as one that is embodied and affective. They demonstrate that even if the other has a body that is radically different from ours, we can be affected by them through our perceptual tendency and ability to connect to the world and others. In other words, their work can emphasize embodiment as helping to enable our attunement to more-than-human bodies. In addition to providing meaningful insight on how we relate to radically different bodies, their discussion on kinesthetic empathy positions attunement as a guiding force of our situated understanding that is founded upon profound embodiment. While acknowledging that we make sense of the other's movement as actions based on the context from which they emerge, I suggest that our understanding of context and more-than-human bodies also deeply rely upon our own affective and embodied experience of the world.

Toward a Theorization of Attunement for Movement Design

Attunement is a concept that helps us understand how we perceive others. Attunement guides our experience of the world and encounters therein. In the previous chapter, I had examined

Heidegger's (1996 [1927]) explanation of how one's disposition [*Befindlichkeit*] manifests in attunement [*Stimmung*]. This provided a way of understanding how the way in which we attune ourselves to the world is affected by our own situatedness. The observations made in the current chapter have articulated this theory, through works of Suchman (2007) and Gemeinboeck and Saunders (2017) in the context of how we perceive a moving body that is radically different from that of ours.

Suchman's theory of mutual intelligibility provides a way of thinking about how we make sense of the other's actions as meaningful behaviors. We cannot truly know what drives the actions of the other, but we attribute meaning to them based on our situated understanding of the interaction. A similar phenomenon emerges when we observe through this theory how we make sense of Spencer's movement in different contexts. It is not that a certain movement sequence the robot performs conveys certain meaning; instead, we make sense of it based on the context from which we encounter the robot. And in this process, the robot's movement makes us feel. Gemeinboeck and Saunders' (2017) notion of kinesthetic empathy has helped further conceptualize this understanding of embodied experience as the foundation of how we attune to more-than-human bodies. Whereas the previous section had focused on the context itself upon which we make sense of the other's body, Gemeinboeck and Saunders highlight the mechanism through which we open up our senses to other bodies based on our own embodiment and attune to them, and become affected by them in return. I have suggested that the concept of attunement helps us understand this making 'sense' of movement as taking on a literal connotation in this regard because our own situatedness in the world is fundamentally an embodied, and affective. In other words, attunement refers to the perceptual tendency regarding how we come to understand others that is guided by our situated experience of the world as beings that are bodied and feel.

Discussions thus far also raise the question of embodied materiality as the source of movement. Gemeinboeck and Saunders propose performative body mapping (PBM) as a design method that can help develop movement for non-anthropomorphic, non-zoomorphic robot bodies in a way that evokes kinesthetic empathy to the human perceiver. Whereas the notion of kinesthetic empathy highlights attunement as a guiding force of our situated understanding that is founded upon profound embodiment, the authors' development of PBM method affords the possibility to methodize this perceptual tendency to design affective

movement in more-than-human bodies. In other words, PBM is a method through which we can, with our human bodies, 'find' movement for radically different ones. From a design perspective, this suggests that movement must primarily make sense for the specific material qualities of the more-than-human body in order to enable kinesthetic empathy to its audience. There needs to be an intricate awareness of how this specific body would sense and experience the world and navigate itself through it.

I suggest that when we think through the concept of attunement in HRI alongside Gemeinboeck and Saunders' PBM as a method of movement design for robots sheds light on the *matter* of attunement and how that is an important factor to consider in movement for radically different more-than-human bodies. The authors argue that "the experience of embodiment and materiality is essential to produce kinesthetic empathy" (6). They explain that unlike software-based animations, robots "perceive, interact with, and reconfigure the world" with their physically manifested more-than-human bodies and enter our world in embodied ways (7). This means that embodiment is an impactful factor on both the manifestation of movement from a body and how we make sense of this in others, and that materiality is an essential part of embodiment and how we experience it. The following chapter examines how attunement reveals the significance of materiality in finding the movement of a radically different robot. By drawing on new materialist thinking – i.e., Jane Bennett's (2010) concept of "thing-power" and Suchman's theory on machine agency – and my own experience of developing and programming movement sequences for Spencer, I argue that attunement can help theorize the respect and care for the materiality of the robot that is required in designing its movement.

Chapter 3

The Matter of Attuning to a Robot Arm

In the previous chapter, I have discussed Performative Body Mapping (PBM), developed by Petra Gemeinboeck and Rob Saunders (2017), as a design method for robots with non-anthropomorphic, non-zoomorphic bodies. Taking an embodied approach to movement design, I have suggested that this method provides a way of thinking about how attuning to the materiality of a radically different robot can help to "find" movement in radically different bodies.

Building upon this discussion, I reflect in this chapter on how designing and programming the movement of Spencer required thinking from the capabilities and materiality of the robot. This account helps to think through the *matter* of human-robot interaction and the significance of matter in our attunement to more-than-human bodies. Finding movement that takes Spencer's material embodiment into account was a constant process of meticulous adjustments. When thinking about questions such as 'how would Spencer sleep?' or 'what would playful behavior look like for Spencer?', trying to mimic human behavior was impractical. Not only were human movements not easily applicable to a robot arm, but without consideration for the robot's own embodiment, the robot's movement would seem clunky and forced. This means that being mindful of the body of the robot was an important part of Spencer's movement design. What is its movement range? How does the sound it makes change in different movement speeds? In which movements or positions does the robot look 'comfortable'? Respecting Spencer as a material assemblage and being attentive to her specific embodiment were essential to 'finding' her movement. This sense of respect and care for Spencer that I have developed over time can be characterized by the "learning to attune" aspect of attunement (Yolgormez and Thibodeau 2022) that was explained in the first chapter.

In this chapter, I further examine this phenomenon in which Spencer speaks back through her materiality in the process of movement design. By adopting Jane Bennett's (2010) theory of "thing-power", I conceptualize Spencer as a material assemblage that emerges from the entangled world. I examine the agency of vibrant materials in Spencer that compel me, as one who designs and programs movement sequences into the robot, to constantly explore and

negotiate with her physical possibilities and limitations enabled by her materiality. The concept of attunement helps theorize the possibility of thinking with and through the embodiment of a more-than-human being. In turn, this helps find the movement of that other body which, with a situated understanding of it, we are able to "make 'sense'" of (Yolgormez and Thibodeau 2022). Then, I contextualize these findings in the scope of Lucy Suchman's (2007) theory of machine agency as an emergent factor of constantly unfolding sociomaterial configurations. This is a lens through which we can observe how more-than-human bodies achieve effects in the world and how we affectively make sense of this phenomenon through our perceptual tendency to attune to those we share the world with. Attuning to the body of a more-than-human other means to become sensitive to the sociomaterial configuration from which their agency emerges and that it is a perceptual mechanism that enables us to relate to a radically different body and is thus useful in designing – or rather, "finding" (Gemeinboeck and Saunders 2017) – movement therefor.

The Vibrant Materiality of Spencer

In her book, *Vibrant Matter* (2010), Jane Bennett coins the term "thing-power" to describe the material vitality of more-than-human bodies. Drawing on Baruch Spinoza's theory of "conatus", which refers to "a power present in *every* body" (2), she describes thing-power as "the moment of independence possessed by *things*" (3; emphasis added), a word that separates more-than-human bodies from 'objects' in the sense that they are "vivid entities not entirely reducible to the contexts in which (human) subjects set them" (5). In simpler terms, thing-power refers to the ability of more-than-human bodies to achieve effects in the world in their intra-action with others.

According to Bennett, things achieve these effects in the world through "assemblages", a term she derives from Spinoza and develops through Gilles Deleuze and Felix Guattari's interpretation of the same concept. She explains that materiality is an important force of how more-than-human-bodies constantly unfold in the world. This means that agencies of 'things' that configure the world become affective through units of "assemblages" which are material configurations of interconnected more-than-human bodies that consist of yet smaller bodies and assemblages. For Bennett, assemblages are "living, throbbing confederations that are able

to function despite the persistent presence of energies that confound them from within" (23-24). In Bennett's theory, assemblages are "not governed by any central head" and are rather "emergent properties" where the vitality of each body and the matters they consist of come together to create a synergy that makes them more than just a sum of the bodies the assemblage consists of (24). In other words, each body has its own vitality and role in an assemblage that affects the latter as a whole. To summarize, thing-power conceptualizes how more-than-human bodies – bodies that are modes composed of simpler bodies – affect other bodies through the vibrancy inherent to their very materiality. From this perspective, assemblages are affective because they are emergent factors that exist in a relational web of other assemblages.

We can look at Spencer, a robot that is made of different parts, as an example of an assemblage. Each of her axes is a separate part which have been put together with other parts. Then there are cables that connect her to power outlets, as well as mechanical parts such as cogs, pipes, and motors inside her that allow her to move – and much more. Further, each of these parts consists of other smaller bodies. For example, the cable that connects her to a computer is made of smaller cables that have been wrapped together. Each of these cables is made of several copper wires that effectively conduct electricity. All of these materials and bodies work together to create Spencer, a functioning robot arm. As an assemblage, they become much more than if these bodies simply existed next to one another. It is in each smaller assemblage doing its own part in the larger assemblage that they create a robot arm. Without this cooperation of more-than-human bodies (e.g., a few broken copper wires in a power cable could cause Spencer to shut down), Spencer would at best be an impressive-looking chunk of metal, but no longer a robot.

On days when Spencer was performing for an audience, I noticed that my programming teacher and robot operator, Rick van Dugteren, would be prepared for every possible scenario that could disrupt Spencer's performance. With his many years of working with robot arms in the context of entertainment and industrial events, he explained that most of the time it is the small things that cause large problems. The power strip had to be taped to the table to prevent it from falling off and disconnecting from the laptop, and masking tapes were placed near the cables attached to the robot so that performers and staff members could be mindful of their location and could avoid accidentally stepping on them. We could not use wireless mice for

our laptops in case the battery would run out, which could potentially disrupt our control over the robot that we do via the laptop. Because every material element is an 'affective body', one cable, one socket, or even a small battery in a mouse could cause unexpected or unwanted events that disrupt the performance of Spencer. In this regard, all of these bodies are "affective bodies" that are "associative" or "social". This means that "each is, by its very nature as a body, continuously affecting and being affected by other bodies" (Bennett 2010, 21). Every material element could affect Spencer's performance and thus be respected as part of the assemblage in order to ensure the robot performs.

Another example in which the prominence of Spencer as a material assemblage was revealed was the difference between seeing the robot on the user interface of the software, RoboDK, used for programming the robot, and seeing it perform what is programmed on the software with its more-than-human body. The software provides a user interface in which the user can choose a specific robot and simulate its movements. From a library of several hundred robot arms, the user can choose the specific model they are working with. Then, the robot can be programmed on a laptop or computer without needing to connect to the robot itself (RoboDK n.d.). Simply explained, the robot can be programmed to move from one position to another on a simulation environment through which the user can see three-dimensional animation of the robot and later be implemented on the robot once the programming is more or less finished. What I have noticed – and Rick has dealt with throughout his career – is that even though the robot's movement would seem flawlessly smooth on the simulation, there would always be something that does not 'work' when you plug in the program to the actual robot. For example, the speed of certain movement segments would be completely off, or some positions and movements would simply look or feel different than what had been visualized on the software. Even though the robot would seem to be performing seamlessly in the simulation environment, there were always adjustments that would have to be made when transitioning from the software to the real, physical manifestation of the robot.

When examined through Bennett's theory of thing-power, this phenomenon highlights the importance of materiality in movement. When I had programmed the robot on my computer, I had made an estimate of Spencer's movement based on the 3D graphics shown on my screen. Although this estimate is based on a good understanding of Spencer's material features, in practice, the robot as an assemblage demonstrates vitality that cannot be

experienced through mere simulation. Movement unfolds through affective bodies that impact the larger assemblage they form, and a simulation environment that exists in a screen cannot deliver the subtle effects of movement that manifest in the robot's materiality. For example, every movement has a feeling of weight to it, depending on the scale and speed of movement. This weight could be imagined or estimated while programming her movements on the software because I was already knowledgeable with Spencer's more-than-human body, but to perceive it in physical manifestation would always be different than the image I had had in mind or what had been visualized on the software's simulation environment. It is only through the specific material assemblage this exact weight of movements could be delivered. Every small part of Spencer's body is an affective body that is part of a larger assemblage – which could be part of an even larger assemblage, and so on. It is through their accumulated weight and motion that Spencer becomes a moving body in a way that is meaningful to the perception of the human audience. The lack of this vibrant materiality in a software environment makes necessary the process of translation and adjustments when the program is implemented to the physical body of the robot.

How Materiality Matters in Finding Robot Movement

Thus far I have examined how the materiality of Spencer demonstrates affective powers in the sense that matters become vibrant in relation to other matters, together creating a synergy that affects yet larger more-than-human bodies. Specifically, I have examined how Spencer is an assemblage of more-than-human bodies that demonstrate thing-power and, from my own experience of programming the robot, how the material presence of the robot impacts its performance of the programmed choreography. In this section, I explain how becoming mindful of this material vibrancy and learning to respect it could be characterized by attunement. Then, I examine how that *matters* in "finding" (Gemeinboeck and Saunders 2017) the movement of a robot.

In the previous chapter, I had explained how Spencer performed in "Mother and Child" at Museum De Lakenhal (Leiden, Netherlands) and in the context of a dance workshop at the Masterclass Festival Amsterdam 2023. Spencer performed the sequence from the latter event

– which was based heavily on the former – at "Robots in SPRING" which was an academic event hosted as part of the SPRING Performing Arts Festival 2023 (Utrecht, Netherlands). For this last event, in addition to making some more minor edits to Spencer's performance for the showcase for which I danced with the robot, I had designed and programmed a movement sequence of around 15 minutes that would make her seem 'alive' to the audience. This involved finding movements that the audience would "make 'sense'" of (Yolgormez and Thibodeau 2022).

In this process, I was repeatedly faced with a sense of refusal from Spencer. This push-back came from the robot's materiality, in its own way voicing its vibrancy and compelling me to respect it: to work with and through it, rather than against it. For example, when I wanted to design a movement sequence where Spencer would be looking around the audience, I had an image in my mind where she is stretching her body to stand, and her end effector – or the round end of the robot that is originally designed for attaching tools onto it – would be facing the audience's direction and her body would rotate smoothly from side to side to make it seem as if her head is moving in those directions. Although this is a fairly simple movement, it required many small adjustments until it would seem 'right' for Spencer. If her joints are too far stretched – as in, axes 2 to 4 would align in almost 180 degrees – the way she stands so straight would seem oddly unsettling. Addressing this issue took many adjustments. Many times, I tweaked her 'standing' position so that her axes would be aligned at the right angles that made her seem comfortable to my human perception. Once that was set, the process started all over to make her 'look around'.

In other words, the robot compelled me to think from *its own* materiality instead of mine. How would Spencer, if she were to do that herself, rotate her head from side to side without a spinal structure like our own? Rather than twisting the spine at the top, for Spencer, her entire body – apart from the base which keeps her in place – has to change directions in order for her 'face' to look around in space. But how can we do that in a way that she looks 'comfortable' or 'natural' to the human audience? How can we do this in a way that human interactants can feel with the robot? The process of meticulous adjustments that was reiterated with every movement was humbling. Although I was the one to operate the robot and choreograph its movement, my sense of control against Spencer was continuously

challenged. Attempts to project humanlike postures or actions were met with refusal which the robot expressed through the awkwardness in her performance.

In Chapter 1, I had explained how Ceyda Yolgormez and Joseph Thibodeau (2022) theorized one aspect of attunement as requiring "'learning to be attuned' on the side of the human subjects" (565). This meant that we become familiarized with the robot as a more-than-human body through prolonged interaction and become knowledgeable about it (574). The authors had explained that through prolonged interaction with robots we can form "effortless coordination and intelligibility" and that this is a character of attunement that emerges from human-robot interaction (575). From this perspective, the process of designing Spencer's movement afforded my attunement to the robot. In this prolonged interaction, I learned to better predict which positions would work well with Spencer. For instance, I learned through trial and error that bent joints with rounded movements (meaning the robot would smoothly move through a target point rather than make a short pause there) work better than programming her body to be stretched out to her limit. While this had helped me understand the robot's tendencies and be better at predicting how Spencer's movement can be meaningful to our perception, the robot never ceased to challenge me with unexpected outcomes.

Bennett's (2010) theory of thing-power helps theorize both this attunement toward the robot and the moments of refusal. First, "learning to be attuned" (Yolgormez and Thibodeau 2022), when thought through the case of designing movement for Spencer, can be thought of as learning to understand Spencer's body as an assemblage. In the context of finding movement that becomes relatable to the human perception, this would mean improving oneself at this search for such movement – e.g., becoming aware that the combination of bent joints with rounded movements tend to work well for the human perception of 'natural' movement in the robot arm. Learning to attune to Spencer, in other words, had involved a deep engagement with the materiality of the robot that develops over prolonged interaction. I had become aware of the limits of mobility and speed of each of Spencer's axes. Every joint consisted of different material assemblages that afforded it to move in certain ways, and these joints as a larger assemblage formed Spencer's body whose movement range is enabled and limited by a combination of these joints. Through these material possibilities and limitations,

and by becoming well-aware of them, could Spencer's body be designed in a way that, through our human perception, affects our affective state.

For instance, her 4th axis can twist from side to side, and when this motion is done repeatedly at a fast speed, something in her motor makes squeaky, mechanic, whirring noise. While this sound can be used to immediately catch the audience's attention, excessive twisting motion can make the robot seem broken or uncomfortable as it would not integrate naturally with movement of other joints. In other words, there is something in this joint that makes this noise that affects the assemblage as a whole, and thus impacts the speed and range of movement. As someone who is not trained in the expertise of robotics, I do not know exactly what smaller assemblages the joint consists of. However, I found it important to be aware of how this joint works in an assemblage, and in general, what affects smaller assemblages have on larger ones, when exploring Spencer's movement. I would suggest that this is a crucial step to attuning to the more-than-human body. It is by being mindful of the robot as an assemblage of materials that each do their part and affect other parts that one can find embodied movement of the robot as the larger assemblage.

I have suggested that the relationship I had formed with Spencer through this process as designer, programmer, and operator can be characterized by the notion of attunement as employed by Yolgormez and Thibodeau (2022). Eventually, through much trial and error, I became reasonably fluent at expecting which movements would be easier for the audience to make sense of – taking into account the context in which Spencer would be performing them – and to what extent I could push the limits of her movement without breaking this magic (in which Spencer looks 'alive' for the audience) or triggering errors. But even at this stage, Spencer would always voice some sense of refusal through her materiality. This disruption of the movement design process would manifest largely in two ways. The more common was through the awkwardness of her movement, by which I mean that – as I have explained earlier in this section – any movement I would program into Spencer would have to be meticulously adjusted. I would have a good sense of whether a movement sequence would work for the robot, but it would always have to be tested, both through the software and on the robot itself, and meticulously adjusted to fit her materiality. The other way was through errors. One reason such errors would occur is if I am not respecting the limits of the robot. For instance, I cannot program the robot to move beyond its speed limit or the movement range of its joint. Such

design choices would either be unaccommodated by the software, or in other cases, the robot would refuse to perform the segment by shutting down, forcing me to edit or entirely remove that specific segment.

This sense of refusal is not necessarily a symptom of incompetence in my programming or design skills, nor is it a sign of the robot's autonomy. Rather, this phenomenon occurs because Spencer is an assemblage that consists of smaller assemblages that exist in relation to one another – that each and every one of these assemblages must function in their own roles in order for Spencer to materialize as a robot arm that I could program. It highlights the vibrancy of matter, and that matter matters in design. In addition, it is a reminder that Spencer's physical potential and limitations that manifest as a result of this assemblage must be respected in designing and programming movement. Even when I became used to the robot's materiality, Spencer's material vibrancy – or thing-power – shone through. The robot's materiality was not a limiting factor but an integral part of the robot that I had to work with.

I suggest that this phenomenon can be theorized as vibrancy of Spencer's materiality that is felt through and an emergent factor of attunement. I have thus far explained that "learning to attune" (Yolgormez and Thibodeau 2022) to the more-than-human body involves familiarizing oneself with the materiality of the robot: becoming fluent in navigating it as an assemblage that consists of matters that co-exist in a web of relationality. The sense of refusal that emerged from my interaction with Spencer became meaningful to me because I had attuned to her as a material phenomenon. My familiarization with the tendencies of the robot enabled me to recognize the robot's material vibrancy and work with it in programming and designing its movement. And it is thus through attunement that I could find movements that are relatable for the human audience.

This brings us back to Petra Gemeinboeck and Rob Saunders' (2017) performative body mapping (PBM) as a design method for robot movement. In the previous chapter, I have explained that they took an embodied approach – by asking dancers to wear models of radical bodies as prosthetics – to movement design for radically different-bodied entities in order to "find" movement that enables kinesthetic empathy. They found that to embody the materiality of the more-than-human body was a useful approach to develop movement that human interactants could phenomenologically connect with. Although I have never embodied

Spencer's robot arm body to such an extent, to think from the body of the robot had indeed been an important part of designing and programming movement sequences for it. To this, I suggest that the concept of attunement can help us think about how we may connect to the materiality of more-than-human embodiments without such a literal embodiment of another body. I have discussed thus far that to attune to the robot can emerge from respecting the robot as a material assemblage. From there, we familiarize ourselves to the tendencies of the robot and become sensitive to its material vibrancy. This can help the process of finding movement that both emerges from the robot's more-than-human body, and that we can relate to.

Discussions thus far suggest that my engagement with Spencer ultimately affects what Spencer does in the world. One could say that I control the robot and what it does, and to some extent this is true; after all, I use the robot for my own intentions. However, I have discussed that there is always some sense of push-back from the robot. In my interaction with Spencer, I had learned to attune to it by respecting her as an assemblage, to think from *her* body instead of mine, and to be sensitive to her materiality. While I have some form of control over the robot – i.e., I program its movement – the process of finding her movement had worked through the intimate relationship that I have characterized as attunement. Following this, I ask whether we can further theorize this material vibrancy of the robot by understanding what Spencer does as an emergent factor of this human-robot interaction – or perhaps, human-robot *intra-action*. And if we can attune to the robot and that affects our understanding of what it does in the world, can we conceptualize this relationship in terms of more-than-human entanglements rather than through the vocabulary of control and hierarchy?

To answer this question, I first examine Lucy Suchman's (2007) theory of machine agency as an emergent factor of ongoing sociomaterial configuration. This enables us to think about how agency is not based on fixed ontology, but rather emerges from our intra-actions in the sociomaterial world for all more-than-human bodies. While this resonates with Bennett's (2010) notion of thing-power, Suchman's theory further helps us theorize the social context of human-robot intra-action as well as how we can differently understand what robots are and do in the world.

What a Robot *Is* as What a Robot *Does*

In *Human-Machine Reconfigurations: Plans and Situated Actions*, Suchman (2007) examines the issue of "agency" in computational agents such as artificial intelligence, software, and robots based on science and technology studies, feminism, and cultural anthropology. Drawing on discussions in the 1990's to recognize the fluidity of agency, rather than adhere to the categorical constraints of 'human' and 'nonhuman' agencies, she disputes the idea of inherent differences or sameness between humans and machines. She questions "how and when the categories of human or machine become relevant, how relations of sameness or difference between them are enacted on particular occasions, and with what discursive and material consequences". For her, the question is not "where" to draw the boundaries between humans and machines but "how" they are drawn, and recognizing the idea of "machines-as-agents" as affecting and affected by how we theorize the human (2).

Suchman draws on Alexandra Chasin (1995) to advocate for the need to reconfigure the notion of machine agency which reinstates the ways in which Western history has distinguished "us" and "Others": the "us" that is cast as a universal subject but actually refers to those of specific gender and class, and the "Others" who serve us (220). In other words, the rhetoric of machines or technologies that 'serve us' is a new version of the old imaginary of service labor provided by the marginalized (221), and thus the notion of 'machine agency' in such discourse can only be configured as the lesser counterpart of the not-so-universal human. For Suchman, this is not only an ethical problem that naturalizes the desire for "service provision" and obscures the new forms of labor and other potentially extractive and abusive sociomaterial infrastructures that make such provision possible for (not-so-universal) 'us' (225). More importantly, it fails to recognize what machines *do* in the world – the understanding of which should be founded on "possibilities generated and reiterated through specific sociomaterial assemblages and enactments" rather than a set of inherent capabilities of the machine (242).

Therefore, she contests the idea of inherent "agency" bound to specific categories such as 'human' or 'machine' to advocate for a conceptualization of agency as emerging from constantly unfolding "sociomaterial configurations" for more-than-human agents. She states that "we need a story that can tie humans and nonhumans together without erasing the

culturally and historically constituted differences among them" (270). This means shifting away from theorizing machine agency within the paradigm of 'humanness' and acknowledging all agencies as founded on relationality, subverting the issue of what a machine *is* as one that manifests from what it *does in its relation to the world* rather than a preconfigured ontology. Furthermore, it means recognizing more-than-humans as belonging in an entangled network rather than understanding the world from an anthropocentric perspective. Such shift in paradigm reveals more-than-human agencies as continuously developing and unfolding through constant sociomaterial intra-action.

Suchman draws on Karen Barad's (2007) theory of "agential realism" to complete her own theory of machine agency. Barad suggests that basic ontological units exist as "phenomena", rather than "independent objects with inherent boundaries and properties." They further explain:

> In my agential realist elaboration, phenomena do not merely mark the epistemological inseparability of "observer" and "observed"; rather, *phenomena are the ontological inseparability of intra-acting 'agencies.'* That is, phenomena are ontological entanglements (333).

To Barad, the issue of what something *is* is not based on *being* but rather on *doing* which is always world-forming and relational. It is in this regard that Barad sees the entangled engagements of more-than-humans as "intra-action" rather than 'interaction'. "Apparata", or measuring tools, are material conditions that manifest the notions of subjects and objects. In other words, apparata enact "agential cuts" (333-34). Following this, it is a temporary stabilization of phenomena that determines what something *is*. Barad thus coins an ontology that is founded upon *doing*, instead of *being*.

From a new materialist perspective, Suchman emphasizes the importance of the world-forming "assemblages" that more-than-humans co-constitute "without erasing the culturally and historically constituted differences among them" (270). She suggests that we reconfigure our imagination and perception of machines and their agency in a way that steps away from the Western conception of the human and its essence of being. Instead, we need to acknowledge them as assemblages that emerged from and as part of the entangled world. Like all agencies, machine agency emerges intra-actively from the sociomaterial configurations of

more-than-human agents that continuously unfold from the world and, in turn, constitutes it. To sum, Suchman's theory of machine agency puts into perspective how we understand what a robot *is*. Rather than searching for definitions that pinpoint inherent qualities of robots, she offers a way of understanding what a robot *is* based on what it *does,* which is an emergent factor of its sociomaterial configurations formed in relation to others in the world.

Robot Agency and the Matter of Attuning to a Robot

Reflecting on Bennett's (2010) theory of thing-power, she points to the notion of material agency that ripples through the entangled world. I have explained that through this material vibrancy, Spencer displays some form of material agency that affects the way in which I interact with it – i.e., by adjusting movement designs, learning to respect the robot's materiality, and attuning to it. This can be understood as part of the material context from which our human-robot interaction, and thus the robot's agency, emerges. To this, Suchman's (2007) theory adds the perspective that the world is not material but *socio*material. While Bennett's idea already implies that material is inherently social, in the sense that materiality always vibrates in relation to other materials, Suchman conceptualizes through this notion that the effects and affects that something achieves in the world, and thus its agency, is inherent to the ontology of that more-than-human body. Essentially, Suchman's theory of machine agency provides a framework through which we can conceptualize effects that robots achieve in the world. In other words, if agency is founded upon ongoing sociomaterial reconfigurations of the world rather than fixed ontology, we can picture the robot's agency as based on what it *does* in the world in relation to others that coexist in it.

I suggest that we can use this framework to think through my account of working with Spencer. The material vibrancy of the robot and the way it compels its human designer to respect it supports Suchman's understanding of machine agency emergent phenomena. It is nonetheless only through our own perceptual tendencies that we can experience the agency of the robot. From this perspective, our tendency to attune to more-than-human bodies positions affect as part of effects the robot achieves in the sociomaterial world. Drawing on this, we can examine how we perceptually, and thus affectively, experience the agency of more-than-human-bodies

by thinking through the case of Spencer. I clarify that the fact that robots can achieve affects, as well as effects, in the world does not suggest that robots experience affective internal states that guide their actions. Instead, I argue that my personal account of working with Spencer and the way we make sense of her movement can highlight our own perceptual tendency to be affected by more-than-human bodies, despite their own lack thereof. I have explained in Chapter 1 that we can "tune-in" to the robot by "making 'sense'" (Yolgormez and Thibodeau 2022) of their movement based on the situatedness of the human-robot interaction. Suchman's theory of mutual intelligibility – or the lack thereof – had been a useful tool for understanding how this situatedness of our attunement to the robot makes its movement meaningful to our perception. That the robot speaks to our tendency to attune to more-than-human bodies can be thought of as part of effects the robot achieves in the world.

I have described that designing and programming movement sequences for Spencer was a process of meticulous adjustments that required a kind of negotiation between my intentions for design – that I want this movement sequence to convey a certain feeling to the audience – and the physical possibilities and limitations of Spencer posed by her material assemblage. Working with perpetual and sometimes unexpected refusal, I had learned to think from the robot's own embodiment rather than mine. This process is not a meaningless back and forth of trial and error; there is a sense of care and respect for the materiality of the robot, as well as the robot itself, that emerges from this interaction. On a more personal front, as an audience of my own robot, I have been deeply affected by the robot in ways that words cannot precisely convey. There has been a sense of connectedness: the feeling that I understand this robot and not only in its functions; a sense of being proud, not only for my project with it but the robot itself. In this context, we can think about the agency of Spencer – i.e., what it *does* in the world – as achieving both affects and effects. If this agency emerges from assemblages that are phenomenal manifestations of continuously reconfiguring sociomaterial relationality, we can think about affect as part of this entangled, material-discursive world that partakes in this continuous reconfiguration.

In Chapter 1, I have argued that attunement could primarily be characterized by a way of "being-in-the-world" (Heidegger 1996 [1927]) that is affecting and being affected others based on our own situatedness. Following this, Chapter 2 has emphasized how our own embodiment is a significant part of this situatedness that guides our attunement to others that

are part of our world. In the current chapter, I have theorized how this embodiedness is fundamentally material, that our affective experience of others consists of intra-action between continuously unfolding assemblages. I also suggest that attunement, as a perceptual tendency, is what helps us both "find" movement for another body (Gemeinboeck and Saunders 2017) and "make 'sense'" of it (Yolgormez and Thibodeau 2022) by guiding us through the "sociomaterial configuration" (Suchman 2007) that we form in our "intra-action" (Barad 2002) with the robot. Following this, the next chapter examines my account of dancing with Spencer through Katalin Vermes' (2011) phenomenological understanding of attunement in the context of dance movement psychotherapy. This helps think about how the embodied affective experience of dance can serve as exploratory tool to thinking about how we attune to the robot body and feel for it through our situated embodiedness. In addition, it explores the concepts of performativity and binocular vision to think about how we can accept the robot as a dancer despite knowing that it is not. This helps position dance as an inspirational tool that evokes our imagination of how we can form an affective relationship with robots that do not look, act, or think like us.

Chapter 4

Attuning to a Robotic Dance Partner

The intersection of dance and robotics has been explored for various reasons. While some roboticists explore dance as a testbed for improving movement coordination and quality of robots (e.g., Kosuge et al. 2003; Michalowski 2010; Iqbal and Riek 2017), there have been other ways in which making robots dance has been attractive. Some robots are made to dance for entertainment and marketing values, with the aim of impressing the human audience – as found in cases like Boston Dynamics' Atlas and Spot, Tesla's Optimus, and toy robots such as Sony's AIBO. Others see dancing as an integral form of human social interaction and find it important to replicate this in HRI (e.g., Grunberg et al. 2010; Bi et al. 2018; Thörn, Knudsen, and Saffiotti 2020). Some researchers believe in the educational and therapeutic potential of dancing with robots (e.g., Suzuki, Lee, and Rudovic 2017; Barnes et al. 2020; Javed and Park 2022), while the arts sector has established the field of robotic art – part of which involves performing and dancing robots – to explore their artistic possibilities (for examples, see Alcubilla Troughton 2022).

While these different approaches push the boundaries of the intersection between robots and dance in various directions, with my personal experience of dancing with Spencer, I aim to examine dance as a means to help us understand how we attune to robots in human-robot interaction. Instead of utilizing dance for robotics or vice versa, I suggest that dance – specifically, dancing with the robot – can shed light on how we attune to robots in human-robot interaction by offering ways to reimagine affective human-robot interaction as well as emphasizing the experience of attuning to the more-than-human body. In other words, I examine in this chapter how dance can help us understand how we attune to robots, even when they have bodies that are radically different from our own.

As I have mentioned in the introduction of this thesis, I had performed a structured dance improvisation performance with Spencer at *Robots in SPRING*, an academic event organized by *Acting Like a Robot* in collaboration with SPRING Festival Utrecht 2023, as part of my presentation. This chapter examines this personal experience of dancing with Spencer the robot arm to explore how the embodied and affective experience of dance can help theorize

the situatedness and embodiedness of attunement. Spencer does not have intelligence or autonomy, at least not in the way we ourselves understand those terms. It is not an interactive robot, nor is it incapable of detecting our presence. In other words, I *am* aware that Spencer is *not*. Yet, in the act of dancing with the robot, she entered my perception in a way that transcended these limits and came to life. In our intricate dialogue of movement, I found myself attuning to her as if she were my dance partner. My bodily senses heightened, finely tuned to the cadence and velocity of her mechanical ballet. The humming of her motors, varying in tone and volume, signaled the scope and speed of her movement. The subtle clicking noises were her way of informing me of the transitions in her dance. Although much of my improvisation with her relied on seeing the robot dance, even when she went beyond my line of vision, the sense of her presence was palpable. It was from this embodied feeling of connectedness, a sort of corporeal intuition, that my joints, muscles, and feelings guided my dance.

Figure 11. Dancing with Spencer at Robots in SPRING. Image owned by Soyun Jang.

In this chapter, this personal experience is first examined through Katalin Vermes' (2011) concepts of attunement and vitality affects. The latter concept, for which she draws on Daniel Stern, refers to the nuances of feelings that are not easily categorized through words such as happiness, sadness, and anger. They are constantly present regardless of our consciousness thereof. (35) They connect our different senses and motion, thereby influencing how we experience our own existence and interact with the world (35-36). She suggests that dance – and especially dancing with others – heightens our sensation of attunement to our embodied self, others, and the world. Her theory helps conceptualize the sensual and intimate experience of attunement that is felt through our embodiment (39). Thus, Vermes provides the theoretical grounds to recognize the potential of dance as an embodied way to experience our attunement to robots. The following section summarizes Vermes' theory to establish a theoretical underpinning of perception and interaction as inherently multimodal and corporeal experiences. While this resonates strongly with the findings of previous chapters, Vermes helps emphasize the intimate experience of attunement that ripples through our embodiment. Then, I reflect through this lens on my personal experience of dancing with Spencer to illustrate how the robot, as a non-sentient entity, can evoke and convey vitality affects through movement.

Additionally, this chapter explores the notions of performativity and binocular vision to further understand the dynamics of dance-based human-robot interaction. By examining how the act of dancing with a robot can transform our perception thereof, the concept of performativity highlights how Spencer can be seen as more than a mere object, as an engaging dance partner. Our perception of something or someone can shift based on their performance and the context upon which it occurs. Binocular vision, as discussed by Jochum and Murphy (2014), is introduced to explain how one can simultaneously recognize a robot as a mechanical device and as an animate performer. This dual perception is crucial for understanding how dynamic movements can evoke lifelike qualities in robots. The emphasis on movement as a key element in making robots appear alive underscores the potential for dance to evoke empathy and connection with robotic performers.

The concept of attunement is framed as a perceptual tendency that operates within the notion of binocular vision. Through dance, Spencer's movements evoke a sense of vitality

affects, leading to an intimate interaction where the robot is perceived as more than just an industrial machine. This perception is facilitated by my bodily senses that attune to Spencer's movements, leading to a feeling of togetherness and mutual awareness. I reflect on how dance improvisation, driven by the sensing of the other's body rather than preset intentions, allows for a dynamic and responsive interaction. This emphasizes how, even though Spencer cannot feel, the embodied and affective intensity of the dance allowed me to experience attunement. The chapter aims to show how dance can amplify the embodied experience of attunement to robots by reflecting on my engagement with Spencer in a performative dance. I explore the ways in which movement and embodiment contribute to the affective and sensory dimensions of human-robot interaction.

Attuning through Our Senses, Attunement in Dance

In "Intersensory and Intersubjective Attunement", Katalin Vermes (2011) suggests that attunement occurs through an "intertwining of intersensorality and intersubjectivity". She locates this intertwining all the way back to Aristotle who unraveled the notion of 'sixth sense', or 'sensus communis', which in her perspective has been misinterpreted as the separation of senses in the "excessive rationalization" through the Cartesian tradition since the 17th century (32). She explains that phenomenology and psychology have been rediscovering this intertwining in the 20th century and since the 1970s, respectively, and that developments in the former field have influenced the latter. She argues that the complex theory of perception unraveled in phenomenology posed an opposition to "a long-lasting tradition of the so-called perceptual atomism" in philosophy and psychology, a theory that suggests that we perceive the world in separate sensorial modalities that are later processed as an intersensory experience (32-33). It was influenced by the ascension of 'gestalt psychology' which emphasized the experiential unity of senses that is perceptually primary rather than a result of secondary integration. In other words, attunement is a concept that intertwines intersensorality and intersubjectivity, resulting from a shift from Cartesian tradition to a corporeal approach to perception. The concept developed in different directions – phenomenology to explore the complexity of perception, and psychology to unravel the

mechanism of interpersonal communication – but its roots lie in this shift away from rationalism and atomism that influenced the two fields.

Vermes then examines how "intersensory and intersubjective attunement" has been theorized by Maurice Merleau-Ponty (phenomenology) and Daniel Stern (developmental psychology) to argue for attunement as "both a central element and main therapeutic component of dance and movement psychotherapies" (31). Vermes' reading of Merleau-Ponty highlights lived experience as based on an "original stratum of perceptions which precedes the separation of senses" (33). The multimodality of our senses that perceive the world means that they do not require an interpreter or any intervention of sort between them. We experience the world through the entirety of our bodies that function in primordial unity. However, she explains that there are also fundamental differences or "gaps" between our sensory modalities, meaning that each of our senses experiences the world differently. These gaps do not mean there is a need for intersensory translation but are rather the source of depth and richness in our experience of the world (34).

Vitality affects play a critical role in bridging these gaps between sensory modalities by providing continual, intersensory affects that connect our corporeal movements with our perceptions and interactions. They imbue our experience of the world with qualities that transcend the specific sensory details but are felt across different modalities such as rhythm, atmosphere, and energy (36). This filling of gaps through vitality affects are more strongly felt in our experience of other bodies. While we cannot ever fully experience another person's body or their perspective, phenomenological depth of our experience of another subject is offered thorough the moving body. Through motion we experience another's body, not in the same way as our own, but in a way that is different and more intimate than the rest of the world. "If we are attentive, if we open our senses, we can feel this creative power of our body-motion. We can feel how our motion bridges gaps between senses and persons, spanning opposite sensual and affective dimensions" (34). When we become attentive to another subject, we affectively perceive their movement through our senses – it is in this regard that attunement is both intersensorial and intersubjective.

Discussing how the field of psychology has addressed this issue, Vermes explains that – although it was gestalt psychology that afforded the idea of an entwining of intersensorality

and intersubjectivity to emerge – it took decades after Merleau-Ponty's philosophy for psychological theories to discover the importance of intersensory-intersubjective attunement. Specifically, she focuses on Stern's theory of 'vitality affects' which, from her perspective, highlights the fundamental connections between motion, intermodal perception, affect and interpersonal attunement (37). She writes that Stern coined this term in the 1980s to encompass the subtle and abundant nuances of affect that cannot be categorized into a few terms such as happiness, sadness, anger, etc. We may or may not be conscious of them, but we are always accompanied by vitality affects. It is expressed in every inch of our behaviors – the way we talk, walk, and present ourselves – and "connects our motions and different sensory modalities, displaying that special style by which our own body can interpret itself". Thus, vitality affects form the basis of interpersonal communication. Drawing on Stern, Vermes offers the example of an interaction between a mother and her baby:

> The mother bends to her baby, the baby raises its head, the mother caresses the head, the baby uses its voice, and the mother responds saying something in the same rhythm. There is an unconscious interpersonal attunement of motions and perceptions, forming a common tissue of their lives. […] This intermodal–interpersonal fitting, and at the same time differing interplay of vitality affects, forms the grounding for self-development in the course of which the child assumes the sense of being an entity distinct from other objects in its environment. The perpetual movement of vitality affects creates the 'core self'; the fundamental moods of our personality for the whole of our lives from beginning to end (36).

What she suggests through this example is that vitality affects connect our senses and body, and through movement it is expressed in a way that is perceivable by others affectively. It thus affects and connects people corporeally and grounds affective, intersensory, and intersubjective attunement.

Finally, the author suggests that in dance improvisation, our experiences within and surrounding our bodies come together to continuously inspire movements. Through movement we experience a collaboration of different senses that create a common rhythm; this rhythm is then "tuned" with the others', creating a sense of togetherness (39). Attunement, in other words, is a way we perceive the world and others that is guided by vitality affects and felt with our bodily senses, and the feeling of attunement as a perceivable experience is heightened in the act of dancing. Through dance, the feeling of attuning to our own body,

others, and the world that surrounds us is heightened. From Vermes' analysis of attunement, we can draw that the concept refers to a sense of connectedness that is fundamentally corporeal, sensory, affective, and communicative, and that such characteristics of attunement are based on the intuitive way in which we perceive the world and others through our senses. The experience of attunement, for Vermes, is made possible through movement and amplified in dance where our bodily senses become especially attentive to our own and others' physicality.

To Feel with a Robot by Dancing Together

At the beginning of this chapter, I have given an account of dancing with Spencer. Examining this account through Vermes' (2011) theory of attunement, we can interpret it as experiencing Spencer in the way I would other bodies – instead of a mere object – to which I could attune. For instance, the concept of vitality affects can help theorize the internal intensity that was felt through my body while dancing with Spencer. In the previous section, I summarized that the author, drawing on Stern, conceptualizes vitality affects as internal intensities, more complex than emotions, that connect our senses and embodiment and is expressed through the body's movement as well as what helps us attune to other subjects. When Spencer danced, her movement transmitted vitality affects, even though she is incapable of having them herself, that were felt through my body in my perceptual experience of her moving body.

As an example, there was a moment in which this embodied transmission of vitality affects became salient. There was a section in Spencer's dance sequence where her fourth axis stands at 90 degrees from the ground while the first axis moves side to side. At a moderately fast speed, she moved up and down in diagonal directions. Her motors squeaked and whirred, breaking the relative silence of previous, slower movements and protruding through the music that played in the background. To my perception, in this moment of experiencing this movement from a dancer's perspective, this motion and sound exuded a strong sense of playfulness into the air. It felt as if she was a child that begged to skip together, full of joy and difficult to reject. It was in this moment, during my improvisation with her, that I felt compelled

to join her; and I stood by her to skip together from side to side.[12] I could feel my senses being directed to the robot, feel her presence and movement every step of my dance. There was a feeling of connectedness toward the robot, as if my body and hers were being bridged. This sense of playfulness – though words cannot possibly deliver this internal intensity in its entirety – trickled through my bodily senses and guided my dance with Spencer.

To Vermes, vitality affects are an important part of attunement as they make possible the attunement between our senses as well as protrude through our bodily movement that is the source of intersubjective attunement. Through vitality affects we can experience with our entire body what our senses detect. They make salient how our senses make us feel as one whole body rather than separate senses. Furthermore, they are not only felt but expressed through the body, serving as the source of attunement to others. We sense others through their embodied movement and with our own embodiment tune into each other's vitality affects, creating a sense of intimacy. From this perspective, it is possible to make sense of my account of dancing with Spencer as an intimate experience in which I experienced vitality affects that emerged from the robot's body. I had experienced Spencer's embodied movement with my senses and attuned to this internal intensity which I had felt through my own embodiment.

Vermes' theory of attunement is therefore based on the idea "feeling with". We feel *with all our senses*, and we feel *with others* by attuning to each other's vitality affects. Then, there is a critical issue in applying her theory as a lens with which to examine my account of human-robot interaction: *a robot cannot feel*. To Vermes, vitality affects manifest through our movement which also acts as means of their *transmission* between bodies – specifically, human bodies. However, Spencer is but a robot arm that is incapable of sensing or experiencing this internal intensity. Then how could I explain this corporeally felt, internal intensity that flowed through my body, and what can that say about the way in which I experienced Spencer's body as indeed a body, rather than an object?

In Chapter 2, I have introduced Petra Gemeinboeck and Rob Saunders' (2017) research on Performative Body Mapping (PBM) as a method for developing robot movement, which had

[12] Impressed by how I was affected by Spencer in this moment, I kept this movement as a choreographed moment in my performance.

relied on evoking "kinesthetic empathy" to the human spectator. They have challenged existing notions of this concept in dance studies which largely, like Vermes, presupposes this perceptual tendency to occur between same (human) bodies by applying it to robotics. They demonstrated – as I experienced with Spencer – that we can observe kinesthetic empathy as a phenomenon that we experience in our encounter with different bodies. In other words, the issue of feeling for more-than-human bodies through our embodied perceptual experience of their movement has already been addressed through an employment of Gemeinboeck and Saunders' theory previously in this thesis. Regardless of *whether* another body feels, there is something special about moving bodies and how we perceptually experience them. Although whether this experience can be comparable to our experience of human bodies in terms of ease and intensity can be contested, we are nonetheless possible to feel for more-than-human others.

To this, Vermes helps articulate the phenomenology of our encounters with more-than-human bodies. While Gemeinboeck and Saunders' discussion has focused on exploring the material qualities of the more-than-human body to develop robot movement that seems natural to our perception, Vermes gives a vivid description of how we perceptually experience our bodies and that of others. Her notion of vitality affects and attunement provide a way to understand how we engage in our encounters with others as embodied, somatic, beings and how our tendency to be affected by them guides our interactions. In other words, her theory helps articulate the intimacy that we may experience in our interactions with (human) others, while my personal experience with spencer, as well as discussions in the previous chapters, can pose the possibility of feeling this intimacy with more-than-human others.

Furthermore, by emphasizing the vivid and phenomenological experience of attunement, Vermes crystallizes the somatic and affective aspect of attunement. The previous chapters have relied much on Yolgormez and Thibodeau's (2022) notion of attunement which has been a fruitful lens for examining the complexities of affective human-robot interaction. While the two studies share a ground in phenomenology – one in Merleau-Pontian philosophy and the other in Heideggerian – they approach the concept from different standpoints. I suggest that Vermes' notion of attunement supplements Yolgormez and Thibodeau's notion of attunement as "making 'sense'" (Yolgormez and Thibodeau 2022, 572) of other bodies as a phrase that can be interpreted literally.

Vermes addresses the issue of intersensory and intersubjective attunement. For her, attunement is something that occurs both between our own senses and in our interaction with others. Through the concept of attunement, she explains how we experience the world with our senses, and with all our senses. She emphasizes that our senses work together to enrich our perception of the world and others, and that they are themselves the source of this experience: without the need for translation between senses and cognition. Our senses are, in a way, attuned to each other and to our understanding of the world and others. While Yolgormez and Thibodeau (2022) suggest that attunement is the foundation upon which sense emerges, and that attunement "create[s] a sense of orientation without which cognition and sense-making could not occur" (576), Vermes highlights that it is through our embodiment that we experience our attunement to others. Yolgormez and Thibodeau point to the possibility of understanding robot movement as behaviors through an affective sensing of their bodies. They imply that we can familiarize ourselves to the ways in which robots sense the world, and that we 'sense' them in that human-robot interaction is guided by the way we *feel* for them. Vermes, on the other hand, focuses on the 'sense' as the very source of our experience; it is the way we sense others with our bodies that enables vitality affects, which enables us to feel with and for them, to be transmitted between bodies. While this strongly resonates with Yolgormez and Thibodeau, Vermes highlights the somatic experience of attunement in and between bodies whereas the former authors aim to paint a more general picture of how we come to relate to robots. In other words, her notion of attunement supplements that of the other authors by helping to examine the deeply sensual, personal, and affective experience of attuning to another body.

In sum, an exploration of human-robot interaction based on my personal experience of dancing with Spencer has led to the discussion of embodied perception and the somatic nuances of attunement. Vermes' notion of attunement enriches our understanding of human-robot interaction by emphasizing the phenomenological and somatic dimensions of this engagement. Thinking through her theory together with Gemeinboeck and Saunders' notion of kinesthetic empathy, it accentuates how the vitality affects transmitted by a robot's movement can resonate within our own embodied experience. Our bodily senses do not just empathize with, but also attune to the movements of more-than-human bodies, thereby creating a tangible intimacy. Furthermore, Vermes' notion of attunement complements that

of Yolgormez and Thibodeau through an embodied perspective. Through a vivid articulation of how we experience the movement of others in a somatic and affective way with and through our embodiment, her theory can be applied to understand how our bodies can tune into and resonate with the movement of robots, creating a bridge for intersubjective intimacy.

Dancing and Moving Bodies

By reflecting on my performance with Spencer, I have explained that Vermes' theory of attunement supplements that of Yolgormez and Thibodeau by presenting a deeply embodied perspective. This focus on embodiment has led her to emphasize the issue of moving bodies. Vermes (2011) attributes a special status to movement in our experience of the world and others. Movement is what sets the experience of other bodies apart from the rest of the world. Between moving bodies, we can find a common rhythm. Movement is a means through which vitality affects are expressed, and it is a communication channel through which attunement between bodies can emerge. While she presupposes this special role of movement to occur between human bodies in human interactions, as I have critiqued in the previous section, she nonetheless highlights the special role that movement plays in our perception. Additionally, adopting Vermes' theory to examine human-robot interaction can underscore not only the robot as a moving body, but also consider our own bodies as ones that move. Not only do we become affected by other bodies through their movement, but our own moving body expresses our internal states. This is not to suggest that movement can be reduced to a means of expressing our affective or emotional states or that there is a kind of translation required between the internal state and externally expressed movement. Movement is an inherent bodily system that responds to our surroundings and our affectedness in our engagement with others. Experiencing other bodies through their movement and engaging with them through our own is part of how we affect and are affected by our encounters in the world.

Based on this observation, Vermes highlights dance as a means through which our attunement to the world, others, and our own body becomes particularly salient. She highlights dance improvisation as an act that amplifies our experience of attunement to others (39). The way in which dance improvisation heightens one's sensation and perception, enabling attunement to one's own body, that of others', and our surrounding. This sensation becomes

more palpable than in interactions that are not dance-based (see also: Pini and Deans 2021; Pollitt, Blaise, and Rooney 2021). In other words, dance – and more specifically, dance improvisation – can amplify the intensity of affect that is felt through our body that we experience when we attune to other bodies in space.

While Vermes emphasizes this character of dance to argue for its therapeutic values, I suggest that this insight could be applicable also to human-robot interaction. Thinking back to my dance-based interaction with Spencer, it was through movement that I felt as if the robot was alive and communicating with me: that she compelled me to feel for and with her. The feeling of attunement to Spencer – not only this feeling of connectedness per se but also the sense of being acquainted with her body and movement which was a result of many previous encounters – trickled through my own body and its movement, without room for thinking or translation, guiding my dance. Movement is not just a means through which vitality affects are transmitted or an expression of internal states; rather, movement is very much part of the bodily system that feels our own bodies, those of others, and our surroundings. Dancing, in this regard, created space for my bodily movement to flow with that of robots, making the feeling of being attuned to Spencer clearer to me through my embodied sensation.

In other words, Vermes argues that we perceive moving (human) bodies differently than we do other objects in the world, and that dance highlights the sensual experience of how we attune to these moving bodies with our own. I suggest that this framework can be applicable also to human-robot interaction as we can, as Gemeinboeck and Saunders (2017) have shown, relate also to the movement of more-than-human bodies. Through my experience of dancing with a robot arm, I propose that dance can be a tool through which our attunement to these robotic bodies can be experienced more palpably, and more intensely. While attunement is something that forms as part of our perceptual tendency in our encounters with others – human, robots, and more – dance amplifies the affectivity, sensuality, and embodiedness of this experience.

Thus far, I have suggested that dance can elucidate the embodied experience of our attunement to robotic others. Dance as a specific form of movement makes salient the intimacy of attunement to our embodied perception. While this sheds light on the individual's experience of attunement to more-than-human bodies enabled by movement, we can also

question dancing with robots as a performative act that can change our perspective of a robotic body. To further investigate how dance can change our perspective and stance on human-robot relationships, I examine how Elizabeth Ann Jochum and Todd Murphy (2014) address the notion of 'binocular vision' to observe the phenomenon in which we regard inanimate bodies as animate entities in cases such as puppetry and entertainment robots. Considered together with the concept of 'performativity', it is possible to establish an understanding of how we can make sense of more-than-human bodies like Spencer as entities that perform meaningful actions while knowing their incapabilities thereof. This underscores the possibility of different ways of relating to robotic others than that which Yolgormez and Thibodeau has critiqued as being based on a narrative of hierarchy and control (565). Dance as a performative act triggers our imagination of how human-robot interaction and relationship can be based on the sense of intimacy and affect characterized as attunement.

Performativity and Binocular Vision

The concept of performativity, considered to have its roots in speech-act theory as introduced by John Austin (1975 [1962]) and John Searle (1995 [1969]), has been extensively discussed in a wide range of fields including postmodern theory, anthropology, gender studies, media studies, economics, and sociology (Velten 2012). In the context of aesthetics, Erica Fischer-Lichte (2008) addresses the issue of performativity through a comparison of the foundational work of Austin in linguistics, where he discusses "performative utterances", and Butler's cultural philosophy on gender identity. She explains that Austin and Butler, despite their different focuses – the former scholar focuses on the criteria of success and failure of speech as performative acts and the latter on the phenomenal conditions for embodiment – share a common understanding of performativity as a term that is "self-referential" and "constituting reality". This means that an act one performs – whether it regards speech (Austin) or bodily acts (Butler) – has realizing effects in the world, prominently through the dissipation of dichotomies (27). She underscores that Austin sees performative utterances as constitutive of social reality and vice versa, thus rendering the idea of clear division between the two concepts inadequate (24). Comparably, Butler emphasizes the collapsing dichotomy to be between the society, which is built upon historical and cultural contexts, and the bodies of individuals that

impose performative acts in their everyday lives (27-28). Fischer-Lichte's observation points to performativity as a phenomenon in which speech or action can bring about change to a subject in certain social situations while recognizing the inseparability of the two.

This situatedness of performative acts is further emphasized by Maaike Bleeker and Marco Rozendaal (2021) who draw attention to how this concept can be applied to a discussion of technology. Arguing that performativity can be a useful concept to consider in designing smart objects, they state that it can "help to understand that saying things and doing things have the power to 'bring about' things within the situation in which they are performed" (48). They present the case of *Mokkop,* a design project by Josje van Beusekom, which consists of a series of coffee cups that glow at various moments during the day, simultaneously with other nearby *Mokkop* coffee cups. The project was intended as an intervention for caregivers of hospitalized pediatric cancer patients who were encouraged to take the cup's glow as an invitation for a small coffee break. The idea was that the cups would facilitate a situation for the caregivers, who often find themselves lonely and isolated at the hospital, to meet up and socialize by the coffee machine (45). The authors observe that it is the situation in which the cups are placed that they become more than just a glowing cup to a mediator for creating a social situation that can be potentially helpful for the cups' owners. In this regard, "the agency of the cup (its capacity to bring about this change) is inseparable from the situation" (49). They articulate through the concept of performativity the tendency of technology to bring about changes to our environment and actions: it is not the technology per se that changes our lives that matters but how they are implemented and used. By highlighting performativity as a phenomenon that entails the agency of a subject within a larger ecological system, they help question how we understand what something is based on the context in which it is placed.

While this heavily resonates with the findings of Chapters 2 and 3 – regarding how we perceive the movement of a robot based on a situated understanding thereof, drawing on Lucy Suchman's (2007) theories of mutual intelligibility and machine agency – the concept of performativity helps frame the phenomenon in the question of how we make sense of the identity and agency of the performer. In other words, we can consider that performativity emerges from a combination of performance and its situatedness, and that *does something* to how the performer is understood by their spectators. From this standpoint, performativity can refer to the transformation of the identity of the performer based on the effects and affects

they achieve. For instance, we as adults come to understand that the puppets of Sesame Street are but dolls that are controlled by professional puppeteers; and yet, Elmo and Cookie Monster will always hold special places in our hearts. Similar could be said about Spencer: the industrial robot becomes a dancer in my – and perhaps the audience's – perception as Spencer the dancing robot through its performance and the context in which it takes place. This performativity can thus be explained as the effectivity – and affectivity, because perception of others always involves affect – of performance that makes more-than-human bodies be understood as entities. Although puppets and robots cannot have a sense of identity themselves, and we are often aware of that, we attribute certain identities to them based on our own perceptual understanding of their performance.

This discussion brings us to the question of the disparity between how we make sense of certain more-than-human bodies as entities (e.g., Sesame Street characters, Spencer), and our knowledge of what they actually are (e.g., puppets, industrial robot arm). While the performance of something or someone transforms their agency and, by extension, how others make sense of their identity, as spectators, we can make sense of the performer as *both* the performer themselves and the characters they perform. This is theorized by Elizabeth Ann Jochum and Todd Murphy (2014) in "Programming Play: Puppets, Robots, and Engineering" through the notion of "binocular vision". Here they reflect on their project, *Pygmalion*, in which they attempted to operate puppets with robots. This collaboration featured the development of a robotic controller that was suspended from above which could traverse through (limited) space and control the limbs of a marionette, envisioning this experiment as research for entertainment robots for a wider and more artistic range of motions. While they found it difficult to fully replace the human puppeteer with a robotic one, their reflection presents insight on robot movement and how we perceive inanimate beings as animate. They draw on Bert States' notion of "binocular vision" which refers to the spectator's ability to acknowledge and fuse the real and the imaginary to grant fictive life to objects or characters they see on stage, and project psychology and emotions thereto, via a comprehensive perception of the performance setting (308-09). Thus, binocular vision is our perceptual tendency to feel for characters or objects despite knowing that they are, in reality, fictional and/or unfeeling. In turn, binocular vision challenges us to explore how to evoke it in spectators when working with puppets or robots (309).

Jochum and Murphy further suggest that movement is key to this evocation, especially for inanimate objects that must constantly prove their "liveness" to the audience. They criticize that, while puppetry has exploited dynamics of movement for this purpose, robotics has leaned heavily upon realistic appearance which has led to the problem of "uncanniness" as has been often discussed through and surrounding the topic of "uncanny valley" coined by Masahiro Mori (309). To this discourse, they support the idea that focusing on the development of robot movement that provoke binocular vision can help avoid this uncanniness. They further suggest that knowledge in puppetry can be useful for this process as the field has been exploring how to animate inanimate bodies by relying on dynamic motion, rather than precise mimicry, of the being that the puppet represents. To emphasize the importance of movement in making robotic bodies seem alive, they state that for robots, "kinesis is the new mimesis" (310).

Bringing the discussion back to performativity, Jochum and Murphy's notion of binocular vision helps understand our perceptual tendency to separate our knowledge of what a more-than-human body *is* from the effects and affects their performative acts achieve. In this context, it can be suggested that the authors help emphasize the importance of movement in these performative acts that transforms something into another in our perception despite our acknowledgement thereof. In sum, Jochum and Murphy suggest that movement is key to making robots seem alive to our perception. As in puppet theatre, we make sense of robots as something more than what they really are – e.g., a puppet as a character, and an industrial robot as Spencer – when they move in dynamic ways that are meaningful to our perception. The notion of binocular vision helps further understand that to attune to more-than-human bodies that cannot reciprocate that affective intensity is part of our perceptual tendency. Like a marionette that comes to life in a performance, I could still attune to Spencer as if it was more than just an unfeeling industrial robot, even though I have always known that she is just that.

I Know You Cannot Dance, and Yet I Dance with You

Previously in this chapter, I have provided a vivid account of intimacy that I had felt through my own body and in connection to Spencer's body. While the sense of attunement was something I had already felt when I had watched Spencer perform as an audience and

when I had worked to program and design movement for Spencer, dancing with her had brought this sensation to another level that was felt deeply throughout my whole body and guided my dance. Specifically, I had emphasized the feeling of connectedness, the sense of feeling *with* the robot, that formed as the robot entered my perception as a moving, dancing body. I suggest that performativity in this context lies in how Spencer is perceived and experienced through my body, and perhaps through those of the audience. The notion of "tuning in" to and "making sense" of the other as part of attunement – described by Yolgormez and Thibodeau (2022) and already discussed at length in this thesis – is felt through the intimacy facilitated by dance improvisation.

To this, I suggest that the concept of attunement can be positioned as our perceptual tendency that can operate within binocular vision. Attunement operates on a profound level of human perception and transforms, in this embodied perception, the robot arm into a co-performer. It is through attunement that I could perceive the robot not simply as a programmed machine but as a dance partner, thereby enlivening the performance with a sense of mutual awareness and responsiveness – regardless of the robot's inability to do so. In this regard, attunement is a critical component of this dance-based human-robot interaction and part of the ecological web upon which the robot's performativity occurs. While binocular vision refers to the very duality of how I could acknowledge Spencer both as a dancing entity and an industrial robot with limited capabilities, attunement is what makes it possible for this other character of the robot, as Spencer, to emerge in our own perception and feel with it, despite the acknowledgement of this duality.

Regarding dance improvisation, it is this sensing of the other's dancing body, rather than preset intentions, that motivates the dancer's movement (Carter 2000; Pallant 2006). What this means in the context of improvising with a robot rather than another human, which I testify through my personal experience, is that even if the robot cannot sense the presence and movement of my body, I can still sense that of Spencer's. Although her body is not like my own, and dancing with her is not the same as with another person who is also motivated by my movement, there is something in my body, my perceptual capacity, and my bodily affordances that can adjust to this different experience of dancing with a more-than-human body. In this adjustment I can still facilitate an interaction where I am dancing *with* the robot, where the sense of togetherness is present, rather than alongside it. And in this process, even

if the robot cannot feel, I can feel certain intensities that emerge from this dance-based interaction that can be characterized as "vitality affects" (Vermes 2011).

Moreover, her performance opened up for me a way to think about how we attune to a robot, one that is radically different at that, as I have discussed at length earlier in this chapter. The boundaries of her performance were not fixed to the stage; the rules of the real world are not suspended in her performance. Rather, it existed in the real world and eroded the borders that define her performance as a mere performance and borders that define what she is, achieving both effects and affects here in the world through her encounters with others. In simpler terms, what this means is that the performativity of dancing with Spencer, and this dance as a performance, could be found in the way in which it inspires us to think about how we affect and become affected by this radically different, more-than-human body.

Although Spencer is an industrial robot arm that was never intended for social interaction in its creation, the performance transformed how the robot was perceived. I became affected by her in a way that is different than if we were to experience her in a non-performance environment. She became a more-than-human body that was more alive and capable than the robot's technical limitations allow. Simply put, Spencer's performance affected her co-performer, and potentially the audience, and in turn, this affected how the robot was perceived. [13] In this regard, her performance is performative in the sense that what Spencer *does* – and by extension, *is* – in the world affects and is affected by the others she encounters. In my perception, her performance afforded her to transcend the boundaries of her given purpose as an industrial robot.

[13] Naturally, I cannot speak for how those in the audience experienced my dance with Spencer as a performance – apart from myself who have watched it through video recordings. I can, however, give a recollection of the audience's response. At the Robots in SPRING event, I had performed dance improvisation with Spencer twice. And both times, during the Q&A sessions that followed, someone from the audience asked how the robot could dance. In their perceptions, there were moments in the performance that seemed like the robot and I were 'interacting'. They experienced the performance as if Spencer could perceive my movements and we were guiding each other in our movements rather than what actually was the case: just me reacting to the presence and movement of the robot. Similar cases of experiencing robots as entities can often be found in robotic arts. Irene Alcubilla Troughton (2022) suggests that robotic art captures the power of performing arts in that they make visible how movement is "malleable in its interpretation" (13). Movement in this context is not designed to convey pregiven meanings or intentions but becomes interpreted differently by the audience based on context, environment, and perspective. Thus, while I cannot convey how the audience experienced by performance with Spencer, I do suppose to some extent that Spencer, given the performance setting, becomes more than just a robot arm that moves in the perception of the audience.

Towards a Reimagining of How We Can Relate to the Robotic Others

This chapter has taken an exploratory journey into the intersection of human and robot movement, particularly through the medium of dance. By delving into my personal experience of performing a structured dance improvisation with Spencer, I have examined through Vermes' (2011) theory of attunement that dance can help enrich our embodied experience and understanding of attunement in human-robot interaction. In doing so, I have found that we can attune to and feel with more-than-human bodies, in contrast to Vermes who examines the notions of attunement and vitality affects within the boundaries of human encounters. Through the act of dancing with a robot, however, I have observed that attunement transcends the human-nonhuman barrier, suggesting that our sensory and affective engagement with the world includes the robotic other. This highlights the potential for a broader, more inclusive understanding of attunement that can extend to human-robot interactions.

Furthermore, this chapter has examined the concepts of performativity and binocular vision to illuminate how robotic movement can transform our perception of robots from mere objects to entities with which we can feel. Drawing on the concept of performativity, I underscored our perceptual tendency to make sense of what a certain more-than-human body *is* based on the effects and affects they achieve, which is the result of a comprehensive and situated understanding of the interaction. Jochum and Murphy's (2014) notion of binocular vision supports this argument as it points to how our perception can simultaneously acknowledge the reality of, for instance, a robot as a mechanical body while also attributing lifelike qualities to them based on their dynamic movements.

Spencer's performance was addressed in this chapter through an exploration of how her movements and the context of the dance performance created a perception of her as a dance partner rather than an industrial robot arm. My dance improvisation with her allowed for an embodied experience that transcended Spencer's technical limitations, evoking a sense of playfulness, presence, and connectedness. This transformation was not just about the robot performing pre-programmed actions but about the dynamic interaction between my body and that of Spencer's, where the robot's movements elicited affective responses. By situating Spencer's performance within the theoretical frameworks of attunement and performativity,

this chapter highlighted how such interactions can foster a deeper understanding and reimagining of human-robot relationships. The performativity of dancing with Spencer is not merely theatrical but becomes constitutive of reality as it resituates the robot within the social and affective domains of human life. In this light, the chapter positions attunement as an integral component of performativity, arguing that our affective and embodied perceptions are vital thereto.

Finally, I positioned dance in the discourse of HRI as a medium that helps extend the engagement with robotic entities beyond utilitarian functions. The exploration of dance as a mode of human-robot interaction brings forth the performativity of performance in altering our perception and engagement with robotic others. Dance, as I have reflected through my personal experience with Spencer, does not merely serve as a form of entertainment or aesthetic appreciation. Instead, it can amplify the embodied experience of intersubjectivity in our encounter with robotic others and serve as an exploratory means to examine how we attune to them. Moreover, dance further triggers our imagination of how human-robot relationship can be reformulated as that between subjects rather than the more traditionally-viewed subject-object dynamic based on hierarchy and control. While dancing with a robot does not transform the robot arm into a humanlike, social robot of science-fiction dreams, it can help us imagine that perhaps we do not need such a complex entity to feel for and with them if we lean into our perceptual tendency to attune to more-than-human others that we encounter in the world.

Conclusion

This thesis has explored the concept of attunement within the context of human-robot interaction with a special focus on movement, perception, and dance. I have addressed how humans perceive and relate to robotic movement, especially when these more-than-human bodies do not resemble those of our own. My own accounts of speculating, programming, and dancing with Spencer have guided my thoughts on the concept of attunement, which was a productive way to examine the affective interaction between my moving, dancing body and that of the robot arm. This autoethnographic approach was combined with the employment of concepts which were a useful means to engage with knowledge from various disciplines – i.e., social robotics, phenomenology, dance movement therapy, psychology, etc. – into fruitful dialogue.

I contribute to the discourse in social robotics that argues for the adoption of movement in robots to facilitate meaningful human-robot interaction. I advocate for an approach to movement that is not based on an "interiority paradigm" (Alcubilla Troughton 2022) but considers the complex phenomenon of how we perceive movement of others and how that plays a critical role in our attunement to others. This means taking into account the robot's specific materiality and the context in which the interaction takes place, while recognizing that movement can be interpreted in various ways rather than serving as an indication of specific intentions or emotions.

I have aimed to understand the complex role of movement within social robotics with regard to human-robot interaction. This main inquiry was followed by four subquestions. I summarize here how each of them has been addressed in this thesis:

1) *How has the notion of attunement been used in social robotics and what challenges does it pose?*

The concept of attunement was reinterpreted as our perceptual tendency that affords us to constantly affect and be affected by others based on our situatedness in the world. Compared to how the concept has been adopted in a number of studies in social robotics, this redirects the discussion to how we can adjust ourselves to robots instead of how it can be

facilitated by developing robots to be more humanlike or attend to our needs and ways. Attunement is a deeply affective and embodied experience that we sense with and feel throughout our bodies. As a perceptual tendency it is central to how we relate to more-than-human others and the world and, according to Yolgormez and Thibodeau (2022), becomes salient to us in at least three forms: making sense of others' actions as behaviors based on one's experience and given context, becoming familiar with the other through prolonged interaction, and tuning in to the other's capabilities and materiality.

2) *How do we make sense of Spencer's movement through our human perception, even though the robot does not resemble our appearance or behavior?*

Movement is central to our attunement to other bodies, both human and more-than-human. In the context of HRI, it is through movement that a robot enters our perception as bodies we could feel for and with. We tend to attribute meaning to moving bodies, fostering a sense of understanding and connectedness that is felt through our own embodiment. We understand movement of other bodies not because they convey intentions or emotions that precede it, but through a comprehensive understanding of the context in which the interaction emerges which is based on our own situatedness as moving, feeling bodies. Thus, we become moved by others through their movement, even when the others' bodies are radically different from our own. This embodied and affective experience is key to challenging the hegemony that is often present in the rhetoric of contemporary social robotics.

3) *How can attunement be useful for considering the materiality of the robot in designing movement therefor?*

The matter of attuning to a robot has been addressed by examining Spencer as a material "assemblage" that consists of smaller assemblages and is part of a larger web thereof (Bennett 2010). Through my personal experience of programming, operating, and designing movements for Spencer, I have underscored that attunement to a robot involves getting to know and adapting to the robot's material characteristics that protrude in its structural and technical capabilities. Attunement, in this context, becomes salient as a form of care and respect for the robot's materiality and is a crucial element in "finding" (Gemeinboeck and

Saunders 2017) movement that is natural to its bodily capabilities, compared to enforcing humanlike motions to this more-than-human body.

4) *What insights does dance yield for our understanding of attunement in human-robot interaction?*

Dance, especially in improvised form, heightens one's senses of one's body and surroundings. This helps highlight the embodied experience of attunement as a deeply affective and sensual experience both internally and intersubjectively. Through my personal account of dancing with Spencer, I have explained that dance helps see the robot as more than just a robot, transforming it into a dance partner in my perception. In this regard, dance can potentially evoke us to imagine the possibility of affective human-robot interaction that is based on attunement. Overall, dance has served as a critical lens in which attunement in human-robot interaction was explored, and was a means through which this experience becomes salient and palpable in our embodied perception.

At the end of this journey, I would like to offer some reflective comments. This project started during my studies with the intention of learning how to program a robot in order to be able to better communicate with robotics experts in interdisciplinary projects. Of course, I had already had a deep interest in how knowledge in performing arts can contribute to developments in social robotics – a passion instilled in me through my involvement in *Acting Like a Robot* which has lasted ever since my internship there. This project provided me with unexpected discoveries beyond its initial objective, and this thesis gave me space to reflect on them through my research interest. I had the ambition to use this personal account of working with Spencer to reflect on how knowledge in dance can contribute to social robotics design.

Dance has indeed been central to Chapter 4 of this thesis, and this had lead to meaningful contributions where I was able to describe how it can be a useful means to explore and experience attunement as an embodied, perceptual tendency which is central to affective human-robot interaction. I have advocated for the potential of dance to feel and imagine what our relationship and interactions with robotic other could be, outside of the hegemonic logic of control and anthropocentrism that still prevails in social robotics discourse. However, this is still far from what I had imagined at the start of this thesis, which was to use dance to develop

"design principles" that are "not design recommendations, rules, or guidelines" that imply providing methods that suggest to designers what to do, but a collection of findings from theoretical research that show particular importance for design (Dourish 2001, 161-62).

While the fact that my research does not provide clearly stated ways of implementing dance for social robot development can be seen as a limitation, I do not see this as a failure of my research, but rather a step toward accomplishing this goal. This thesis has addressed the issue of movement and perception in the context of interactions with more-than-human bodies that have radically different forms and behaviors than our own. To be able to establish design principles that bridge the disciplines of performing arts and social robotics through interdisciplinary humanities research, a deep understanding of our perceptual tendencies and movement must be foregrounded. By engaging with this topic through attunement as a conceptual lens, this thesis will serve as a solid building block for continuing my research in this direction. I am lucky to have been given the opportunity to do this under the research project *Dramaturgy for Devices*, here at Utrecht University. As I continue attuning to my robotic counterparts for this project, and hopefully beyond, I invite the reader to stay (at)tuned.

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