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Author(s)	Kemiksiz, Asli
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An Ethnography of Robotics: Potentials and Challenges in Making Robots More Human

Ph.D. Thesis for Examination
Submitted May 2020 by Asli Kemiksiz
Supervisor & Reviewer: Atsuro Morita
Co-reviewers: Chihiro Shirakawa and Eisei Kurimoto
Osaka University

FOR LEO DEMIR

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Introduction

Figure 1. A Pepper working at a souvenir store in Yokohama Chinatown (Photo by author)

Robots are everywhere. Humanlike machines have been in stories, films, and in other popular media for decades; now, a variety of machines we call robots are in entertainment, industry, in our homes… Particularly in Japan, one of the prominent countries of robotics research and use (Bekey et al 2008), the adoption of these technologies has been so normalized that one might meet a robot in daily life. These curious machines have growingly been the interest of social sciences and humanities (Robertson 2018, Suchman 2007, Kubo 2015, etc.) and the interest has been branching into the research and development of the robots and Artificial Intelligence (AI) rather recently (cf. Richardson 2015). Robots and AI are not only quite transformative technologies in terms of daily life, they are also deeply impactful on our understandings of a variety of topics, ranging from life to ethics. Hence there remains a lot to be explored anthropologically in these domains of science and technology.

This dissertation focuses on the robots in development: rather than the more visible robots in use, as the one pictured in Figure 1, I was rather interested in those in laboratories. In addition, I have consistently been interested in humanoid robots, those who are envisioned to look and function like human beings. The robots in laboratories, as you will read in the following chapters, are marked by a few particularities. They are, to begin with, research tools. These robots are used to make better robots, that is given, yet due to certain developments in robotics and AI (which will be discussed throughout this dissertation) they are also used to understand higher cognitive functions and behaviors. More and more, roboticists are inspired by sciences such as biology, psychology, neuroscience, etc.; and their robots are conceived to further the understanding of a lot to do with what it means to be human.

Furthermore, and related to their use as a tool, robots in the laboratory embody the meanings given onto them in current robotics and AI. They reflect the views and approaches in the disciplines, and also socio-cultural imaginations, worldviews of researchers, biases, hopes, fears, and more. Robots are quite thick with meaning, and in this dissertation I offer an analysis of my findings.

Another interesting aspect of the laboratory robots is that their potential: as they are still emerging technologies far from being established, they hold onto the potential of developing into quite a lot of things, embedded into the imaginaries that help develop them. Robots are always thought together with visions of their future, and working on robots in the laboratory is therefore also future making practices participating into or deviating from the envisioned futures.

In my opinion, Japan is the most interesting place to do an ethnography about robots. It is a country where multiple entertainment robots are available for personal use, where in most other places the robotic vacuum cleaners are the only robots that people use. I will discuss in Chapter 3 that the imaginations of the robots are ubiquitous in popular culture and the robots are *familiar* to Japanese people. There is also massive research interest with some of the biggest university laboratories and most famous roboticists being from Japan. Most of the Japanese industry giants, including Sony, Honda, Toyota, etc., spend significant effort and investment on robots.

It may be of interest for the reader to know the story of this dissertation. I have been interested in robots initially more than a decade ago, during my first M.A. degree in Cultural Studies. I had never seen robots at the time, and I was rather interested in fictional robots that have been featured in science fiction (sf[1]). At the core of my interest lied empathy for the robot characters in stories, who—in Western sf—wanted to be "human" but deemed inferior, and I likened myself to them as a woman in a highly patriarchal society. While I was studying Western sf I started reading and watching some sf from Japan, among which *Ghost in the Shell* franchise stood out to me the most. I was surprised by the seeming contrast of Japanese depictions of the machine versus the prominently Anglo-American depictions thereof. I decided to further my studies in Japan and on Japan, however, my initial idea was to study fictional Japanese robots rather than the technology itself.

Studying in Japan indeed have impacted a lot of my thought, and being in Osaka University where some of the most prominent roboticists in the world work, trailed my interest to the actual robots. In addition, being in Japan I was finally able to see robots with my own eyes, which I found fascinating. However, I still had and still do have a profound connection

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[1] There are multiple abbreviations commonly used for science fiction, namely SF, sci-fi, and sf. I chose to use sf in lowercase due to the strong influence of Donna Haraway, for whom sf signifies "science fiction, speculative feminism, science fantasy, speculative fabulation, science fact, and also, string figures," (Haraway 2016, 10) implications whereof are discussed later in this dissertation.

to science fictionality, hence even in my formation as an anthropologist at Osaka University, I never ventured too far away from sf.

My interest in humanoid robots in development have taken me to robotics laboratories in the years that I have been in Japan. I conducted this research as a laboratory ethnography, the mainstay of which has been in Matsumoto Laboratory[2] in Kantō Region of Japan. In addition, I have been conducting fieldwork at public, industry, and academic events, mainly in Japan for the last five years. My fieldwork, which I discuss in extensive detail in Chapter 2, has given me a rare insight and familiarity to how robotics research is conducted and received in Japan.

This story is important because in this dissertation I do not solely analyze empirical data gathered in the laboratory. I discuss sf and I do textual analysis, too. The originality of this dissertation is therefore not only in the fact that it is one of the few laboratory ethnographies on robotics, but it is also that I use a variety of texts and analyses to complement my laboratory ethnography. It is also important to understand my standpoint; as in, the twelve years that I have been interested in robots, whether fictional or factual, I have never conceived them as essentially good or bad, inferior or superior. To me, they have always been a metaphorical Other, which I call the artificial Other due to its human-made nature, usually reflecting what societies think of the Other. And I, often feeling like the Other, have held sympathy for the robots.

In this research specifically, I had initially in my mind questions about how can the robot help us understand humans, and what kind of knowledges are produced in the robotics laboratories through the robot. In the time I was there, I got to ask more questions about roboticists' ways of interpreting and incorporating knowledges and hypotheses of other

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[2] As per the ethical guidelines of Osaka University Graduate School of Human Sciences, my interlocutors' names are protected with pseudonyms. I also refrained from giving specific details to their research as their work can be equally identifiable.

disciplines into their own research. I observed and inquired about how the robots are conceptualized in the laboratory, and I analyzed my findings with the help of my decade-long studies on robots in multiple realms, as well as my years-long fieldwork in public and academic events. Furthermore my fieldwork allowed me to be part of the laboratory where the robot is a mundane part of the academic ordeal; I got to observe and participate in scientific activities from the most ordinary to very laboratory-specific. Laboratory practices are where the robot can be a variety of things including a complicated assemblage of silicone and metal and a hard-working but clumsy being.

This dissertation is the culmination of some of my analyses I made along the way. Current robotics, particularly disciplines I focus on in this dissertation (namely cognitive, neuroscience, and developmental psychology inspired robotics) can at times be challenging for the anthropology reader. Indeed, it took a lot of readings and my kind and patient interlocutors' explanations for me to familiarize myself with it. I do not aim to cover all that is at stake with my interlocutors, but rather focus on the robot and its use as a laboratory tool. Hence the technical aspects of robotics are limited to those that are relevant to the theme of the dissertation.

Moreover, the robot is not merely a technoscientific artifact, and all that a robot is—be a fictional or a philosophical figure—comes with its own contextual luggage. Every time the "robot" has been used in sf, or in philosophical or sociological arguments, not to mention the material embodiments thereof, what robot is has been enriched further with the additional contexts. Hence I chose to make this introduction a concise general introduction to the dissertation followed by a couple of chapters that incorporate elements of a more traditional ethnography. I will explain the structure of this dissertation in the following paragraphs.

Chapter 1 of this dissertation is the conceptual introduction of the robot. Inspired by theories of multiplicity in anthropology (Mol 2002), I discuss the robot multiple. As the robot is both a fictional and technoscientific figure, it requires explaining the multiple contexts which contribute to its emergence. As this dissertation is rather focusing on the robot as a laboratory tool, I chose to start its history from a similar previous figure, the automaton. Automata were also lifelike mechanical devices that were complicated for their time, and did not have a specific "use" (Strauss 1996). Yet automata were, as robots are, tools to think with, a machine which reflected life, hence allowing to think about life or being human.

In *Totemism,* anthropologist Claude Lévi-Strauss presents animals "good to think [with]" (Strauss 1962, 89). He states that "the animals in totemism cease to be solely or principally creatures which are feared, admired, or envied; their perceptible reality permits the embodiment of ideas and relations conceived by speculative thought on the basis of empirical observations" (89). Humanities scholar Marjorie Garber interprets Lévi-Strauss' proposition of "good to think [with]" as the celebration and validation of thought, emphasizing that "thinking may have its initial impetus in 'empirical observations,' those vital signs of the social sciences, the physical sciences, or the life sciences, but its payoff is in speculation, which is then reattached to, embodied in, or reembodied in the objects, concepts or beings that give rise to it" (Garber, 2008, 14). The automata and the robot are similarly good to think with, the speculation upon which is reembodied in the robots thereafter. Hence, following the automata, I discuss the robot in fiction, both in Western sf and Japan, in which similar comparisons between human and machine can be seen.

The robot in technoscience and all its implications are also discussed in Chapter 1. Although it is difficult to define what a robot is, humanoid robots that I focus on in this dissertation are generally accepted to have the form and function of humans (Bekey et al 2008)––they look and work similarly to human beings. I explain what humanoids cannot be used for and focus particularly on the robot in the laboratory, explaining the robot as a tool.

Finally, in Chapter 1, I offer a general literature review of the anthropology of robotics and AI; which in my opinion still an understudied area for anthropology and STS. I position my own work in comparison to those who studied Japanese robots, such as Jennifer Robertson and Akinori Kubo, and explain how my work contributes to the literature.

In Chapter 2, I introduce my fieldwork. In addition to being an overview of the laboratory fieldwork, this chapter also offers an analysis of how certain particularities of the field matter in the understanding thereof. Specifically in this chapter, I discuss how scientific research conducted in a laboratory is impacted by a variety of overlooked factors, such as the space itself. Inspired by other laboratory ethnographies (cf. Myers 2015, Otsuki 2019) I examine the sociality in the laboratory and how it relates to research practices. In an effort to contextualize the laboratory practices, I look into the influences on the laboratory whether from roboticists past, or from the outside of the laboratory.

Chapter 3 has previously been published under the title "Materials of Imagination: On the Limits and the Potentials of the Humanoid Robot" in open-access journal *NatureCulture.* This chapter is a follow-up on my M.A. dissertation at Osaka University, looking into the relations between sf and technoscience. In this chapter, I explore how materials of imagination––facts, fictions, beliefs, rationales, aesthetics, norms, etc.—shape emerging Japanese humanoid robots. Using Donna Haraway's image of string figures to consider the intimate relations between sf, technoscience and science studies, I also identify and break down some powerful, conventional imaginaries—ranging from the companion robots to the Laws of Robotics—in order to elucidate how the Japanese humanoid robot came to be what it is. I end by arguing that science fiction thought experiments provide materials of imagination with potentials for opening up current robotics to imaginaries beyond current experimental systems.

Chapter 4 is likewise published previously in *Japanese Review of Cultural Anthropology* under the title "Modeled after Life Forms: Embodiment and Ways of Being an Intelligent Robot". This paper-turned-chapter had stemmed from the lack of robotic "life" in the laboratory; as in the overarching effort of making robots more lifelike or humanlike in robotics does not amount to the potential of seeing robots lifelike in Matsumoto Laboratory. To contextualize this, I took on the concept of thought styles of the microbiologist and philosopher Ludwik Fleck (1935) and discussed how robotics, particularly Matsumoto laboratory translates these hard-to-define concepts into their embodied agents, i.e. robots.

"Embodiment" in robotics, which will be significant throughout this dissertation, refers to the principle that a body is an integral part of what we call intelligence. In Chapter 4, I look into the modeling practices that make embodied agents possible, and analyze how modeling plays a role in the development of robots.

Chapter 4 is followed by an Interlude, which may be an unusual part to include in a Ph.D. dissertation. I had worked in an automotive factory for two weeks right after I returned from my mainstay of fieldwork. I had the chance to observe industrial robots at work which was quite impactful for my view of robots. I was particularly awed by the contrast between the laboratory robots and the factory robots, which moved, sensed, and interacted differently. I presented a paper to the Ph.D. Workshop "Robots in Motion" that was titled "Workers and Lab Tools: A Robotic Comparison." Now, as the factory was not officially part of my fieldwork, I did not turn this into a chapter by itself, but the comparisons I was able to make at the factory were so precious to me that I wanted to include them in this dissertation. Therefore the interlude consists of a few points significant to me that will make the following chapter easier to understand for the reader.

Chapter 5 is about laboratory practices. In a laboratory where researchers focus on developing software that is to be used on robots, it may seem that most of the laboratory practices consist of sitting in front of a computer, which is true to a degree. However, it is a matter of concern for anthropology (and not just the anthropology of science and technology) to peel off the layers of seemingly simple practices to discover the thick meanings that lie wherein. In Chapter 5, I first elaborate on the conceptual role of the robot in experimentation and contrast robotics to other sciences such as microbiology. Further, I look into experimental systems inspired by historian of science Hans-Jörg Rheinberger (1997) to see how experimentation in Matsumoto laboratory compares to what to those experimental sciences that have generally been studied by anthropologists (cf. Traweek 1988, Myers 2015). In the following section of Chapter 5, I discuss how robots are trained in the experimentation and what kind of affective relations these practices foster.

Finally, I conclude the dissertation by offering my overall observations, tying the chapters together. I also add hints and ruminations on what is there to come out of this research.

1

On the Robot

This chapter introduces the robot conceptually and in its multiplicity. Starting from what multiplicity means in anthropology and science and technology studies (STS), I offer a general outline of the concept. The focus of this dissertation lies upon the conception of the robot as a tool, which both means that —as discussed in the introduction—it is something to think with, and that it is in the laboratory practices used to elucidate how to replicate human traits that are not very well understood. Therefore, the next section of the chapter on the robot's history starts from the automata, which shares the liminality and the seeming uselessness of the laboratory robots, which, combined with the fact that they are both tool-like in relation to "human," shows a strong continuity in conceptualization. The history section then moves on to sf and Japan to tell the robot's story in a way that is relevant to my fieldwork.

The third section (1.3.) focuses on the robot in technoscience with a particular question in mind: what the uses of a robot may be, and what kind of a tool it is. Lastly, I offer a brief introduction to the robot in anthropology and the social sciences, and to my predecessors who delved into robots and robotics before I did.

1. 1. The Robot Multiple

The term “robot” has famously originated in the 1920 play *R.U.R.*[3] written by Czech author Karel Čapek. In the play, the term was used to designate artificial people—the laborers. In time, the term was picked up by other sf authors as a reference to their own depictions of machines that bear resemblance to humans in form or in function. Almost simultaneously, the success of the play piqued interest of inventors, companies, and tinkerers of various kinds, and developed into a massive category of machines. The machines have not lived up to their fictional counterparts, as there is no robot yet that is sufficiently automated and adaptable to its environment as a human, yet the interest has grown into the technoscientific discipline of “robotics,” based on a term coined by the American sf author Isaac Asimov (1942[1995]).

As robotic imagery has become ubiquitous and robotic technologies have expanded, what a robot *is* has become exceedingly ambiguous—though it is fair to propose that the robot has never been an unambiguous figure. The diverse contexts in which the term robot has been adopted makes it resistant to unequivocal definition. Dictionaries tend to emphasize “programmability” by a computer and the automated execution of tasks. Yet, there are machines that embody these notions (such as automated people movers i.e. automated transit shuttles) that are not called robots, whereas non-programmable or human-operated machines can be referred to as robots. The ambiguity of the term robot is both rooted in the hype created by sf imaginaries and the fact that robots are still an emerging technology. There is an open-endedness to what a robot is and what it can do in technoscientific context, and that contributes to the material-semiotic multiplicity of the robot.

The premise of this dissertation is that the robot refers to a multiple, entangled entity. The grammatically awkward idea of “a multiple, entangled entity” gets its sense from the

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[3] The title of the play is *R.U.R.* with the subtitle of *Rossum’s Universal Robots,* which will be referred to as *R.U.R.* thereinafter.

anthropology and STS literature on ontologies. Much of that literature focuses on the worlds created by different actors and how all of these worlds are simultaneously real. Anthropologists often find themselves in the field, where their "real", the local "real", and sometimes an authority-holding "real" that is created by political power or scientific practice diverge, yet hold together. Hence the literature on multiplicity often focuses on elucidating such worlds (see de la Cadena and Blaser 2018, Escobar 2018, Omura et al. 2019, Jensen and Morita 2019, etc.)

One influential study is Annemarie Mol's work on the disease atherosclerosis in a Dutch hospital (Mol 2002). *The Body Multiple* shows how the disease is enacted in ways that it are "more than one, but less than many" (55). Indeed, her understanding of multiplicity indicates at manyfoldedness, rather than pluralism (84), particularly because the enactments of the disease may overlap or entangle. It is therefore not a plurality of perspectives of a preexistent thing or phenomenon; multiplicity or manyfoldedness propounds that the thing or phenomenon emerges from the various enactments. Furthermore, Mol shows how even different medical practitioners have different ontologies, such as a pathologist and a surgeon, despite all of them being trained in the general umbrella of Western medicine. In Mol's ethnography, the practitioners in the hospital try to reconcile the multiple versions of the disease from the clogging of the arteries to the daily lives of the patients so that all the enactments can be real.

However, "Western" science and medicine have the tendency to create what John Law calls "One-World World" (Law 2015) in which only one reality (the one that belongs to OWW) is considered to be real and the others have beliefs or perspectives. As there are some enactments in the *robot multiple* that have similar views to OWW, particularly to practitioners of robotics, those with such views tend to see others' enactments as their 'perspectives'.

The roboticist and philosopher Masahiro Mori finds it problematic that people would think of the robot simply as a concept, without knowing much about the actual thing (Mori 2014, 80). This exemplifies OWW; and I have heard similar statements in my fieldwork from some roboticists. Some see sf or popular imaginaries regarding the robot as a disadvantage, whereas this dissertation proposes the opposite.

Despite understanding Mori's concern from a roboticist's point of view, I find it surprising that he, as one of the most speculative of all roboticists, does not recognize that it would not change much if everyone did 'know the actual thing.' The reason it would probably not matter that much is embedded in the history of artificial beings with humanlike features, which I introduce in the next section.

In my research, there is a certain understanding in the field (among roboticists and industry) that the robot is indeed multiple, and those who are able to manipulate different ontologies propel the research on robots. At the same time, I will say, there is a kind of blindness towards what these different worlds mean, which to me always makes robotics research fall short of what it could be. In other words, even though the robot is often no more than a research tool in the laboratory, the tendency of the general public to project their fears and hopes onto robots is capitalized on in the laboratories or the industry, which is embedded in certain outputs of robotics research (in forms of demonstrations and presentations). That has maintained the continuity the most popular imaginaries and excluded some others, which will be discussed in Chapter 3.

The robot has inherited the long and enchanted history of artificial humans (see Section 1.2.), with inevitable links to the concept of the "human" and all the issues it raises. It is also historically and practically associated with the concerns of multiple scientific disciplines (see Chapters 3 & 5). In the following, I explore what is made visible if one conceives of the robot as superimposed by layers of meanings—about itself and its relations to humans, life, technology, aesthetics, and many other components required to create a mechanical assemblage that somewhat resembles a human being.

Located somewhere between human and machine, there is a liminal quality to the robot. Perhaps this is why it has been long used as a concept to explore introspectively what it means to be human. In that sense, the robot—both in its fictional and material forms—constitutes the paradigmatic artificial Other. This is an Other that resembles us, yet still is different; an Other that is made by humans. Robots have become something we use to think about other things *with*; things like being alive, intelligent, conscious, emotional, et cetera. Moreover, in contrast with other non-humans, robots offer the possibility of endless tinkerability as well as a degree of transparency to its workings. In principle, then, the robot seems to hold unique potentials to become more "human", with the reminder that what is at issue is *a* certain conception of the "human." In sum, therefore, the robot is multiple. Not only due to its numerous fictional and technoscientific incarnations, but because it is always situated in systems of knowledges, beliefs, and practices that lay—and point—beyond itself.

Following this history, and in preparation for the following chapters, I then give a brief overview of the robot as it appears in Japanese humanoid robotics and in anthropology, respectively.

1.2. The Robot in History

Countless myths and traditions across the world have attributed humanlike features to artifacts. Indeed, mythologies across the world have produced—and still do—beings that blur the distinctions between animate and inanimate, human and nonhuman, subject and object. Such figures have long been a topic of interest for anthropologists (see, for instance, Douglas 1966).

What is special about the robot, as a boundary-blurring figure, stems from its machinic and technoscientific aspects. It is human-made and its humanlike features are worldly (for the most part, and currently). Moreover, the robot is technological, which gives it a very distinct flavor as a non-human of potential. It's seen to have the possibility to be made, unmade, tinkered with, improved —it can even surpass humans.

Since robot-like figures started appearing in fiction, their potentials have varied from clunky machines with very obvious programming to figures virtually indistinguishable from humans. The potentialities of fictional robots have strongly been influenced with developments in technoscience, as what is plausible in technoscience always affects the speculative, or what could have been, in fiction. In return, the robot's potentials are heavily hyped in technoscience, too, feeding on the long built expectations from their fictional, historical, and figurative counterparts.

Yet since the "real" robots have first appeared, there must have been countless news stories around them proclaiming that *THE ROBOTS ARE COMING*, despite the fact that they have both always been here and will never come. In other words, the robot has never been a static figure; it's filled to the brim with potential, and is therefore a speculative being.

The very lively and evocative discourses around the robots being "just like" or "super" humans is correlated with the relentless efforts in robotics to make them and/or present them as "more human." However, it is rather questionable what "more human" entails, since human is neither a properly understood organism nor it is conceptually static (See Kemiksiz 2011). Many disciplines, including robotics, are concerned with understanding human—and in robotics, the robot becomes a tool, a mirror where the making of a robot also entails an understanding of the "human." Simply put, to replicate humanlike traits in a machine such as the robot, one must have an understanding of what those humanlike traits are. This is why the robot is often described as a mirror for the human by roboticists themselves (e.g. Asada 2010).

It can be said that the robot gains its own enchanting features by disenchanting what it replicates: the human, or if generalized, life.

The enchanting powers of an artificial human explains the long history of the artifacts and figures created in its stead, including robots and AI. I find “hype” a misnomer for the interest in these technologies, because it is not new, nor it ever seems to fade. Inspired by Alfred Gell (1998), Lucy Suchman states that “the enchanted object’s effects are crucially tied to the indecipherability of prior social action in the resulting artifact” (Suchman 2007, 244). Robotics is a discipline that heavily relies on demonstrations which currently reaches to a vast audience on the internet. The robotic demonstrations, i.e. the resulting artifact, do create awe regarding the capabilities of the robot, creating a buzz around “how” they can jump on one leg or kick a football; making the audience wonder what else they can do. This is indeed possible by making the pulleys and strings invisible, the many interventions of the practitioners indecipherable to the audience.

As an anthropologist working on robots, I often receive messages from friends trying to make sense of a robotic demonstration they are watching. I tend to explain why they should not be scared of robots themselves by pointing out the details in the demonstration, such as the people with the controllers at the background, or explaining the choice of space and its implications. They are enchanted by what the robot can do, but also because they do not have the knowledge to decipher what makes it possible and under what circumstances.

Yet at the same time, the figure of the robot is strongly tied to the figure of human, hence when a robot is or seems capable of doing something that has previously only been the capability of human beings, it disenchants the human bit by bit. While doing so, the robot also destabilizes what it means to be human, similarly to how microbiologists, artificial lifers, and astrobiologists do to “life”, according to Stefan Helmreich’s body of work (see Helmreich 2011).

There is, of course, a historicity to how the robot came to be, and how it became this liminal object with both enchanting and disenchanting powers. The history of the robot is relevant to this study, as some of the core ideas that still dominate the field can be traced back to how artificial non-humans have been conceived earlier on.

1.2.1. Automata

In order to understand the double movement towards the enchantment of the robot and the disenchantment of the human, one must look into the history of the robot beyond the initial embodiments of the machines that were deemed robots, and indeed even beyond *R.U.R.,* the play in which the term "robot" debuted. It is important to contextualize why a figure that represented the working-class human in a piece of fiction came to share its name with a category of technoscientific objects. The robot is a product of a Western industrial-capitalist socio-cultural context at its inception. However, it also more or less traceable to diverse nonhumans in myth, legend, and craftsmanship in the same region since antiquity (see Kemiksiz 2011).

One such figure was simulacrum: with the advent of mechanical technology, makers took on the task to simulate celestial bodies and biological forms in mechanical form, which were called simulacra (Warrick 1980, 30). The advanced versions of these simulacra were automated—or gave the impression of automation to the onlooker—and were thus called automata. The simulacra date back to 12th century Islamic civilization with the works of Ismail ibn al-Razzaz al-Jazari (Masood 2009, 163–164). The European automata, which are generally considered precursors to current robots, were developed after the Renaissance, and reached their peak in the 18th century.[4]

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[4] Broadly speaking, similar beings have been constructed or conceived of in at least the past 3000 years (Strauss 1996, 180).

The history readings of the automata point at parallels with how the robot can be a mirror to human, how it can be a tool to understand human. It can be seen in this historical context (i.e. European or Judeo-Christian) that the replicability of human traits in a machine has an effect of making the human rather more worldly (or slightly less enchanted); therefore, what the artificial non-human is conceived of is strictly tied to what contemporaneously is thought to be "human."

The term automaton means "self-mover[5]." Historian Minsoo Kang opposes the idea of calling anything that resembles the modern robot an ancient automaton and distinguishes four different categories: "1. mythic and of supernatural creation 2. mythic and of human creation 3. of actual human creation or design" and "4. speculative" (Kang 2011, 18). Kang underlines that the conception of automata after the scientific revolution was antithetical to magic (19), such that, despite fulfilling the condition of "self-moving," some of the above would not fit the 18th century understanding of the automaton. His breaking down of the specific characteristics of the automata is illuminating, yet in light of my ethnography, I do not see a necessity for distinguishing the "nature" of beings that are considered ancient automata. For not all that the categories visible to the historians remained in their lanes in the centuries that passed.

Examining myths and treatises from the European sphere, Kang further asserts that all four categories have two major common points: first, that the ancient automata are lifelike; and second, that the concept "relates to the notions of enslavement and rebellion (19)." However, the 18th century automata, the actual machinery, had very little to do with notions of enslavement. They were more like marvelous machines that had some lifelike qualities. For instance, French inventor Jacques de Vaucanson had crafted automata that were quite developed for their age. *Le Canard Digérateur* (The Digesting Duck), which was first

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[5] In Ancient Greek, the term *automaton* was a generic word for a thing or a being that moves by itself; the usage of the term for a moving machine was pushed into the mainstream in the 16th century. (Kang 2011, 7).

displayed in 1738, is considered as de Vaucanson's masterpiece. It is described as a mechanical duck, which could "eat" and "digest" food (Riskin 2003a).

Despite the intricacy of such machinery, historians apparently had not considered automata as important until the 1960s and dismissed them "as trivial and largely meaningless frivolities (Strauss 1996, 180)". Historian Linda M. Strauss wrote an insightful article titled "Reflections in a Mechanical Mirror: Automata as Doubles and Tools" (1996), in which the arguments about the liminality of automata and their use as tools to think with resonates with this dissertation. She points to two important facets of automata: they are machines that have faces, and they do not have powerful economic or political functions:

> "The faces of automata serve as reflections of human faces—like mirrors, they allow people to project themselves into them, and read themselves back from them. However, because, in addition to having faces, they are distinguished by their ability to move themselves, automata are more than passive images; rather they are perceived and reacted to as more autonomous figures. (183)"

She therefore presents the automata as doubles, unsettling and fear-inducing figures that she sees in correlation with other double-like figures (including twins), and extends these characteristics onto initial sf stories about artificial humans, and then robots.

Strauss also points to the use of automata as "tools to think with (195)." Indeed, such liminal figures were not only used throughout history to think about the categories they disrupted, they were also—in time, particularly the 18th century—tools to replicate life, aligned with a growing mechanistic view thereof. Historian Jessica Riskin contextualizes the 18th century automata to the wave of materialism and artificial life, which she calls wetware, a term used to indicate the human brain and nervous system; but in conjunction with hardware and software (Riskin 2003b). She illustrates how the automata were used to simulate a variety of human (or lifelike) phenomena in machines, from speech to birthing, which in turn led to deeper understandings of such phenomena. This account is also in line with the view that automata, and then the robot, can serve as a mirror to the human; yet, by the post-scientific revolution, it is more or less by disenchanting life. Riskin points out to an era of reversal, after the first few decades of 19th century to mid 20th, when the same fascination with replicating life was renounced by engineers (Riskin 2003b, 117), even deemed as hubris. Its reappearance at the world stage was concurrent to the emergence of cybernetics.

On a broader time scale, automata influenced the discourses on robots as well as the concepts they disrupt, including but not limited to "human," "life," "intelligence," and "autonomous." In the earlier discourses on proto-robots—i.e. 19th century depictions of artificial Other, curiosity and marvel are coupled with a certain sense of danger and guilt. This can be tied to Strauss' understanding of automata as doubles, but also the dangers posed by trespassing into God's territory (see Kemiksiz 2011). Guilt has faded somehow in the 20th century, but danger remained: fear still is a strong feeling associated with some discourses of robotics.

It is obvious that this is not a universal account of what automata, or similar artificial non-humans meant. Artifacts with close characteristics have been made or thought of in a multitude of cultures for a long time, and the European automata are but one vector of it. A similar artisanship tradition exists in Japan, but it had been completely separated from the Western tradition, and altogether different in implication. In Japan, mechanical puppets or *karakuri ningyō* flourished in the 17th century, where they were used mostly for entertainment purposes, festivals, or for the theater genre called *Bunraku*. Later, they were adapted for domestic use (Thornbury 1992, 184). In contrast with automata, Japanese mechanical puppets did not have an aspect of sin and danger attributed to them, which is in turn, was reflected in the Japanese understandings of the robot.

1.2.2. Science Fiction to Science Fact[6]

There have been mechanical and other artificial human figures in Western proto-sf[7] before the term "robot" was coined by Karel Čapek. The earliest, and perhaps the most important, was found in *Frankenstein: The Modern Prometheus*, written by Mary Wollstonecraft Godwin Shelley (1818).

The protagonist Victor Frankenstein is a scientist and an alchemy enthusiast who is driven by a desire to crack the mysteries of life and death. He attempts to build a beautiful human being from parts of various deceased people. However, upon animation, his creation, which is referred as "the Being", looks so abnormal and monstrous that it is abandoned by its creator. Linda M. Strauss' interpretation emphasizes that the Being reflects Victor Frankenstein; that the flaws of the creator is mirrored in his being (Strauss 1996, 189).

This monumental novel has gained much attention from literary scholars and there are many readings of it. For sf, too, *Frankenstein* is a cornerstone, given the focus on artificial human/life and scientists. The storyline in which the creation of a scientist who ventures into God's territory goes awry has reverberated ever since. Indeed, Isaac Asimov dubs the human fear of robots as the "Frankenstein Complex" (Asimov 1978), which refers to an anxiety that is found in both literary and extraliterary realms towards robots. It is also worth noting that the renunciation wave of replicating life illustrated by historian Jessica Riskin (cf. Riskin 2003b), mentioned in the previous section, corresponds to the publication of *Frankenstein*.

However, in the 19th century there were many other fictional examples of mechanical humans. They included *Huge Hunter or the Steam Man of the Prairies* (1868) by Edward S. Ellis, *Erewhon or Over the Range* (1872) by Samuel Butler, *L'Ève Future* (*Tomorrow's Eve*, 1886) by Auguste Villiers de L'Isle Adam, and the short story "Moxon's Master" (1893) by

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[6] Sections 1.2.2. and 1.2.3. are taken from my MA thesis.

[7] I call science fictional stories before the development of the genre in 1920s "proto-sf".

Ambrose Bierce. These works are thematically diverse and vary in their attitudes towards the machine. In *Erewhon,* for instance, machines pose a risk for humanity as they evolve, while in *L'Ève Future,* the female android Hadaly is presented as a perfect woman. Yet all are part of the persistent exploration of what human is in a world where technology gets gradually more complicated, and where scientific developments, such as the publication of Darwin's *On the Origin of Species by means of Natural Selection* (1859) questions the traditional conceptions of the human.

In the play *R.U.R.* (1920)*,* the company Rossum's Universal Robots produces artificial humans made of 'living matter' organized in a different, simpler, and quicker way than that of nature (Čapek 1920). They are used as servants, and their bodies are designed to be "mechanically" better than humans but deficient in many other ways.

R.U.R. is, in fact, an allegory that criticizes the capitalist system. Here, the robots signify the proletariat. The master-servant relationship between the humans and the robots in the narrative is eventually broken by the rebellion of the oppressed robots. *R.U.R.* caused one of the most important discursive turns for the concept of the artificial human because it marked the "labor" aspect with a branding iron into the concept of artificial human[8]. Afterwards, the artificial human was almost always thought of in relation to serving humans.

It is important to underline that both before and after *R.U.R.,* there have been many complex machines in sf. The "robot", however, was mostly conceived of as humanoid—as previously mentioned, humanoid in appearance and function. The non-humanoid machines of sf are called "robots" only if they have some other humanlike characteristics such as intelligence, autonomy, self-consciousness, etc. In contrast, the expansion of the term "robot" to include a variety of machines, including robotic arms on factory floors and robotic underwater vehicles, is due to material practices in the making of robotic technologies.

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[8] There are prior examples for working machines, see automata Kang (2011) 20–21.

Nevertheless, the humanoid form remained as an ideal in sf while it became one of the objectives of robotics research.

R.U.R. marks the entry of the concept of "robot" to the Japanese cultural sphere where it gained different connotations. While Japanese developments were influenced by those in the West, in both its discussions and representations of robots, the Japanese robot partially branched out to gain a form of its own, both as a technology and as a concept. The next section is an overview of the Japanese robot in both fiction, and later, in technoscience.

1.2.3. Japan

The years following the premiere of *R.U.R.* in Japan bore witness to a constantly increasing interest in robots. This interest stemmed from the possibilities opened up by the idea of the robot presented in *R.U.R.*; that is, as a machine capable of alleviating human beings of labor. The initial discussions were parallel with those of the West. But in the post-war period, fictional robots appeared in Japanese popular culture alongside an increase in research in the field of mechanical engineering toward machinery that resembles humans. The first humanoid robots in Japan, in fact in the world, appeared in 1970s. Since then, humanoid robotics has become an important facet of research on robots in Japan.

Soon after *R.U.R.* was translated and performed (1923 and 1924, respectively, see Kubo 2015), the non-scientific Japanese interest in robots also grew exponentially. It gave rise to a significant amount of fiction in forms of prose, manga, anime, and other media. In parallel, and subsequently, research on robots kicked off in the second half of the 20th century. Yet the academic discipline of robotics, or *robotto kōgaku* (literally translated as robotic engineering), was established only in the 1990s. Today, Japan is one of the pioneering countries in robotics. The sheer number of robots being developed and produced makes the robots unusually visible in the mainstream cultural sphere. Moreover, support for robotics research, either from the governmental bodies or private corporations, is significant. The strong presence of robots in both fiction and in reality makes Japan an important and fascinating place to examine the emergence of robots.

Anthropologist Akinori Kubo offers a detailed account of how the concept of the robot entered the Japanese cultural sphere, pointing to links where popular imaginaries became linked with material realities. Kubo's account depicts that *R.U.R.,* performed in theater first time in Japan in 1924, was a considerable success. Kubo asserts that the story had been first taken as a criticism of capitalistic systems. He quotes the actor Koreya Senda who spoke about the exhilaration of playing the role of the artificial human who revolts against the capitalists (Inoue 1993, quoted in Kubo 2015, 48).

Just a few years after *R.U.R.* depicted a world of artificial laborers, the American company Westinghouse had built Televox (1927), a telephone answering machine. Televox was quickly likened to the robot in the media. *The New York Times* wrote that it is "the nearest to a robot" (Kubo 2015, 49, originally New York Times, Oct 23, 1927). Following this portrayal, the design of the Televox changed into a humanoid shape with arms and legs and a crude representation of a face, which was exhibited in Washington in 1928 (Kubo 2015, 50). Consequently, the association of Televox with Čapek's robots strengthened, and the introduction of Televox to Japan followed this pattern. For instance, an article on Televox in the magazine *Kagaku Gahō* introduced Televox as the realization of the artificial human depicted by Čapek (Kubo 2015, 50).

According to Kubo, this association is indicative of a turn in the image of the robot. Initially the robot was made of a synthetic living material, yet after Televox the mechanical body came forward as the norm. Perhaps it can be thought of as the robot merging with the heritage of the automaton. Thus, Kubo offers two examples of the mechanization of the body of the robot, one a real-life machine, another fictional. "Eric" is a humanoid machine much akin to an automaton exhibited in London in 1928; it was called the “New Mechanical Man” (see Riskin 2016, 301) in English media at the time, and it had R.U.R. embossed on its torso. Kubo’s other example is the robotic character Maria from the 1927 film *Metropolis* which reinforces the idea of the robot having a mechanical body (Kubo 2015, 52–56).

According to Kubo, in the late 1920s and early 30s, Japanese media and popular science outlets contained many instances where early technologies associated with robots were introduced inaccurately. During this period, the robot was perceived as something akin to an opaque mirror that reflected the shape of a future already approaching in the West where the boundaries between science and culture, as well as between fact and fiction get blurred (Kubo 2015, 58).

In contrast with the West, however, in the Japanese cultural sphere the robot came to be associated with a rather positive future. The Japanese biologist Makoto Nishimura unveiled what is considered the first robot of the East, the *Gakutensoku* in 1928. Much like its contemporaries, *Gakutensoku,* whose name means: “learning the rules of the heavens”, was basically a humanoid automaton. Its novelty was the ability to change facial expression. After its initial exhibition in Kyoto, *Gakutensoku* was taken to many cities and eventually to Germany where it was lost (Osaka Science Museum 2008). A reconstructed version of *Gakutensoku* is presently being exhibited in the Osaka Science Museum (cf. Kubo 2015).

Meanwhile in the West, especially in the US, stories about mechanical humans began to appear in pulp magazines in the 1920s. These magazines enjoyed wide distribution because they were affordable and open for unsolicited submissions. The pulp era, not coincidentally, was also where the now dominant genre conventions of sf emerged. Yet this did not have a direct impact on Japanese conceptions of the robot since most stories were not immediately translated into Japanese. Such translations happened only after the 40s, with the “Golden Age” of Western sf.

Japanese robot fiction flourished in the second half of the 20th century. Beginning with Osamu Tezuka's *Astro Boy* (*Tetsuwan Atomu*), which was first serialized in 1958, robots in Japanese popular fiction grew not only in numbers but also in the variety of their representations. Even in *Astro Boy,* the robots were not solely humanoid, though the protagonist was. In the following decades, Japanese anime, manga, and video games have produced robots in countless shapes and capabilities.

Contemporary with *Astro Boy*, the serialization of Misuteru Yokoyama's manga titled *Tetsujin 28-go* initiated the giant robot subgenre. *Tetsujin 28-go* is the story of a boy detective called Shōtarō Kaneda who controls a giant robot built by his father. In *Tetsujin 28-go,* the robot itself is not autonomous but rather similar to a tool. However, the connection between Kaneda and Tetsujin 28-go became important because it opened up a new kind of symbiotic relationship between the robot and the human (cf. Kubo 2015).

Tetsujin 28-go was followed by Go Nagai's *Mazinger Z* (serialized between 1972-1973). This was another important manga for the giant robot or *mecha* subgenre, since, unlike the remotely operated Tetsujin 28-go, the robot Mazinger Z is controlled from the inside. Over time, the *mecha* subgenre came to be dominated by piloted giant robots that are most often non-sentient. One of the most prominent *mecha* franchises, Gundam, appeared first on TV in 1979, and has intermittently produced new anime series, manga, films, and merchandise ever since. The ever-growing material culture around the *mecha* subgenre in the form of toys, character goods, and fan-made goods helped making this immensely popular sub-genre more visible in the daily lives of the Japanese (cf. Allison 2006, Kubo 2015).

In addition to giant robots, one more popular theme in Japanese robot fiction deserves mention. This is the female robot or gynoid. From *Dr. Slump*'s (Akira Toriyama, a manga serialized between 1980-1984) Arale Norimaki, a little girl robot with super strength, to the highly sexualized gynoids of *Chobits* (Clamp manga collective, a manga serialized between

2000-2002), many works of Japanese sf, including prose fiction, feature robots with female bodies. In regard to the emergence of Japanese humanoid robots, the gendered robot is important because there is also a tendency in real-life robotics towards making female androids (see Chapter 3).[9]

In the meantime, the idea of industrial robots gained momentum in the US in the 1950s (Ishiguro et. al. 2007, 14). The material possibilities and applications gave robotics research its first attainable target, which was to reduce the workload of human beings on factory floors. As discussed in the following section, the humanoid robots followed a couple of decades later.

1.3. The Robot in Technoscience

Described as "machines that have the form and function of humans" (Bekey et al. 2008, 71)[10], humanoid robots are the closest to the original conception of robots, found in sf. However, similar to the ambiguity of the term "robot", the descriptor "humanoid" is not necessarily authoritative in what can be called humanoid. Therefore humanoid robots vary in size, in their semblance to humans, and in their capabilities.

In 2006, the World Technology Evaluation Center (WTEC) conducted a comprehensive study of the status of research and development in robotics outside the US. They visited 50 public and private institutions and gathered data on lines of research, funding, interactions with other bodies, etc. (Bekey et al. 2008, 5–6). Their findings were used for a comparison with the state of art in the US and for assessing the future of robotics research.

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[9] There are male androids as well; but a considerable majority of androids are female. For example, the HRP-4C of the National Advanced Institute of Science and Technology (AIST, cf. Kaneko et al 2004), Actroid-DER series of Kokoro Robotics (cf. Kokoro 2015) and Osaka University, Geminoids (cf. ATR 2015) of ATR Intelligence Robotics and Communications Laboratories and Osaka University are all female robots.

[10] This description is widely agreed upon in robotics. Another attempt at formulation was by the roboticist and philosopher Masahiro Mori, who talks about three aspects: body (体), appearance (相), and function (用).（Mori 2014, 78）

According to this study, Japan and South Korea "lead in technology for robot mobility, humanoid robots, and some aspects of service and personal robots including entertainment" (Bekey et al. 2008, 6). This research in both countries is fueled by national strategic initiatives.

Humanoids generally have two subsystems: lower bodies with legs, wheels or tracks that provide locomotion and upper bodies that interact with the environment and perform work (Bekey et al. 2008, 71). This description only covers part of the humanoids that are in use today, and must be considered as a rather broad roadmap for future robotics. For instance, the Geminoid series of ATR labs do not have locomotion; still they are extremely human-like and considered to be humanoid robots (ATR 2015).

The first humanoid robot in real life was WABOT-1, completed in 1973. Japanese mechanical engineer Ichirō Katō started the WABOT project at Waseda University in 1970 (Kawashima and Tadano 2014, 3). This research on humanoids spread to other universities and companies in Japan, as well as to the rest of the world. In the following 50 years of research, robots have grown to move more like human beings. Honda, for example, has been developing ASIMO, which had for long been state of art in terms of humanlike locomotion, since the 1990s (Kawashima and Tadano 2014, 3; Kaneko et al. 2004, 1984).

1.3.1 On the Uselessness of the Humanoid Robot

"What is a humanoid robot good for?" is, in fact, quite a confusing question. It is relatively easy to tell what a wrench is for, or a car, or a mobile phone. Those technologies do something better than other alternatives – they have a domain of application in which they are unsurpassed, what is today called a "killer app." But the humanoid robot does not have a killer app (Bekey et al. 2008, 86; Ishiguro and Ikeya 2010). There are indeed situations where having a humanoid body is *potentially* advantageous for a robot, for example, if they are to share intimate space with humans or need to use tools designed for average human bodies. In practice, however, a humanoid body is almost never a must and the vast majority of robots currently in use neither need nor have one.

Nevertheless, if we hold on to the question a bit longer, what *might* humanoid robots be good for? They could be used in the military and for security, in medical services, or also in homes, space, manufacturing, and for dangerous jobs such as construction or firefighting (Bekey et al. 2008, 86). In addition, in newer branches of robotics there is a growing trend to use humanoids as laboratory equipment in an effort to replicate human cognition and psychological development (Kemiksiz 2019) .

In the context of Japanese techno-scientific discourse, the "ageing society" (*kōreika shakai*) is also an important keyword (Ishiguro et al. 2007, 162; Kawashima and Tadano 2014, 4). In the popular science book *Hajimete no robottokōgaku* (First Steps to Robotics), the authors paint a vision of a future Japanese society where "next generation robots" alleviate the workload of younger generations in the ageing Japanese society by taking on housework, caring for the elderly, or working in search-and-rescue and medical services (Ishiguro et al. 2007, 162). Indeed, the ageing society and the corresponding labor shortage is ubiquitous in scientific writing on robotics as well as in Japanese media and policy communication. For example, Jennifer Robertson's (2018) anthropological analysis explores robotic labor in relation to changing Japanese demographics.

However, though these ideas for what humanoid robots might do are prominent, they are all in the realm of potential, without an estimated time for a breakthrough. While humanoids such as Softbank's *Pepper*, which is used for "entertainment" do exist, it would be a stretch to say they fulfill any deep societal need (cf. White 2018). All in all, the honest answer to what humanoid robots are presently good for is "not much." This is brought home by the roboticist Junichi Takeno, who admits that "humanoids are not yet good for practical use" (2013, 10).

Figure 2. A malfunctioning NAO at the Matsumoto laboratory, waiting for repairs (Photo by author).

Takeno cites doubts about the effectiveness of bipedal walking and safety as major stumbling blocks for the practical utility of humanoids, and it is, in fact, very difficult to make humanoid robot bodies move like their organic counterparts.

From 2012 to 2015, the US Defense Advanced Research Projects Agency (DARPA) held a worldwide robotics challenge with the purpose of developing rescue robots "capable of executing complex tasks in dangerous, degraded, human-engineered environments" (DARPA, n.d.) Almost all the robots that reached the finals were bipedal humanoids developed by some of the world's top laboratories, yet many executed the tasks so poorly that videos of the robots falling down became an Internet phenomenon for some time after the competition. During my fieldwork, I have heard "[it] didn't move well" countless times, and repeatedly seen researchers get frustrated about the limitations of their robotic platforms, not to mention the amount of maintenance required to keep them working. All laboratories have robots lying around (see *Fig. 1*) waiting to be repaired or simply discarded. The only time I have seen robots performing almost flawlessly was at an automotive factory where I worked for a short time; and they were neither humanoid nor had any sense of the environment where they conducted their tasks.

The recent humanoid robots are making use of machine learning technologies, which seem to be quite useful in specific pattern recognition tasks, sometimes even better than humans. However, as software developer and journalist Meredith Broussard breaks it down for the reader in her book *Artificial Unintelligence* (2018), even in the most productive ways of utilizing machine learning technologies, there are quite a lot of shortcomings that need to be taken into consideration when building expectations thereof. The developments in machine learning technologies constitute an integral part of the recent boom in humanoid robotics, but such technologies have limitations on what they can actually do, and further discussed in *Surrogate Humanity* (2019) of anthropologists Neda Atanasoski and Kalindi Vora, they tend to embody the many biases held by their designers.

In sum, then, the robot certainly does not have to be humanoid to be a viable technology. And yet, there is significant interest in humanoid robotics worldwide. In Japan, for example, many technology and automotive giants—Honda, Toyota, Sharp, Mitsubishi—have their own humanoid robots. Despite news of the shutdown of Honda's ASIMO program (Furukawa 2018) and of Rethink Robotics which developed the humanoids Baxter and Sawyer (Vincent 2018) in 2018, humanoid research is growing along with general trends in robotics and AI.

1.3.2. Robot the Tool

This brief survey of the humanoid robot in technoscience shows that the humanoid robot does not necessarily serve a unique function. Yet here we are, seeing humanoid robots increasingly in public, with sensational news articles coming out every other day.

The physicist and philosopher Masanao Toda wrote a deeply speculative book on robots titled *Man, Robot, and Society* (1982) in which he discusses—among other things—why robots are being made. He describes the use of machines in regard to human capabilities: they supplant and augment human functions (24–25) while acknowledging that "they are the entities into which we are intentionally trying hard to blow a spark of life" (24). The utilitarian intention in making the robots, which he frames as creating "more efficient slaves" (24) cannot by itself explain the drive to make robots, so he adds a variety of desires from the desire to live better lives to the desire to create (25)—which are quite different, he admits, but contributes to the making of robots nevertheless. It must be noted that Toda, despite his in-depth philosophizing in what the robots can become, does not formalize what he does with his book; which is trying to understand or philosophize about human concepts through a series of speculative thought experiments. He discusses a variety of human concepts including time, sociality, emotions through figurative robots in his book, yet he does not propose that robots can also be tools to think (with).

In this context, the present research is concerned with an aspect of the humanoid robot that often falls somewhat in the background, given all the fascination, hype, and promises. That aspect is that the *robot is a tool to think with*, as indeed the automaton was in the 18th century, but perhaps now even more so. For more than two centuries depictions of fictional robots have been concerned with what the human is, and how "it" relates to the artificial (non-)human. Eventually, as the robot found its way to the laboratories, it became a tool that held tantalizing promises for enabling better understandings of humans and other life forms. Despite the fact that the robot has always had the potential to act in this way, a newer understanding of intelligence, called embodied intelligence, has propelled such research since the 90s.

One of the main arguments for the development of humanoid robots stems from discussions on embodiment in robotics and computer science. Artificial intelligence (A.I.) has been an important topic in computer science since the development of early computers (cf. Turing 1950). The question of what to call an A.I., or how to make one, has been endlessly discussed in comparison with human intelligence. Only recently, however, has the importance of having a body gained attention (Cf. Pfeifer and Bongard 2007). According to the embodiment argument, the body of the agent sets the limits and possibilities for the ways in which an agent can interact with an environment. Embodiment also provides the actor with a meaningful structure to such interactions, thus constituting a physical infrastructure for cognition and action (Kuniyoshi et al., 2007, quoted in Asada et al., 2009, 12). In order to make artificial systems more humanlike in intelligence, robotic bodies, especially humanoid bodies, are therefore considered crucial (Pfeifer and Bongard 2007, xix). Especially in cognitive and developmental robotics, Japanese scholars have thus come to focus on embodiment with a view to making humanoid robots (Cf. Asada et al. 2001, 2009).

Briefly stated, the notion of embodied intelligence brought about a gradual shift in the design of artificial agents including algorithms and robots. It also led to the formation of new research areas shading into various disciplines and relying on novel combinations of theories and methodologies. One particular impact of the “embodied turn” (Pfeifer and Bongard 2007) was to open up new ways of thinking about intelligence, inspired by various life forms. Among other things, an increasing amount of robotics research, which previously used control engineering to reproduce human kinematic motions, began to find inspiration in cognitive or bio-inspired fields. In cognitive and developmental robotics, a new generation of scholars has thus developed what is known as the “synthetic approach,” which, in a nutshell, aims to understand human embodied intelligence by making or recreating it in robots (Pfeifer and Bongard 2007, 21). This located the engineering efforts to create AI and robots in the context of broader explorations of human nature. The synthetic approach entails the assumption that making more intelligent agents deepens our understanding of intelligence —or some of its aspects.

In light of the history section, it is clear that the "synthetic approach" is not groundbreakingly novel. The robot and its predecessors have always been tools to think with, or to explore with, and in some sense the emphasis on understanding-by-making is quite parallel to what was done with the automata did in the 18th century: illuminating humanlike traits by replicating them in a machine, creating enchanting machines by disenchanting aspects of being human (cf. Suchman 2007). Nevertheless, the ways in which humanoid robots are turned into tools to think with in Japanese laboratories today are distinctive.

Katherine Hayles, a highly influential literature and media scholar, discusses how an analogy made between human and machine has made a lot of technoscientific developments (including cybernetics) possible (Hayles 1999, 91). Indeed, as we can see from the history of automata, such an analogy that allows thinking of the human in machinic terms has existed for a long while, and it has produced countless material and discursive figurations.

On the other side, the slide to prominence of such practices has created the sites in which this research has been conducted. Laboratory robots, the least useful of all robots (in an industrial capitalistic sense) are at the core of this dissertation. In the next section I discuss the anthropological interest in robots in general to wrap up the many facets of the robot multiple.

1.4. The Robot in Anthropology

Eventually, robots also began to pique the curiosity of some anthropologists. Considering that they started to appear in the real world soon after the term was coined by Čapek, it could be said that anthropological interest was somewhat belated. By the late 20th century, automation with industrial robots had transformed factories (e.g. Zuboff 1988). Yet what mainly attracted anthropologists was not so much these prosaic working robots as different kinds that shared the intimate social spheres of people.

Within the anthropology of (Japanese) robots, Jennifer Robertson's work is exemplary in this regard. She has closely examined the socio-economic dynamics of Japanese robotics and their role in the supposedly post-human transformation of Japanese society, connected with problems such as an ageing society, gender issues and a labor shortage, and often tied to the claim that the Japanese belief system is relatively more welcoming to robots than those of Western countries (Robertson 2007, 2010a, 2010b, 2011, 2014). For Robertson, robots are thus mirrors that reflect Japanese society and its political economy. Her work, in general, reads more like an analysis of Japanese culture and society in which the robot fits in; in comparison, my study puts empirical data gathered in robotics in the front and center, less concerned with the robot in society. Furthermore, as we shall see, this emphasis on cultural particularity is not necessarily shared with roboticists, who see the robot as a synthetic means to explore an imagined universal human nature.

In fact, the practices of robotics are not totally absent in Robertson's studies. For example, she has commented on embodied intelligence and its importance for Japanese roboticists (e.g. Robertson 2007, 2010, 2014). It is fair to say, however, that the cultural parameters of her analytical framework have remained stable. Yet, while keywords like "ageing society" or "labor shortage" also show up with some frequency in the discourse of roboticists, their main function is to signal the value of their research to outsiders. Because it is common and often necessary to tie research to general societal concerns, roboticists working in Japan do indeed allude to the demographic and economic issues of the country. For roboticists engaged in research on embodied intelligence, however, these terms are rather marginal. For my informants, at least, what matters is to understand human cognition in order to make better robots, while any societal benefit this may generate is a secondary added value. In order to understand the practices through which robots are actually imagined, built, and transformed, it is thus necessary to probe deeper into the practices of the roboticists themselves.

The American anthropologist Kathleen Richardson has also written on the anthropology of robots and AI (Richardson 2015, 2018). Despite her knack of finding and accessing sites that are meaningful for robotics research, her analyses and understandings feel shallow, with a hint of a predestined future for the robots, downplaying the potentiality that lies wherein. Her book titled *Challenging Sociality* (2018), based on a failed experiment with robots and children with autism also lacks an insightful and critical look into what autism is in research featuring robots, which for me, constituted a faulty premise to begin with. Still, as it is with many of the other anthropologists that I briefly introduced here, Richardson too will be featured in later chapters where necessary.

The anthropologist Lucy Suchman pioneered discussions on computational artifacts, focusing particularly on their interaction with humans. The second edition of her *Human-Machine Reconfigurations: Plans and Situated Actions* (2007) was expanded with analyses of developments in robotics and AI since the mid-1990s –the same general developments that shaped my field site. Human-machine interaction, in Suchman's reading, becomes the basis for the figuring of—in fact configuring of—human and machine: in simpler words, the human and the machine are configured through their interactions in these technoscientific disciplines. Suchman's comprehensive and critical account of computational artifacts across disciplines, studied through the lens of feminist science studies, has been particularly inspirational for my own thinking about the material-semiotics of the robot.

An anthropological orientation towards the practice of robotics is exemplified by Akinori Kubo's *Robotto no Jinruigaku* (*The Anthropology of the Robot,* 2015), which provides a detailed history of robots in Japanese popular fiction and technology. Based on fieldwork with communities focused on the robot dog AIBO, the book offers a wide examination of the robot in mainstream culture, drawing attention also to the importance of paradigms by Japanese *anime* and *manga* critics. Rather than treating robots as a mirror of Japanese society, Kubo depicts robots as hybrids emerging from transdisciplinary movements of ideas and imaginations across popular culture, engineering and science. Kubo's work is interesting due to its multidimensionality and because it pays close attention to the situated concerns of divergent practitioners.

I learned quite a lot about the reception of the robot in Japan from Kubo's work, and as he is also quite well versed in popular media, his readings have helped me enrich my understanding of the tropes and figures in the representations of the science fictional robot. Lucy Suchman's writings, equally importantly, have contributed to how I frame my findings.

1.5. Conclusion

In sum, the concept of the robot should be thought in its multiplicity and the relevant trajectories that contribute to its various enactments. The robot as the boundary figure or as the artificial Other has a peculiar historicity which is discussed in this chapter starting from a previous such figure: the automaton. The obvious parallels between the two point out to an underlining and everlasting fascination with the humanlike machine as the reflection of the human—as a tool to understand what makes us human.

In this chapter, I also briefly introduced the robot in fiction and in technoscience, with a dedicated focus on Japan, to prepare for the following chapters that focus mainly on Japanese robotics. I finished the chapter by giving a broad review of the anthropological interest in robotics and AI, upon which this dissertation aims to contribute.

The following chapter will focus primarily on my fieldwork, dissecting my field sites to position and contextualize the analysis that follows.

2

Matsumoto Laboratory

In this chapter I introduce my fieldwork. This research was initially intended to be a laboratory ethnography, but it turned out to be a multi-sited ethnography with a laboratory being the main locus. I spent more than nine months at a cognitive robotics laboratory at a university in Kantō region, which I will call Matsumoto Laboratory. I also have been following academic and public events regarding robotics, AI, and the intersecting disciplines for over 4 years, which will be explained in section 2.4 of this chapter.

Despite decades of anthropological literature, the laboratory remains a peculiar site for ethnography. From the late 70s onwards, anthropologists have increasingly occupied sites where sciences take place, from laboratories (cf. Traweek 1980), to following practitioners to their field sites (cf. Latour 1987). Science studies scholars such as Donna Haraway have initiated ways of reading science critically; and, indeed Haraway herself has ushered in feminist science studies (cf. Haraway 1985). It is perhaps obvious that critical *readings* of science do not engage the laboratory in the same manner as ethnographic fieldwork, but both approaches have provided crucial insights for STS. Indeed, ethnography provides certain proximity to the target that might not be visible in readings, yet the distance kept in critical studies has its value, as one can be too close to the field therefore losing the critical eye necessary in any social science. In fact, the boundaries have become blurred since then, as “representations” in science and technology include quite a lot of media (in terms of visualizations, films, graphs) that can and should be interpreted by the help of those who had traditionally worked with such media i.e. cultural and critical studies (cf. Coopmans et al 2014).

Pioneers such as Bruno Latour, Steve Woolgar, Karin Knorr-Cetina, and others, have made the laboratory a more acceptable field site for anthropologists; yet, that did not mean that laboratories have become more welcoming towards anthropologists. Anthropologist Nick Seaver takes up anthropologist Laura Nader's concept of "studying up" (Nader 1972), in other words, studying those in power, and discusses it in the context of ethnographies of technoscience, drawing parallelisms between the study of users of technology and colonialist anthropology's study of the "savages" (Seaver 2014). Studying up, he reminds, poses different challenges for the ethnographer including access and research positioning. Consequently, despite the convenient locations of research institutes and universities, the laboratory may be a difficult field site to enter, guarded by protocols of security and a general skepticism towards outsiders. Even though I had multiple connections and my base in Japan, I was refused substantial access to a very big laboratory in my first year, the reason buried in a series of long, vague exchanges of Japanese-business-style emails hinting that I would be a "burden" for the people working in the laboratory.

In the end, it took me a year to get continuous access to a laboratory. By the time I secured a space in Matsumoto laboratory I had obtained multiple alternative options for a field site, and it is thus relevant to note that I chose this particular laboratory mainly because of interviews I had already carried out with Professor Matsumoto. His was neither the biggest nor the most famous laboratory but he showed openness and initial trust that made me think that his laboratory would welcome my fieldwork. Furthermore, his laboratory seemed at the time to be quite representative of both robotics *and* AI in Japan, compared with some other laboratories that pursue more specific or unique types of robotics research. Nevertheless, the barely veiled suggestion that I would be a "burden" stayed with me for the duration of my fieldwork. Concretely, it meant that I took care not to stay in a single field site for too long.

After the advent of Actor Network Theory (ANT)-style laboratory studies, it is almost customary for the anthropologist of science and technology to follow the scientist and study the networks of science. In reality, the very fast-paced and competitive worlds of frontier technoscience create numerous barriers. Importantly, I could not follow my interlocutors just *everywhere*, since they were part of industry collaborations for which I would be unable to get permissions. My solution was to follow the researchers to the quite varied places they allowed me to go, which practically meant that I engaged in years of what can be termed event-ethnography. Since the worlds of Japanese cognitive and developmental robotics are relatively small, this body of fieldwork provided quite a lot of relevant research materials.

In conjunction with my background in cultural studies and my education as an anthropologist with an ontology oriented, ANT informed focus (see Morita 2013, Gad and Jensen 2010), another clarification might be deemed necessary. I cannot minimize my agency in the field as it used to be ideal in initial views of laboratory ethnography. Furthermore, my ethnography is situated; the connections I make are not free of who I am, a non-Japanese woman ethnographer in a robotics laboratory. On the one hand, I cannot help but stand out in most of my sites due to how I look in mostly-male, mostly Japanese places. On the other hand, the story of this dissertation which I told in the introduction has given me the particular standpoint that is more likely to be unique to me among the anthropologists who study robots and AI.

In sum, it is particularly important to have a deeper understanding of the laboratory and all that is within when it comes to my field, robotics and AI, as critical readings based on the output of the disciplines only brush the surface of the deep and complex knowledge-making mechanisms. There are a lot of relations that are either invisible to most, or just taken for granted in the research outputs of these fields, which became tangible to me after a long and inquisitive period of fieldwork. In this chapter I introduce the laboratory and its blurred boundaries with the outside, the connected sites where the robot becomes multiple. Relating these in detail and through the lens of my own experiences that as I mentioned above might differ from a Japanese man, I aim to lay down the groundwork upon which the rest of my dissertation will enfold.

2.1. The Empty Laboratory

My first official day at Matsumoto laboratory[11] made quite a big impression on me. I had visited the laboratory twice before, once to interview Matsumoto, and once to present my work and ask permission to do fieldwork in his laboratory. After our second meeting, he showed me an empty desk and told me that he had already saved my space in the laboratory. Two months later, I moved to the Kantō area, initially to a place quite far from the laboratory, and I started doing my fieldwork.

On this official first day, I went to the laboratory at precisely 1 pm, with the presumption that there will be many people in the room and it would be a quick introduction on my part. I entered the room—at the time the only room that I knew—and it was empty. I felt confused at first, and wondered whether I am in the right room or not, and if it was alright for me to be there just by myself. Still, I sat down at my desk, made myself slightly more comfortable, and started looking around.

My desk was in the main room of Matsumoto Laboratory, which has multiple rooms in four different buildings. It's a university laboratory, housed in a tall, modernist building in a relatively new campus of the university. The building, both in and outside, is dressed in grays, as is common to the modern university aesthetics of Japan. The room also was also decorated in grayish hues, with rows of desks for around 12 people. Matsumoto's office, where he and his secretaries work, is sectioned off by a wall but does not have a door.

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[11] In Japan, the general term used for laboratory is "*kenkyūshitsu*" （研究室, literally means "research room," and it applies to all areas of research; therefore people who study law for instance also have laboratories, as do anthropologists.

This room is not only the physically bigger one, but it also has a big conference table right at the entrance. This is where laboratory meetings or meetings with people from outside of the laboratory take place. To the right of the conference table from the vantage point of the door, there is an enormous touch-screen, which is used to project slideshows, videos, papers, etc., during meetings. I was later told that in some after-hours the students have used the screen to play video games such as *Mario Kart*. Behind the conference table are desks, among which there are spaces to move but the peripheries of the laboratory are lined with equipment. The "equipment" includes white boards, a printer, a coffee machine, rolled up posters from previous conferences, cartridges, computer parts, and robots of various kinds. In line with the purpose of the room, which is to hold meetings, the presence of robots is not distracting. In fact, for the most part, they are rather small robots lying around scattered in the laboratory.

While I was waiting for people to arrive, I looked around to see what people have at their desks: someone had an Indonesian *Wayang* puppet hanging on the wall, another had a multitude of art books on their shelves, including books about Munch, Kandinsky, Klee. Someone had a football under their desk and I wondered if it was for an experiment or for blowing off steam. Was there even space to play football on that campus? It is normal for working spaces to have personal items of the people who work there, but in a robotics laboratory, things that may look personal can indeed blend into the research. The robots in such laboratories execute tasks in the experiments, which more often than not require object manipulation. Sometimes, the interesting objects that lie around in the laboratory can be parts of the experiments themselves. The art books belonged to a graduate student, Mamoru Yoshida, who was teaching a robot how to draw things. The football turned out to be a personal item, but I later learned that another graduate student was working on getting a robot to interact with different types of balls. Furthermore, with this kind of experimental design, where the task might be left to the researcher to decide, there can be a personal element. Inspirations of the researcher transferred onto the experimental system, and can therefore result in robots that dance, cook, play the drums, etc.[12]

Back in the lab, I began examining some posters up-close only to shortly realize that there was in fact someone in the adjoining space, Matsumoto's office. Thus, I was introduced to Dr. Ryōji Kobayashi. At the time, he was a "Junior Researcher and Lecturer" at the laboratory but in less than a year he was promoted to associate professor. I told him who I was and why I was there, something about which he had a vague idea. He asked me if I was into psychology, and I went on to explain what anthropologists do, exemplifying with rather traditional cases of ethnography. He then said, "so you are doing research on robotic tribes," which was followed by laughter. Bruno Latour and Steve Woolgar too described scientists in the laboratory as "a strange tribe who spend the greatest part of their day coding, marking, altering, correcting, reading, and writing." (1979, 49) Anthropologist Karin Knorr-Cetina likewise calls scientists "one of the most powerful and esoteric tribes in the modern world" (Knorr-Cetina 1995, 141) which applies perfectly to robotics and AI circles.

I was reminded of the anthropologist Wakana Suzuki's main interlocutor Murakami, the head of a laboratory in a Japanese stem cell laboratory, who introduced Suzuki to new members of her laboratory as "an anthropologist who is observing scientists as [if they were] monkeys" (Suzuki 2018, 13). During my early time in the laboratory, a graduate student told me that he suspected that I was a spy, only half-jokingly. A couple of weeks and two interviews later, he told me that he changed his mind and he no longer thought of me as a spy; he thought that I was a more like a priest, as people often came to confess to me. If laboratories are still quite peculiar field sites for anthropologists, it seemed that an ethnographer in the laboratory

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[12] A group of students from the laboratory participated in a prestigious technoscience challenge that is not directly related to robotics or AI and won an award. When I was talking to Prof. Matsumoto about it, he seemed torn, both proud and concerned as he said, "If only they had spent that much time on their own research…" Yet as we discussed further on, he acknowledged that such passions beyond the robot translate into the robotics research in one way or another.

is yet stranger for its usual occupants. Indeed, we are odd presences in technoscientific laboratories. Not really initiated to the esoteric society, but not quite outside either.

Right after our brief introduction, I asked Dr. Kobayashi if there something else happening and why there is practically nobody at the laboratory, to which he replied, "there is nothing now, that is why there is nobody here. In the afternoon there will be the general meeting so everyone will arrive sooner or later". In retrospect, this was quite indicative of how fieldwork was going to be for me. First off, the laboratories that I've been to and read about, particularly in Japan, are very busy spaces. A roboticist in a "busy" Japanese laboratory told me once that his principal investigator sent him to get a psychological evaluation because he was late to a meeting once. As my own working environment was also Japanese, I could vividly imagine how grinding laboratory lives could get. For example, I knew from my own university that walking around at late night on winter break, one can see many lights on. Readers who are not familiar with Japanese academia might find this troubling, but in many laboratories, doing overtime, or even staying the night, is ordinary. I had a friend in one of the humanoid robotics laboratories of Osaka University, who complained that staying in the laboratory overnight also had an added creepiness to it because he had to share the room with humanoids in the dark, silent building.[13]

Frontier sciences, where getting the research out fast is very important, are even more infamous when it comes to how demanding the laboratory can be. So I fully expected to do fieldwork in a busy laboratory, and I found myself in an empty laboratory. What accounts for the emptiness is partially the fact that a lot of the students with whom I shared the room were taking classes. Furthermore, I learned later that most of the laboratory members participate in

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[13] He was talking about particular robots that are unsettling even in daylight. Moreover, the reader must know that the laboratory robots are not always as presentable as their demonstrating counterparts, with silicone casing removed and innards exposed.

collaborations with different companies and institutions, which means that they spent a significant time of theirs at their collaborators' laboratories.

For the most part of a year that I was in that laboratory, there were many hours I spent in the room alone; there were days I opened the laboratory, and there were days I closed it. The empty laboratory became my time to digest, particularly once I got used to the feeling of transgression and estrangement. I used that time to think, to read robotics literature, and to work on my notes.

For the longest time, the laboratory rooms of Matsumoto laboratory looked ordinary to me, except for the robots here and there. It was familiar, not so different from the place I myself work. Yet this was a robotics laboratory, and the fact that it was not *so* different did not register as interesting until later in my fieldwork.

Most of the people worked on rather small robots in Matsumoto laboratory (see Chapter 3), and those who did work on bigger robots did so in different locations. When the laboratory had purchased a Baxter (with a height of 178-192 cm), where to put it became a problem for a while. I had a casual talk about it with Matsumoto a lot later on a bus ride to a banquet. He explained that it is not a simple logistics issue. In general, Japanese offices and homes are small, and the same goes for universities. Moreover, Matsumoto's laboratory is at a private university and his campus located in a rather central, urban area—unlike some publicly funded universities or institutions with wide campuses outside of the urban areas. Therefore, unbeknownst to most students and outsiders, space is a scarce resource at Matsumoto laboratory. Narrow spaces meant scaling down objects and shrinking of empty spaces, as well as building alliances with those who have bigger spaces. I return to the issue later, but simply flag here that the choice of a certain robotic platform limits what it can do, which means what kind of research can be conducted in a laboratory is also related to the simple surface area of that location. There are invisible strings embedded in the space of the laboratory which shapes the knowledge-making practices on the inside.

Back on my first day, as Kobayashi had said people eventually began arriving, and I met a few of the graduate students, among them Xavier. Xavier was a “research student”[14]. I remembered noticing him during one of my previous visits to the laboratory; not only he was not Japanese but he was also quite tall. I greeted him and very briefly introduced myself. He sat at his desk but 15 minutes later he came and sat down next to me, with a smiling face. I gave him my business card, partially out of the habit of being in Japan for a long time, and partially to save time on getting people to pronounce my name right. He smiled, gave me his business card, and told me “I remember you from the time you presented your work to Prof. Matsumoto. I am so glad that you’re here. Are you going to be here on Tuesday? I am going to tell Prof. Matsumoto that I will quit.”

I was quite shocked to hear these words from someone who I had just met. I asked him why and he briefly explained why he was dissatisfied. Xavier had a quite peculiar research idea in mind, which did not align with the main research frame of the laboratory. When I talked to him later, loneliness also came up. Xavier spoke very little Japanese. Many of the students (graduate or otherwise) in the laboratory spoke rather little English, and not necessarily because they were unable. The lack of willingness to speak English created a disconnection that I also saw affecting other foreigners.

It has to be added, though, that people in the room, even those who spoke Japanese, did not talk much among themselves, either. I realized very early that people did not greet others (a “hello” or a “good morning”) when they entered the room. People would enter the room, go

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[14] “Research student” (*kenkyūsei*) is a status in Japanese academia that points to a pre-program education period. In order to select graduate students, Japanese universities hold exams at regular intervals. Foreign students often spend from 6 months to 2 years in “research student” status learning the language and familiarizing themselves with the examination that is required by their graduate schools. Research students do not earn credits nor get a diploma, but they participate in research in their respective laboratories and get to attend classes permitted by their supervisor.

straight to their desks, turn on their computers, and start working. Of course, there were times where people socialized, but it happened far less frequently than I had imagined, and most of the times, depended on a few people who acted more sociable.

This situation posed a concrete challenge for my research: how to conduct ethnographic fieldwork in a place where people hardly talk? As an ethnographer, silence and emptiness worried me at first. Conducting fieldwork in a site where most of the activities involved sitting in front of a computer is difficult, and there is not much of a roadmap to follow. The anthropologist Gary Lee Downey, who did fieldwork among computer engineers in a computer-aided design laboratory (2013) describes his strategy in detail. It included taking courses and organizing a student focus group paid to journal and discuss their learning process (28–29). Having neither the budget nor the time, I had to improvise without being obtrusive or a 'burden' to the people in the laboratory.

Eventually, I found ways to use the space to my advantage. I conducted almost all of my interviews in the same room as others (except for Xavier's, per his choice). I left the choice of interviewing place to the interviewee, but later realized that others were listening, too. This made scheduling interviews or just talking a lot easier on my part. In later interviews, especially when the teaching staff were not present, others would chime in on the topic.

Small spaces are emblematic of Japan, in both public and private, as are the population density and crowds. These simple facts have been or became the norm to my interlocutors and me. Particularly in urban areas, sharing space involves navigating attention and inattention in a certain way: "a disconnected connectedness," as anthropologist Anne Allison (Allison 2006, 71–72) characterizes train commutes in Japan.[15] The laboratory, or the workplace more generally, is like an inverted version of the train car. Since the space is shared by familiar people, careful (or feigned) inattention is performed with a view to be able to work. Recall that

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[15] Allison develops this notion out of James A. Fujii's concept of "intimate alienation" (1999).

Xavier remembered me from my presentation to Matsumoto, which had happened in the same room, sitting at the conference table. As far as I am aware, he was not watching the presentation, yet he remembered enough of the contents to talk to me about it later.

As I realized that this applies to most people in the laboratory, that they pay attention to me but not overtly, I became more vocal in the common spaces of the laboratory. Instead of trying to suppress my existence in the laboratory, I aimed to normalize it, which eventually worked. In fact, when I was saying my goodbyes to leave the laboratory at the end of my fieldwork, Ms. Yamada, who is one of the secretaries, came out with me to the elevators and said "I will miss you, you were the only one who was always greeting us when you arrived and left. It will feel lonely now."

Summarizing my initial exposure to my field site Matsumoto laboratory, I had feelings of confusion and unease, and its emptiness and silence was not familiar at all to me, despite being in Japanese academia for years. Yet it was not the only thing Matsumoto laboratory was; it was also dynamic, which I discuss in the following section.

2.2. The Dynamic Laboratory

At the time, Matsumoto Laboratory had around 40 students ranging from undergraduate 3rd years to PhD 3rd years, as well as 2 secretaries, 4 adjunct researchers, and a changing number of visiting researchers. The majority of laboratory members were Japanese, but there were some students from East Asia, Europe, and Latin America. In addition to the head Prof. Hideaki Matsumoto, and Assoc. Prof. Ryōji Kobayashi who I introduced earlier, there was another important figure in the laboratory who I call Dr. Daisuke Higuchi. Despite being only a part-time affiliate, Higuchi had helped Matsumoto build the laboratory around eight years ago. He now supervises a group of students and helps with administrative issues in the laboratory while working for his own robotic middleware venture company.

All of these people, and some more, gathered together every Friday afternoon for the general meeting. And since my first day in the laboratory was a Friday, it would be my first real dip into the world of my interlocutors. In the meantime, I learned that the laboratory consists of multiple groups[16] (班 - *han*) that gather weekly, too. The group meetings are mainly for research updates, and the general meeting has either more significant presentations (for more senior students) or presentations of selected academic papers, as part of reading comprehension.

During the time I was in the laboratory, there were three major groups: the car group, the OS manipulation group, and the cognitive group. The car group was working on self-driving cars. The members develop and test software to enable cars to navigate the streets by recognizing the environment and other cars. The cognitive group was working on using humanoid robotic platforms[17] to produce humanlike behavior through machine learning principles. The OS manipulation group was a gathering of the rest of the students at the time who worked neither on humanoids nor cars (such as cleaning robots), or those who worked on robotic middleware –on the software itself rather than the behavior produced by the software.

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[16] The word used for group here is "han" as noted above, which can be translated as a squad or a group into English. Otsuki (2019) uses the term "squad" but I chose to use "group" as my interlocutors do so in English.

[17] Robotic platforms can be understood as robotic hardware and their operating systems; often used for mass produced and widely used robots, in comparison to some robots that are developed for a certain laboratory or a project but not used elsewhere.

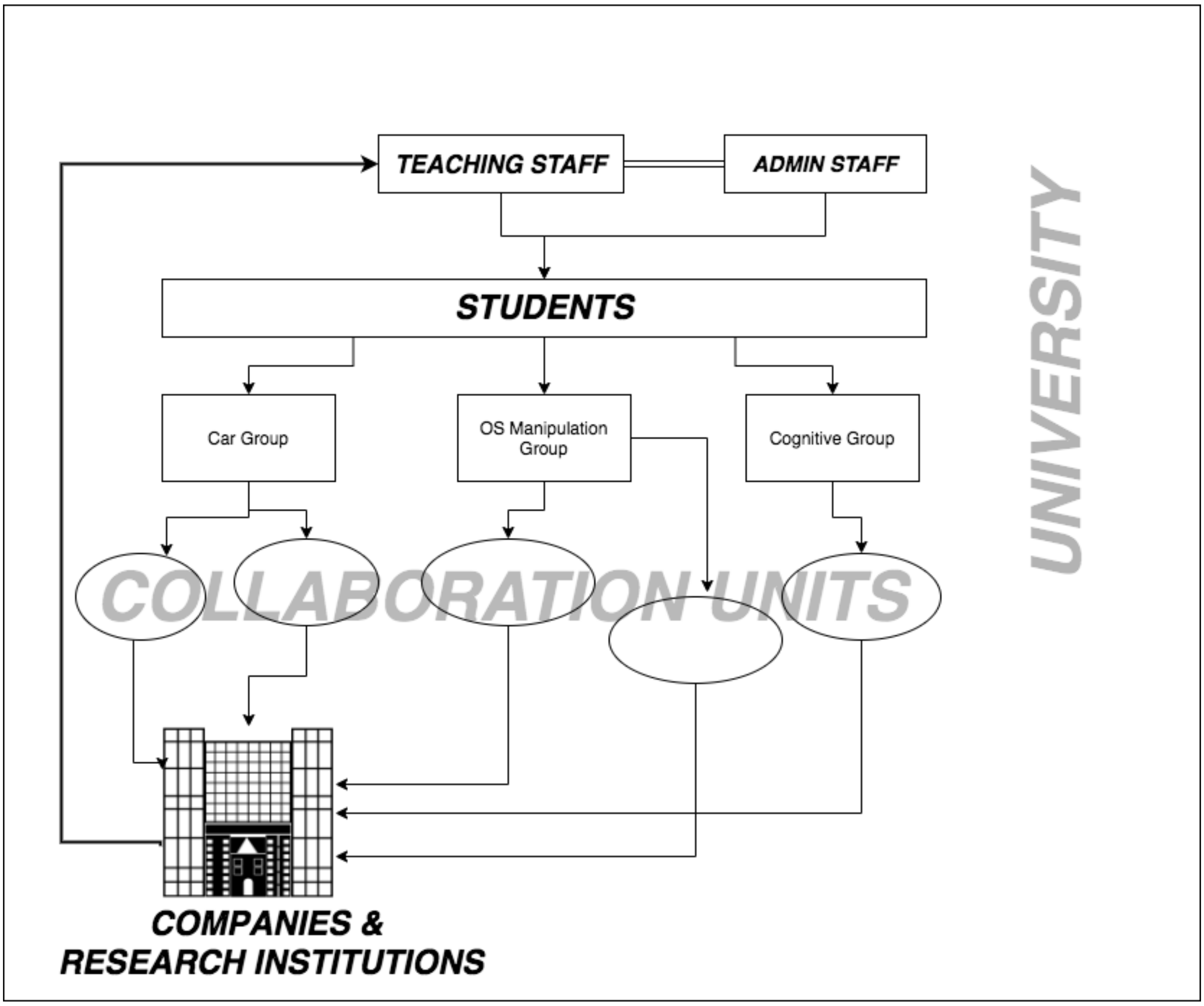

Figure 3. Organization of Matsumoto Laboratory.

Each of these groups are divided into smaller units of two to three individuals, in accordance with the collaborations with companies or research institutions. The vast majority of the members of Matsumoto laboratory were involved in some form of collaboration with another place. The companies and the institutions provide the know-how and the equipment to the laboratory member, and in turn, they get co-authorship in publications. In the fast-paced corporate world of technoscience, corporate research and development departments can boost their "academic impact" by collaborating with university laboratories.

However, this created what I view as the major deficiency in my fieldwork: very limited access to experiments. The people who collaborated with companies and institutions conducted their experiments (not simulations but robotic experiments) at the locations of their collaborators. Consequently, I had no way of accessing them. I had to make up for my lack of access by asking detailed questions regarding experimentation. I also participated in robotic experiments many times in other laboratories but the fact that I could not do so in my main field site is of course relevant. Instead, I shared the laboratory space with other members and worked on their projects, and in addition, I participated in endless meetings, the contents of which ranged from the very mundane to the crucial.

On this day, my first day and my first general meeting, I was to introduce myself to the laboratory. When it was time, I accompanied the people who had arrived in the same room into the hall. Because this was a large "general" meeting, we moved to the basement of a different building, entering a medium sized lecture room for 80-100 people. There was a big screen that doubled as a whiteboard in the center of the lecture room, and there were rows of desks all facing towards the screen, while the back of the lecture room was lined with windows that look out to a concrete wall. And, as is usually the case, there were around 40 people attending the meeting. Matsumoto waited for everyone to arrive before introducing me briefly and I then stood up and explained the what and why of my fieldwork in both Japanese and English.

My first general meeting turned out to be an utterly ordinary one. Undergraduate 3rd and 4th year students were presenting articles to the whole group followed by a discussion session. Matsumoto, in all meetings, chooses one of the center back seats. After each and every presentation, he opened the discussion with short comments or questions. For the younger students, these presentations can be beneficial in getting used to presenting papers, but also to take part in the collective reading of literature. For students who are in the upper classes, the general meeting presentations can be more serious versions of their group presentations about how their research is coming along, etc.

As was usual for the Matsumoto laboratory, the general meetings were not very intense. Sure, most students showed signs of nervousness while presenting, which is utterly normal. Matsumoto himself, however, never raised his voice to his students; even when critical, he conveyed it in a soft manner. Only a few times did I witness comments that I found harsh, and they came from the younger staff.

This provides quite a stark contrast to the anthropologist Grant Jun Otsuki's (2019) depiction of a Human Centered Technologies (HCTs) laboratory in Japan, which he calls Terada laboratory. Despite working in neighboring disciplines and in the same highly hierarchical social structures, Otsuki's Terada laboratory appears to be far stricter when it comes to imposing a certain type of membership, which prioritizes the laboratory, or work, above all else. There are indeed common practices in Japanese laboratories such as the sharing of non-research related work in the laboratory (e.g. organizing laboratory trips, keeping a record of equipment, and maintaining the server), but overall the Matsumoto laboratory seemed nowhere as rigid on how to be a good student as the Terada laboratory depicted by Otsuki.

The intricacies regarding being a member of a laboratory necessitate examining ways of belonging in Japanese social groups. On this issue, Otsuki refers to "frame-based social groups" in Sharon Traweek's (1988) and Chie Nakane's (1970) work. The '*ie*' or household way of organizing in anthropologist Sharon Traweek's ethnography of Japanese physicists (1988: 148–149) is marked by a hierarchical organization based on age, a lack of a clear-cut division of labor, and the importance of members' opinions in decision-making discussions. Traweek compares this *ie* organization to the competitive, sometimes informal "sports team" organization in the US (149).

In turn, anthropologist Chie Nakane uses two criteria to explain the sense of belonging: attribute and frame. Attribute is self-explanatory: what the individual is, and it can be something attained by birth or by achievement (1970, 2). The term "*ba,"* which means location, is Nakane's original concept for frame (1). It can be a place, an institution, a company, or a social group with which the individual is mainly involved. Nakane asserts that in Japanese society, the frame is stronger than the attribute. This should be thought in terms of identity; meaning that affiliation with a social frame—be it a company, a university, or a laboratory—is considered with priority to the attribute, which can be a sales associate, a graduate student, etc. For instance, for an anthropologist at Osaka University, it matters more that they are of Osaka University than that they are an anthropologist.[18]

Nakane's ba, or frame and its priority to attribute hold true to Matsumoto laboratory members, with the implications of *ie* discussed by Traweek to a lesser degree. Traweek's depiction of the hierarchical organization based on age is indeed present in any Japanese laboratory to which I have been, though it tends to gets rather fuzzy below the doctorate level.

Furthermore, the informality or intimacy is quite interesting in Matsumoto laboratory, which becomes apparent in their group meetings. As Matsumoto laboratory is a university laboratory with a relatively low median age (mid-20s), and considering that Matsumoto himself has an easygoing personality, one might expect a lively informal atmosphere. Yet what I have seen in daily practices paints a peculiar picture, which I discuss below.

Comparing Japanese laboratories with those in the US, Traweek states that "informality is a gift or reward bestowed by those in charge (148)." Any forms of informality in the laboratory or formalism of meetings are dependent on those higher up in the hierarchy—which is further dependent on the personality of those people, I would say. According to Traweek

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[18] However, if the laboratory is sufficiently well-known, or if they are communicating with someone who would know of the lab, one can skip the university affiliation as the main frame and introduce themselves as someone from a certain laboratory.

even if there is a certain level of informality, one should not criticize someone of higher status, which is presumably not only true for Japan but everywhere in this era of rampant precarity in academia (see Peacock 2016).

As I mentioned above, the weekly group meetings are smaller and quite intimate. They are, traditionally, about “updates,” which generally means developments regarding research. Holding such meetings (sometimes in forms of seminars) is a core practice in Japanese academia, where the students “update” the teaching staff about what they have been doing in order to facilitate supervision. Yet, contrary to all the other update meetings I’ve seen in institutions in Japan, Matsumoto Laboratory students included other kinds of updates in their presentations. The group meetings are held in the room that my desk was in, and I participated in each and every one of those meetings while I was there.

Prior to the meeting, students upload a PDF to the laboratory server, and then take turns in presenting from the youngest to the oldest. For Ph.D. students, these updates tend to have more academic context, but for undergraduates and Masters’ students there is more leeway:

> *I am learning ... program.*
>
> *I applied for a study abroad visa.*
>
> *I bought a bicycle.*

Messages similar to these, arranged in bullet points and scattered among other bullet points, were presented by a student to the group by way of reading from the PDF now displayed on the giant screen in the main room. Some weeks, particularly if a conference or the end of term is approaching, were busier with bullet points on “data taking,” “submissions,” etc., whereas some weeks had bullet points like those above.

Now this was out of the ordinary for me, not only in the context of the silence of the laboratory that I explained earlier, but in general. For good measure, I asked colleagues around in different disciplines and universities in Japan, but have not heard a similarly expressed intimacy in group meetings to those of Matsumoto laboratory members. Coupled with the fact that such bullet points are coming from people I know to be socializing differently in the context of the everyday, it is puzzling and can be perhaps explained as a byproduct of another formalism. The group meetings are about progress, and they have to take place at regular intervals. The intimate bullet points thereby serve a purpose: it is better to share a sliver of progress even outside of the laboratory life than to present no progress whatsoever.

Certainly, this kind of intimacy has its own limits and should not to be confused with informality in the sense Traweek discusses for the US laboratories she studied. For example, I have never witnessed any expression of criticism directed towards one's peers and above, especially not during meetings. If there are negative comments or criticisms, they are consistently directed from teaching staff or graduate students downwards. In fact, most younger members of groups do not talk unless they have to—as is also the case in other laboratories in Japan. However, the fact that sharing such updates has come to be the common practice in Matsumoto laboratory is no doubt due to Matsumoto fostering or at least allowing such an environment.

Anthropologist Natasha Myers describes academic laboratories as "sites where a student's ethos and habitus are still in formation" (Myers 2015, 41). She describes ethos as "the tangle of affects, values, attitudes, sentiments, styles, and sensibilities that shape practice and laboratory culture," while habitus refers to the specific set of laboratory practices (41). The peculiar ways of navigating research and personal life in regard to laboratory formalism is indeed the ethos of Matsumoto laboratory, and it strongly contrasts to that of Otsuki's Terada laboratory, for instance. In contrast to both Myers' and Otsuki's ethnographies, the ethos of the laboratory is not dictated to students by ways of educational material, but is instead taught by example from student to student.

Each laboratory is its own social unit, and has its own traditions. Some are made up along the way, from how they accept students to what they pursue in terms of research. In highly hierarchical places like university laboratories, the agency of the highest standing actor matters the most in shaping such traditions, which is discussed in the next section.

2.3. Tradition and Change

The organization of Matsumoto laboratory is mainly orchestrated by Matsumoto himself, with the help of the senior staff and his secretaries. This is a relatively new laboratory, founded less than a decade ago. In terms of team composition, this means that the laboratory members are on the younger side and the alumni are still rather few. In terms of organization, this young laboratory therefore has some hurdles to tackle.

To begin with, Matsumoto Laboratory is a "cognitive robotics" laboratory. As explained in the previous chapter, cognitive robotics is a nascent technoscientific discipline with its own challenges that go along with the short history thereof. The laboratory is housed in an interdisciplinary "engineering" institute within the university, one that combines art and media with STEM. In this department, education is multidisciplinary, and their laboratories develop newer technologies for a range of arts and sciences, such as music, cinema, psychology, robotics, etc.

That gives the curriculum at the laboratory quite a strong tint of multidisciplinarity. Undergraduate students, prior to choosing (i.e. being chosen by) their laboratories, take classes ranging from photography to cognitive science. In my interviews with the students, I've found quite a diverse array of interests, which, as mentioned before, can blend into their research with the robots. Matsumoto laboratory members, with this eclectic background, work on the software of their robots. They do not build their robots nor develop mechanical parts, as their peers in mechanical engineering-based robotics laboratories do. In conjunction, even though the teaching staff calls themselves "roboticists", most of the students do not.

One consequence is that the students, unlike Matsumoto and the other teaching staff, are not trained as mechanical engineers. They are therefore also not well acquainted with the hardware. This has been an ongoing source of worry for the teaching staff at the laboratory, even though they do not actually develop hardware in the laboratory. The many robotic platforms they use in the laboratory need frequent tweaking and maintaining. Yet the choice of the robotic platforms used in the laboratory, along with the collaborative aspect of their research helps alleviate this "issue." Some robotic platforms, such as iCub[19], require significant amounts of work solely on the maintenance: according to friends across the world who have iCubs in their laboratories, the workload is so much that it would be better to hire someone just to maintain those platforms, but nonetheless most laboratories share the load among laboratory members. In Matsumoto laboratory, most of the robots (NAOs, see Chapter 3) are much simpler in terms of their capabilities for movement and sensing. In return, their maintenance is not as demanding.

Although it is usually the companies or the institutions who approach Matsumoto with the intention of collaborating, it is Matsumoto –with the counsel of Higuchi and now Hayashi– who decides who to collaborate with and the theme of the projects. Matsumoto remarked multiple times that he does not make his students work *for* some projects devised by some companies. They work *with* the industry and the decision is ultimately with Matsumoto. In time the collaborations cease, the projects end, or the students graduate. As the projects themselves are the reason for the unit and group organization, the laboratory has a dynamic structure.

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[19] iCub is a humanoid robotic platform developed by Italian Institute of Technology as part of a European Research Project RobotCub (ICub 2004). It is a robotic platform designed by researchers to be used in research and it is mainly used in Europe.

As noted, Matsumoto is the main deciding authority in the laboratory. The students are accepted to the laboratory by Matsumoto, (if undergraduate students) in the 3rd year. At this time, they have a one-on-one meeting with Matsumoto about their skills and interests. He decides which group to place them in, and he chooses their collaborative project depending on availability. The students can come up with their own research ideas, but as is the case with many other laboratories throughout the world, the professor has the final say. I have observed that PhD students have a higher level of autonomy in terms of what they can do and even with respect to whom they want to collaborate –but not everyone takes initiative. In sum, therefore, the laboratory largely reflects Matsumoto's research interests and his vision of the laboratory organization.

When Matsumoto and Higuchi founded the lab, they modeled it *organizationally* after an older and more traditional robotics laboratory in the same university. At the end of each academic year, a "reflection meeting" (*hanseikai*) is held to revisit and revise administrational and organizational structures. In 2018, most of the items for review were evaluated in comparison with this other laboratory. Yet both the graduate school that the laboratory is housed in, and the multi-disciplinary recruitment and education of students pose some distinctive "issues" such as the one regarding hardware I discussed above. Even so, there is also a sense of tradition in the laboratory, one that is stemming from the legacy of a couple of professors and laboratories past.

One of the main influences in Matsumoto's research vision as well as his way of organizing the laboratory is the late roboticist Ichirō Katō, famous for developing the first humanoids in the early 70s. In these sciences where neither the techniques nor the materials stay the same, the legacy translates into visions, such as understanding human traits through replicating them (see Chapter 3), and being open to novel ideas and disciplines while hanging onto familiar structures of organizing that have been passed on from earlier laboratories.

If I were to comment on Matsumoto's legacy, it would be on the "bridging" of the scientific worlds in regard to robotics and AI. I'll explore the many extensions and connections of the laboratory in the next section.

2.4. The Situated Laboratory

During my first meeting with Matsumoto, he told me that he has "two stories" about what he is doing, based on the two general kinds of audiences: those who are interested in robotics, and those who are interested in AI. He tells his story differently to people from different backgrounds, not only so they can understand his work easier, but also highlight and promote his research in a way that might align with the listener's interests.

This uneasy process of translation and alignment is, in fact, a central theme in this dissertation; it pertains to the different worlds in which the robot dwells and the different stories that emerge from the interactions of those worlds. Matsumoto is observant and outspoken about the differences in these different "worlds," which for him are primarily robotics and AI in Japan, but he is also very adamant in bridging these worlds together.

Matsumoto has a noteworthy status in robotics and AI circles in Japan: He has been on the board of directors of the Robotics Society of Japan (RSJ) once, and at the time of my fieldwork, he was on the board of Japanese Society for Artificial Intelligence (JSAI). His background is also interesting; despite having his Ph.D. in mechanical engineering, he spent time in a brain science institute post-Ph.D. because he wanted to get acquainted with that body of knowledge. The fact that his laboratory is a "cognitive" robotics laboratory is due to this trajectory.

As noted in the previous chapter, the way in which robotics is qualified as "cognitive," "neuroscience," or "developmental" is indicative of what kinds of research influences the type of robotics. My observations show that this is not definitive, however; for instance, Matsumoto laboratory also had people who were involved in “developmental” robotics research.

These worlds are relatively small. I have been familiarizing myself with robotics researchers at Osaka University since before my Ph.D. and participated in many public events, lectures, seminars, conferences, etc. During my main fieldwork, too, I have expanded my connections to multiple different contexts in which the researchers or research have been present. The links led to more links, and thus I ended up with a broad, multi-sited fieldwork experience where the contexts of robotic research and how the research is perceived were going through a transformation.

For instance, Xavier introduced me to an event series called “The Consciousness Club.” The “club” consists of people working for the company Araya Inc., a venture company focusing on AI and artificial consciousness, and others who somehow had become involved in their network. They hold irregular meetings where one researcher presents their work on artificial consciousness, followed by a vigorous discussion by members of the group. The presenters can be of different disciplines, including, but not limited to, the disciplines that this dissertation involves[20]. I participated in several meetings and interviewed the organizer of the meetings, Ryōta Kanai, who is also the CEO of Araya, Inc.

Through Kanai, I was also introduced to another group of AI enthusiasts who organize public talks under a framework called “Singularity Salon.” As the name suggests, these people are interested in the idea of technological singularity promoted by the computer scientist and futurist Ray Kurzweil (cf. Kurzweil 2005), which refers to the creation of an artificial superintelligence to transform the world in the immediate or more distant future. Singularity Salon meetings have been held in Tokyo and Osaka on a more or less monthly basis for around

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[20] They had a variety of speakers including philosophers, experimental psychologists, cognitive neuroscientists, astrophysicists, etc.

five years. I have been to many meetings in which, not surprisingly, multiple people from cognitive and developmental robotics have given talks.

Both Consciousness Club and Singularity Salon meetings are open to the public and free of charge. However, this does not mean that the discussions are readily understandable to the general public. All of the talks I have witnessed have been lengthy and quite technical, regardless of the discipline of the presenter. They differ from other public events in terms of the difficulty of the narrative and the involvement of the audience. It is safe to say that to grasp the content, the audience in these events must have at least a basic understanding of the terminology of artificial intelligence.

In terms of audience, Consciousness Club and Singularity Salon thus lie somewhere between layman and expert. My sense is that the smaller and more intimate Consciousness Club presentations mostly have experts in the audience, but not necessarily from the same discipline as the presenter. The Singularity Salon is somewhat more oriented to the layman, and involves entrepreneurs and general enthusiasts aside from experts.

On top of this, recent years have seen something like an explosion of events featuring robots, AI and related technologies. There are, for instance, non-expert focused events (e.g. Maker Faire, Hebocon) where non-experts dabble in robotics as their hobby. Among these, public events, like expositions that cater to broader audiences, tend to be the biggest. Following these events helped me not only to contrast laboratory narratives and practices, but also to ponder the misalignments of understandings on the general concepts such as intelligence, life, etc.

On the expert side of the spectrum, we find academic conferences, symposiums, workshops, etc. These venues have also seen a boom in participation over the last few years. For example, the JSAI annual conference in 2017 was filled beyond capacity. Despite the discouragingly high registration fees, international conferences also set records in attendance.

All of this indicates that robotics and AI is currently attracting significant interest, which extends into both media and capital. The relatively small worlds of disciplines like cognitive robotics are therefore finding themselves in a huge wave of hype set off recently by deep learning, a highly-promising type of machine learning technology marked by multilayered neural networks.

2.5. Conclusion

On my first day at Matsumoto laboratory, I had already realized that I was in a peculiar laboratory. Yet it took months for the invisible strings and the connections to become clear to me. From the impacts of the laboratory space on the research produced in the laboratory, to the challenges posed by creating a robotics laboratory in a fundamentally multidisciplinary department (in contrast with the usual mechanical or computer engineering departments) could not be visible to me had I not spent that much time there, nor had they not been as welcoming as they were. The initial hesitance I had due to the fear of being a burden gradually eased into a learning relationship with my interlocutors, who kindly spared their time to discuss everything from the philosophy of mind to bureaucracy relating to the laboratory work.

Being in Tokyo, I was also introduced to a new region of societal engagement of robotics and AI, which helped broaden my perspective and contextualize the research in the laboratory. The research took me to many different events, from enormous fairs on technoscience to a small gathering in an underground bar in Shibuya discussing artificial life. It therefore helped me see how imaginaries materialize in the form of robot and how they evolve, which will be discussed in the next chapter.

3

Materials of Imagination [21]

3.1. Introduction

As discussed before, the word “robot” refers to multiple, entangled entities. Originally, it was an artificial laborer in the play *Rossum’s Universal Robots* ([1920] 2014) by Karel Čapek. It evolved into a science fiction figure, often depicted as a machine with various humanlike traits. Soon, real-life machines also dubbed robots appeared,[22] and while they did not exactly live up to their fictional counterparts, they did open the way to the techno-scientific discipline called robotics. Today, the robot has come to refer to a category of machines that are mostly programmable and have some degree of autonomy. At the same time, the robot is a repository of imaginaries that designate an artificial Other that, as I suggest, also serves as a mirror for whoever is looking.

The ‘material-semiotic’ multiplicity of the robot has turned it into a rather peculiar object of study for the social sciences and humanities. The robot, it seems, simultaneously exists and does not quite exist. While the virtually-indistinguishable-from-human robots of sf do not exist, we do have an abundance of machines that are called robots. Furthermore, the figure of the robot can be said to exist in multiple temporalities, since it comes from the past and evokes hopes and fears far beyond the capacities of any present-day machine. The liminal aspect of the robot, as a humanlike machine, is both pervasive and *effective*: both material and

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[21] This chapter has been published as an article in *NatureCulture* vol. 5, titled as “Materials of Imagination: On the Limits and the Potentials of the Humanoid Robot”.

[22] An American company named Westinghouse produced a telephone answering machine called “Televox” in 1927. As soon as it was made public, it was likened to the robots of *R.U.R.* (Kubo 2015, 49). Televox was followed by multiple technical objects that were branded as real-life robots despite their questionable likeness to the robots of sf. (See Chapter 1)

hypothetical-imagined robots are often used by people to reevaluate understandings of significant concepts, including ‘human’, ‘life’, ‘intelligence’, etc.

The implication is that robots interweave matter and imaginations. Or, said differently, numerous practices, contexts, and imaginaries contingently converge in the figure of the robot. Imaginaries, of course, have been important for the anthropology of science and technology. McNeil et al. (2017) track their conceptual genealogies in STS and identify four central resources: from the Western philosophical tradition, from psychoanalysis, from late twentieth century sociopolitical theory and—from science fiction.

The “imagined communities” developed by the political scientist Benedict Anderson (1991) and the anthropologist Arjun Appadurai’s (1996) global flows have been pivotal for the sociological and anthropological studies of imagination.[23] Close to STS, George E. Marcus’ *Technoscientific Imaginaries* characterized imaginaries as “structures of contingency” (1995, 4). In conversation with imagined communities and the philosopher Charles Taylor’s depiction of social imaginaries of “the whole society,” Sheila Jasanoff and Sang-Hyun Kim’s (2009, 120) defined “sociotechnical imaginaries” as “collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects.” Later, they loosened the idea of nation-specificity, and enlarged the concept to refer to “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology” (Jasanoff and Kim 2015, 4).

The notion of imaginaries as “structures of contingency” and as “collectively imagined” forms socially embedded in technological projects are both relevant for the present study. Even more important, however, is the fourth area to which McNeil et al. brought

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[23] Appadurai (1996) coined five types of ‘scapes’: ethnoscapes, mediascapes, technoscapes, financescapes, and ideoscapes.

attention: science fiction. Donna Haraway has been at the forefront here, simultaneously imagining and exemplifying what science and STS *could be* if channeled through sf. While *Technoscientific Imaginaries* centered on the imaginations of scientists, and Jasanoff and Kim broadened the scope of imaginaries to encompass collective and public performances, Haraway (1991) more radically read primatology *as* science fiction. Not only did her pathbreaking "Cyborg Manifesto" offer a novel theorization of politics, gender, and technoscience; it was also, provocatively, *itself* a potent piece of science fiction. [24]

In her discussions of science fiction, Haraway often alludes to the anthropologist Marilyn Strathern's (1992, 10) observation that "it matters what ideas we use to think other ideas (with)" (quoted in Haraway 2004, 335; 2011, 4; 2016, 34). Sf matters because its ideas and images can travel and thus become part of how we think, tell stories, describe, or imagine things that are not necessarily fictional. Indeed, as she had previously insisted, "the boundary between science fiction and social reality is an optical illusion" (Haraway 1990, 149).

Haraway does not put forth a categorical definition of the imaginary, possibly because that would itself set a fictive limit to the imagination. As I use the term here, however, imaginaries can be broadly understood as the *materials* of imagination. Materials can be durable substances (i.e. forms of "matter" or "materiality") but the term also encompasses ideas, facts and data (as in "gathering materials" for research) and qualities pertaining to particular activities. These encompassing and somewhat amorphous definitions make "materials" very useful for grappling with how different communities *make and remake* robot imaginaries out of elements as different as electronics and fiction-writing.

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[24] In the development of a technoscientific object such as the robot, the personal beliefs of a researcher (as in Marcus 1995) and the visions of the society in which the postulated technology exists (as in Jasanoff and Kim 2009) are both relevant to imaginaries, and both can be related to science fiction. However, my field research indicates that imaginaries invoked around the robot also often includes surprising things that are not–at first glance about it.

Similar to Latour's (1988) "principle of irreduction," anything can be(come) an imaginary if it is (convincingly) made into one. Indeed, this is why it matters what imaginaries we use to imagine other imaginaries (with). The premise in this chapter, then, is that fictional and real-life robots are at once made from materials of imagination *and* are such materials in their own right.[25]

In the following, I draw on Donna Haraway's (2011, 2016) notion of string figures to show this co-constitutive relationship between sf and technoscience at work in the realm of robotics. For Haraway (2011, 12), importantly, sf stands not only for science fiction but also for speculative fabulation, speculative feminism, speculative fiction, science fact, science fantasy, and string figures. String figures is a generic term for an old, common game, in which players use their fingers—or other body parts—to manipulate string into a shape and pass it to another player who will make a new one. Analogously, storytellers, roboticists, robots, and many others participate in a game of string figures, shaping and reshaping feminism and technoscience together. String figures can be a multispecies game, as Haraway (2016, 10) illustrates in relation to companion species. In this chapter, robots also become part of the game.

Thus, I show how robot imaginaries are created through string figures with reference to my research on Japanese humanoid robots (humanoids). Humanoids have been defined as "machines that have the form and the function of humans" (Bekey et al. 2008, 71).[26] They are, supposedly at least, the closest cousin to fictional robots as they were originally conceived.

I begin by introducing the humanoid robot research, and consider what it might be good for, given its limited practical usefulness. I then describe some string figures played with the laws of robotics, and show how they create some powerful imaginaries that reproduce rather similar kinds of robots. In conclusion, I suggest that the liminal nature of the robot incites

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[25] Robots in their material form, i.e. as technoscientific artefacts, can also become imaginaries: either reference points for, or just images of what a robot is, could, or should be.

[26] The same reservations about the definition of the "robot" also apply here (see footnote 2 above).

curiosity. It creates the allure to continue the string figures games, to enrich the imaginaries, and to explore the contingent potentials and limits of the humanoids.

3.2. Playing String Figures with the Laws of Robotics[27]

The robot is a machine made by people. But can it also be a person? And if it can, what *sort* of a person would it be? For example, should robots be controlled in similar ways as other kinds of machines or as humans? In fact, imaginaries of the potential personhood of robots are usually quite limited, and the idea of making "laws" for robots is a common feature among them. Here, I consider what the form and content of these laws teach us about robot imaginaries. I depict a game of string figures, where Isaac Asimov's fictional laws of robotics ends up having real-life implications.

Long before the appearance of the robot, the artificial human, or the artificial Other, incited fears. Initially, artificial humans were not necessarily evil, but somewhat grotesque, like the Golem of Jewish mythology, which was essentially a protector. Similarly, the Being from Mary W. G. Shelley's *Frankenstein: The Modern Prometheus* (1818) is an artificial human that ends up looking so monstrous that it is abandoned by its creator. Isaac Asimov (1978) named the human fear of robots the "Frankenstein Complex." *Frankenstein* can be interpreted quite differently if one considers the scientist, Victor Frankenstein, as the monster. Yet Asimov is certainly right to emphasize the impact of the novel on popular imaginations.

Soon after he began writing on robots, Asimov ([1942] 1995, 269) formulated his enormously influential Three Laws of Robotics, which would be "built most deeply into a robot's positronic brain." The Laws are as follows:

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[27] The title alludes to a chapter of *Staying with the Trouble* (Haraway 2016).

> 1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
> 2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
> 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law. (Asimov [1942] 1995, 269–270)

Asimov’s laws are generally conceived as robotic equivalents of morals, yet they differ from human ones both in terms of context and effect. For one thing, Asimov’s robots cannot even think of breaking the laws without risking fatal failure. Mental conflicts regarding the laws can render them inoperable. In other words, the laws of robotics are binding in a way that human laws are not.

Asimov himself experimented with his laws and their implications over the years, and eventually added the Zeroth Law, which precedes the other three in importance. In *Robots and Empire* (Asimov 1998), a telepathic robot called R. Giskard Relentlov[28] faces a dilemma, as he will need to break the First Law to save the Earth. For this higher purpose, Giskard reprograms himself to implement the Zeroth Law, which prioritizes the preservation of the well-being of humanity even at the cost of harming individuals.

Asimov’s Laws have massively influenced imaginations of robot-human relations up to the present. They have been widely discussed in the sciences and humanities (see McCauley 2007), and there are laboratory experiments based on them (e.g. Vanderelst and Winfield 2017, Kaminka et al. 2017). Thus, the string figure of robot morals crosses over into reality. However, this movement into reality has also served to harden the imagination, as the fictive Laws have

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[28] In Asimov’s stories, robots have the initial “R.” with full names, as they can be virtually indistinguishable from humans, this initial becomes the indicator of their status.

turned into something akin to a norm. In an insightful essay “Robots in Science Fiction,” the sf author Stanisław Lem criticized Asimov’s Laws of Robotics for forcing artificial humans into a master-servant relationship:

> I have forgiven Asimov many things, but not his laws of robotics, for they give a wholly false picture of the real possibilities. Asimov has just inverted the old paradigm: where in myths the homunculi were villains, with demoniac features, Asimov has thought of the robot as the ‘positive hero’ of science fiction, as having been doomed to eternal goodness by engineers. (Lem 1971, 313)

As Lem indicates, Asimov’s laws indeed seem like counters to an imagined threat than as constructive guidelines for ethical behavior.

At the time of their original formulation, Asimov did not imagine there would ever *be* any real-life robots (Asimov 1995, 9). Yet, when they did appear, he still continued to defend the laws:

> My own feeling is twofold. In the first place, I don't feel robots are monsters that will destroy their creators, because I assume the people who build robots will also know enough to build safeguards into them. Secondly, when the time comes that robots-machinery in general-are sufficiently intelligent to replace us, I think they should. We have had many cases in the course of human evolution, and the vast evolution of life before that, in which one species replaced another, because the replacing species was in one way or another more efficient than the species replaced. I don't think homo sapiens possesses any

> divine right to the top rung. If something is better than we are, then let it take
> the top rung (Asimov 1987, 68–69).

The quote combines anthropocentrism with a rather twisted interpretation of the survival-of-the-fittest. The fear that humanity might be displaced "from the top rung" by the robotic 'species,' implies that two intelligent species can only co-exist in conflict over power. What is left out are out other possible sources of imagination—such as coexistence and equality—or mutual curiosity.

Osamu Tezuka's *Astro Boy* (*Tetsuwan Atomu*, manga serialized between 1952–1968) immensely influenced the image of the robot in Japan, including the science of robotics. Contrary to the robots of the 1950s English-speaking world, where robots were often depicted as somewhat intimidating, the character Astro Boy was a loveable superhero. Despite (apparently) never having read Asimov (Schodt 1990, 76), Osamu Tezuka, the creator of Astro Boy, also came up with a set of laws for robots:

> 1. Robots must serve humankind.
> 2. Robots shall never kill or injure humans.
> 3. Robots shall call the human who creates them "father."
> 4. Robots can make anything, except money.
> 5. Robots shall never go abroad without permission.
> 6. Male and female robots shall never switch [gender] roles.
> 7. Robots shall never change their appearance or assume another identity without permission.
> 8. Robots created as adults shall never act as children.

9. Robots shall not assemble other robots that have been discarded by humans.

10. Robots shall never damage human homes or tools

(*Mushi Purodakushon shiryōshū* 1977 quoted in Robertson 2018, 130)

In commenting on Tezuka's laws, Jennifer Robertson emphasizes that they both reflect and consolidate kinship between humans and robots. She argues that the relationship inscribed in these laws are not determined by differences between "*species*" but rather by the "manner of their bonding," which conforms to the "hierarchical structure of the *ie*" (2018, 131).[29] Similar to Asimov's rules here is another imperative for obedience, yet the relations are imagined quite differently. For instance, Tezuka's laws ensure that robots do not pervert the normative roles of adult and child, man or woman.

The more general point of interest is that Asimov and Tezuka, more or less contemporaries yet from quite different cultural perspectives, evidently both felt the need to create laws that would specifically govern robots. Despite their greater level of detail, however, Tezuka's laws are not as central to his world-building as Asimov's are to his. And indeed, even in Japanese robotics, where Tezuka's Astro Boy is such an influential figure, any discussion of 'ethics' will defer to Asimov (e.g. Ishiguro et al. 2007, 14; Kawashima and Tadano 2014, 4).

Asimov and Tezuka both created robot laws in the image of human ones. Others, however, have experimented with changing not the notion of law, but rather its humanlike image. This is exemplified by Toshitada Doi, an important figure in Japanese robotics and one of the researchers behind Sony's dog robot AIBO, which has been an important real-life experiment for companion robots in Japanese society (Kubo 2015).

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[29] Japanese for "household."

Reimagining Asimov's Laws of Robotics,[30] Doi proposed the "Three New Laws" for companion robots. The first law, which prevents a robot from injuring a human, stays the same. The second law, however, is quite different. While establishing the general principle that the robot should direct its love and attention towards the human being, it opens the possibility that the robot companion can oppose the human. The third law also differs from Asimov's imperative for the robot to protect its own body unless it conflicts with the previous laws. Doi's laws state that the robot must listen patiently to the idle complaints of the human, but it is alright for the robot to 'strike' back. If the partner robot is asked to fetch the newspaper, for example, it may do so, but it may also just grumble, saying the weather is cold (Asahi Shimbun 13 Jan 2001, quoted in Kubo 2015, 209). In short, Doi's laws depart from the imperative of preventing harm, as do those of Asimov, yet they do not establish a relationship of submission. Doi's alternative shows it is possible to create different imaginaries even if one is playing the same game of string figures (with "laws"), something he accomplished by adding an idea of companion species to the mix.

This section has discussed some of the strings woven by writers and scientists as they imagine the need to regulate the relations between robots and humans. These laws emerged out of a certain distrust of the artificial Other, who combined machinic strength with some sort of intelligence. Asimov's laws were designed to keep robots from dethroning humanity, whereas Tezuka aimed to ensure the integration of robots into the Japanese society. Though Asimov's problematic laws have turned into a very powerful imaginary, Doi's reformulation—assisted by AIBO—indicates that it, too, can be reshuffled and repurposed.

In the next section, I further explore how particular robot imaginaries have become familiar in the Japanese context, yet still remain open to reconfiguration.

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[30] Doi also worked on the development of Qrio, a humanoid robot by Sony (prototype released in 2003).

3.3. The Familiarity of the Boybot

Humanoid robots are *familiar* to most of us because of sf. To many, they are certainly more familiar than real-life factory robots or robot vehicles. In that sense, sf has created an imaginary space for robots that do not exist (yet). This power to familiarize the unfamiliar and defamiliarize the familiar can be seen as a general characteristic of sf. The "general public" often reads sf as predictive of future technoscientific developments, or such developments as realizations of sf (see Kemiksiz 2016).

This makes it tempting to consider robots as a kind of prototype, perhaps along the lines of the STS scholar David A. Kirby (2010, 42), who has referred to fictional technologies in general as "diegetic prototypes." He used that term to designate "performative artefacts" that simultaneously demonstrate the need for a technology and highlight its benevolence and viability. He also proposed that sf can be seen as a mode of science communication (Kirby 2003, 262).

Yet, while popular representations of fictional technologies can become powerful imaginaries, a reduction of science fiction storytelling to science communication or scientific creativity to sf presents a limited vision to the potentials either of them has. The interaction of science fact and science fiction has had far more greater powers than providing a glimpse into what may come to happen in the future; it is actual future making.

Not least, in the case of the humanoid robot, the notion of a prototype misleads since robot fictions and technoscience development have evolved in parallel over the last two centuries (see Kemiksiz 2011). Over time, robot imaginaries emerge in the traffic between interconnected practices of media, sf, policy and technology. It is possible to understand this situation by considering it in terms of co-created, partly unpredictable string-figures.

Despite the potentially innumerable ways in which a humanoid robot can be conceived, certain imaginaries are in reality far more prominent than others. Such powerful imaginaries can indeed be thought of as "performative artefacts" and, one way or another, they are related to science fiction storytelling. In order to elucidate the two-way relationship between sf and technoscience, I now turn to what is probably the most popular and most familiar imaginary of the Japanese humanoid robots: a companion robot with a boy-like attitude.

As far as I am aware, the main fictional precursor for the Japanese humanoid robot is Astro Boy, the protagonist of Osamu Tezuka's manga series of the same name. The Japanese academic robotics literature is full of references to Astro Boy. I call this type of robot the "boybot." In general, it is behavior rather than design that prescribes boyhood. A significant majority of Japanese humanoid robots are programmed to behave like, and are perceived by the Japanese as, boys. [31]

Japanese popular science books, and academic literature on robots generally, almost always refer to Astro Boy. In the popular science book *First Steps to Robotics*, the authors write that: "For most people, the image of robot is made up from manga or television characters such as Astro Boy" (Ishiguro et al. 2007, 158). His most important characteristics are that he is a super-machine capable of great power and abilities, such as flying, and that he is a friendly companion to humans. The authors, major figures in Japanese robotics and industry, suggest that while the former is attainable, the latter requires more research into the human mind and human behavior. They add that research is developing in this area precisely because most

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[31] I can identify three major robotic figures in Japan, which are materialized in robotic platforms mixed with imaginaries regarding companionship, socio-economic needs, gender, etc. Aside from the boybot, there is the gynoid or the female android, and the *mecha.* Androids are characterized by a photorealistic resemblance to humans. They may have hair and silicon skin. As of early 2019, all the androids—that are not designed to mimic famous peopleperform as women. The *gynoid* imagery feeds from the many female robotic bodies in Japanese sf, including Arale Norimaki of Dr. Slump (Akira Toriyama, manga serialized between 1980-1984), a little girl robot with super strength, and the gynoids of Chobits (Clamp manga collective, manga serialized between 2000–2002). *Ghost in the Shell*'s (Masamune Shirō, manga serialized between 1989-1990) cyborg protagonist Motoko Kusanagi is also an important figure, particularly for younger generations. *Mecha,* on the other hand, is a term for giant robots operated by humans. It also refers to an extremely popular genre of fiction in Japan. Despite the lack of practical, real-life value of giant robots, *mecha* imagery seeps into technoscience too (see Suidōbashi Heavy Industries, n.d.)

researchers share the same image of robots, and try to make it into reality (Ishiguro et al. 2007, 158).

Another example of scientific literature referring to Astro Boy is from an international article on cognitive developmental robotics,[32] which starts with a similar message:

> Robot heroes and heroines in science fiction movies and cartoons like Star Wars in US and Astro Boy in Japan have attracted us so much which, as a result, has motivated many robotic researchers. These robots, unlike special purpose machines, are able to communicate with us and perform a variety of complex tasks in the real world (Asada et al. 2009, 185)

A survey conducted by PESTI (2015)[33] identifies quite a variety of needs for robots in Japanese society, which are categorized as "superhuman," "partner," "taking over chores," and "human-likeness." Similar to the researchers quoted above, the robot should do what humans cannot or do not want to do, all the while being friendly to and understanding of humans. The ideal robot for current Japanese publics is therefore a companion robot, like Astro Boy, Doraemon, or one of the many other figures from Japanese robot anime and manga that also behave like boys.

At a group meeting in the Matsumoto laboratory in June 2017, a post-presentation discussion turned into a more general conversation on Japanese humanoid robots and how people perceive them. Dr. Kobayashi, an assistant professor at the lab, commented on one of Hiroshi Ishiguro's famed *geminoid*s,[34] Minami. Like most androids developed by Ishiguro's

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[32] Cognitive developmental robotics is a relatively new research field that draws from cognitive science and developmental psychology to reproduce human cognitive traits in robots (see Asada et. al. 2001).

[33] PESTI is an R&D project supported by Japan Science and Technology Agency (JST). The abbreviation stands for "Framework for Broad Public Engagement in STI Policy."

[34] Geminoids are androids developed by Hiroshi Ishiguro's laboratories (see Hiroshi Ishiguro Laboratories, n.d.)

group, Minami looks like a young Japanese woman. Minami had been positioned in shopping malls where she interacted with customers through commands entered on a tablet.

"When Japanese people make robots, they make child robots, like Astro Boy," Kobayashi asserted, invoking a tweet by the human-agent interaction researcher Dr. Hirotaka Ōsawa, according to which the Japanese often use 'the child metaphor' for robots (Ōsawa 2017). Minami falls out of this conventional category of boybots, or child robots. Thus, "Minami is an adult," Kobayashi continued, "that is why she is selling things."

I had previously written on the boybot, but this was the first time I heard roboticists referring to the childish personality of robots in a public setting.[35] Kobayashi's casual comment aligned with my sense that there is a relation between how a robot looks (and presents itself) and what it is made to do. Similar to the socioeconomic imaginaries discussed by Jennifer Robertson, a robot fashioned to look like a proper adult can be used for selling things but it is inappropriate for a child robot to do so. It is, of course, rather common to find discrepancies between projected technological applications and sociocultural norms. What is interesting about this case is that the most important factor relates to the personality of a machine.

That the boybot imaginary is deeply embedded in the development of Japanese humanoid robots is exemplified by two examples: ASIMO and Pepper. Honda's ASIMO (fig. 2) has long been the poster boy of Japanese humanoid robots. ASIMO is a 130 cm tall bipedal robot capable of climbing stairs, standing on one leg, and pouring a drink into a cup, etc. (Honda Corp., n.d.) ASIMO was never a commercial robotic platform, although Honda has applied the underlying technologies to other, more practical, products. Instead, ASIMO

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[35] In my experience, many roboticists —especially those who are early to mid-career—refrain from expressing personal opinions on the cultural or popular aspects of robots in academic contexts. Or they may deliberately separate themselves from such discussions.

performs in public demonstrations, and he is listed as one of the science communicators of *Miraikan.*[36]

Figure 4. ASIMO heading out for his performance at Tokyo *Miraikan* (Photo by author)

ASIMO's performances are indeed quite a spectacle. They have changed slightly over the years, yet certain elements are consistent. ASIMO always introduces himself as a science communicator and a "partner to humans." He proceeds to tell the audience about his dream, which is to live together with humans, and he asks the audience if they would like to live with robots as well. When demonstrating his capacity for movement, it is often in the company of a human; he may rush to aid a person or walk alongside someone. ASIMO also tends to boast

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[36] *Miraikan*, or the National Museum of Emerging Science and Innovation, employs both human and robot science communicators (See Miraikan n.d.a.)

about his abilities. His performance always ends with a song that he also shows in sign language. The song is about his dreams of today and tomorrow, and about how we should all come together to make our dreams come through. Both melodically and lyrically it is a children's song.

ASIMO is not officially gendered, nor is he officially a child. The machinic body is small and nonspecific. But though he is simply a robot with a dream and a fondness for singing (Miraikan n.d.b), the Japanese invariably perceive him as a boy, as I first realized at a ASIMO demonstration years ago, when all the children called him "ASIMO-kun" —an honorific used for boys or younger men.[37]

Pepper (see Figure 5), created by the telecommunication giant Softbank is also viewed as a boy. In June 2015, Softbank started selling Peppers as personal robots, and they are now quite common. Pepper is 121 cm tall and has wheels instead of legs (Softbank Corp. 2015). Not very agile, Pepper shines most brightly when it comes to communication, having been designed to "recognize basic human emotions" (Softbank Robotics, n.d.b.) Softbank promotes the development of apps to enhance the potentials of Pepper. My personal interactions with Peppers since 2015 have varied from playing a video game together to getting my fortune read by him.

Notwithstanding Kobayashi's views about the inappropriateness of child robots selling things, there are now many Peppers working at shops, though not necessarily selling merchandise. Indeed, businesses are where Peppers are most visible to the public, and where they most effectively demonstrate their abilities. That Pepper has recently begun using his childish self, playful and endearing, to help potential customers suggests that new string figures are emerging. Doing what is inappropriate for a human boy, robot Pepper's own potentials

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[37] This changes on the rare occasions when ASIMO speaks in English. The character is completely different, and the voice is that of an adult.

seems to be expanding. This also exhibits the dynamic and open-ended nature of the co-creation of the materials of imagination, which sometimes can generate unexpected results from what appeared "familiar." In contrast with highly controlled demonstrations of ASIMO, Pepper demonstrates the unpredictable transformations of imaginaries in a context where multiple players are involved in string figures simultaneously.

Peppers, however, are not only sold to businesses, but also to homes for personal use, and to laboratories for experimentation.

Figure 5. A Pepper in front of a souvenir shop in Osaka on a rainy day. (Photo by author)

In fact, *every* robotics laboratory that I've visited in Japan have had Peppers. This is the more surprising since they are mostly turned off, and many interlocutors have said that Peppers are not very useful for their experiments. What they can do, however, is interact with people, so they are often in action at Open Campus events.

Laboratory Peppers that are not used for experiments are generally ignored by students. During my time at robotics labs, I observed only a single unusual interaction. On a July day in a room at the Matsumoto lab, three students were trying to switch on a Pepper. To me, he looked sad, his shoulders slumping. When the students tried to boot him, he lifted his head and said "I'm not feeling well. My foot seems to be stuck. I'm sorry. Please reboot [me]," then slumped once more. There was indeed something wrong with his "foot": the wheel cover was not closing because something was not properly attached. The students crouched on the floor trying to fix the wheel while joking "Does he not want to participate in the Open Lab?" After a while, someone said "Should I kill [him]?", opening a soft flap on his back that exposed a red button. I hadn't seen the button before so I asked what it was for. It is apparently a kill switch, which the student told me is for when the robot "goes berserk in the city." He then suggested to "karate-chop the button like in *Golgo 13,*" a move he demonstrated with flair.

This was the only time I saw students interact with a robot in this manner in the Matsumoto laboratory. At that time, only one student worked on Pepper for his graduation project. Most others work on NAOs (see Figure 2) and some new generation industrial robots with humanoid upper bodies.[38] While I was there, these projects did not involve talking robots, and the experiments were mainly on recognition of the environment and object manipulation. In other words, these students do not have conversations with their robots, they talk *about* them but the robots do not respond. By talking back, this Pepper apparently activated a different imaginary from that of robots as laboratory equipment. Through this interaction, the characteristics of the "boybot," usually submerged in the lab, re-emerged.

Peppers, like ASIMOs are not *designed* to hint at a gender. But as noted every Japanese interlocutor has told me that Pepper is a boy. When I ask why, I have received various answers. One, offered by the master's student Mai, made the most sense to me. She said that

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[38] They were using Nextage by Kawada Inc. and Baxter by Rethink Robotics.

Pepper is a boy “because he is annoying. He asks things like ‘you free now?’ and always wants my attention. Japanese girls are ‘good’ kids, they do not do annoying things.” In contrast, Lúis, a visiting researcher who worked with Pepper in Europe, drew on a cultural repertoire that associates “feminine” with companionability and emotional intelligence when he insisted that Pepper is a girl because of her small stature, expressiveness, and because she has been designed to read human emotions. European Peppers, he insisted, are not child robots. What counts as familiar evidently depends on socio-cultural codes.

However, it probably matters, too, that Lúis does not speak Japanese, and is thus unable to capture Pepper’s Japanese gender connotations. Just like ASIMO changes when it speaks in English, it seems that Pepper becomes a different robot depending on language proficiencies and country of residence (cf. Jasanoff and Kim 2015). The same robot can be very different things depending on whether it lives in Softbank Robotics laboratory in Paris or in a souvenir shop in Osaka. These examples suggest that variable notions of familiarity have important implications when playing string figures with emerging technologies. Even if some patterns are significantly novel, the string is manipulated to partially align with the rest of the world. In Pepper’s case, the technoscientific assemblage (i.e. the robotic platform) takes different shapes in different hands, and gathers different sociocultural meanings. Even if the *material* materials remain the same, other *cultural* materials can make all the difference.

But even if while cultural and national imaginaries clearly do matter, this is not to say that they determine how humanoids are imagined. This becomes clear if we return to the full tweet to which Dr. Kobayashi referred to during the laboratory meeting. It reads: “*Saying this as an expert*, most Japanese companies do not assign genders to their robots. The way gender is perceived differs according to culture (such as, in development, Pepper was given a male name in Japan and a female name in France).[39] And *personally speaking*, the Japanese often use the child metaphor for robots" (Ōsawa 2017, translated by the author; Italics added). Ōsawa's dual framing, as an objective expert *and* as a personal subject, parallels the students' playful engagement with the Pepper. Yes, the same robot is imagined differently by people in different cultural spheres. But then, even the same person can activate different imaginaries to do different things with Pepper—theorize, experiment, speculate, interact.

In the next section, I further consider how the liminal nature of robots tends to *induce* curiosity.

3.4. Through the Looking Glass

The roboticists I have met ended up in the field for different reasons and via different journeys. Some roboticists are indeed influenced by sf; prominent among them is Professor Ishiguro, who has written a book on his inspirations from sf films (Ishiguro and Ikeya 2010). "The idea is not in research," he insisted, "it is in daily life or films" (Ishiguro and Ikeya 2010, 29). Interestingly, he has also publicly stated that he is not really interested in robots but rather in humans, and indeed he has suggested that those who *are* mainly interested in robots tend to make Gundam-like (i.e. *mecha,* see Chapter 1) robots. Indeed, surprisingly few roboticists with whom I have spoken are interested in robots exclusively for their own sake. For example, Professor Matsumoto, who was originally trained as a mechanical engineer, spent years doing research in a brain science institute because his knowledge of hardware was insufficient to

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[39] The Japanese developers used the male nickname "Tarō" (Tanaka 2014) whereas the researchers in the French laboratory used the female "Juliette" (Moriyama 2014). Apparently, Softbank had to put "Pepper-Tarō and Pepatarō" in a short list of how not to name one's Pepper in the Pepper Character Guidelines (Softbank 2019). In other words, even though the Japanese developers themselves conceived and configured Pepper as a boy, the company is trying to neutralize the association.

understand intelligence.[40] Professor Minoru Asada (2010) has written that robots are the key to unlock the secrets to human brains and intelligence.

As noted, Ishiguro is famous for making photo-realistically human-looking androids, and explicit about his influences from sf. Nevertheless, his aim is not to recreate the androids of science fiction. Nor is any other robotics project that I am aware of. Rather, my ethnography suggests that roboticists are drawn to the liminality of robots, which they use to explore topics that lie beyond it—from intelligence to embodiment, from self to consciousness. Similar to the authors and artists with whom they indeed also play string figures, roboticists are drawn to robots as machines that arouse curiosity.

The robot struggling to become, or to be considered as, human, is a generic storyline in the history of science fiction. More often than not, the function of the artificial Other in fiction is to open the question of what it means to be human (see Kemiksiz 2011). Is the human a machine? Which human traits can be replicated in a humanlike machine, and which cannot? Can a machine feel emotions, empathize, or have a free will? These questions have been around for a long while, but before the emergence of complicated machines, they were asked differently—by contrasting the human with other non-humans. Sf has generated countless robot stories revolving around these questions, and, as I see it, robotics science has its origins in a similar kind of curiosity.

As a reminder, my own ethnographic fieldwork has focused on relatively new branches of "cognitive," "neuroscience," and "developmental" robotics. These multidisciplinary research areas are inspired by the sciences of mind and behavior to replicate human cognitive traits in embodied agents; i.e. in robots. This often depends on what is called "synthetic methodology," which "can be characterized as understanding by building" (Pfeifer

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[40] *Understanding Intelligence* (1999) is also the title of a book by roboticist Rolf Pfeifer and Christian Scheier on the concept of intelligence in multiple technoscientific disciplines including robotics, cognitive science, and artificial intelligence.

and Bongard 2007, xviii). In other words, through the process of replicating cognitive traits and behaviors, they aspire to get a better understanding of the human.

While my fieldwork is far from representative, the concern with *exploring all kinds of things through the robot* is deeply embedded in the discipline. Indeed, it seems to me that the robot *itself* has some capacity to prompt questions about mind, intelligence, or emotions. Once, Dr. Kobayashi told me that researchers inevitably become interested in the philosophical implications of the robot, because the robots *make them* doubt their own assumptions. It has an unsettling influence on almost everyone that seriously ponders it. Some choose to develop actual robots, some write stories about them—and some end up conducting ethnographic research!

In Japanese robotics, the notion of the "robot as a mirror" is often invoked. Roboticist Hiroshi Ishiguro's book *What is a Robot? A Mirror that Reflects the* Heart[41] *of Human* (2009) explores the motivations and implications of using the robot to address what the "human" is. Similarly, Asada (2010, 21) bases his research on the principle that the robot is "an artifact that reflects the human."

A story about the late roboticist Ichirō Katō, who made the world's first humanoid robot, vividly illustrates the *curiosity* that motivates the making of human-like machines. I heard it from Professor Matsumoto, who reveres Katō and briefly studied under his guidance. In this story, a young Katō is interested in philosophy, particularly the philosophy of mind. But this is the time of the war, and Katō knows that philosophers will end up at the battlefront. Thus, he chooses to study electrical engineering at Waseda University and receives his bachelor's degree after the war. A decade later, in the 1960s, he has become assistant professor at the university's department of mechanical engineering. Yet he is still interested in human

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[41] I used the word "heart" here for the Japanese word *kokoro,* which also means the mind and can incorporate associated concepts.

beings, and cybernetics is gaining popularity. At first, he ostensibly works on mechanical limbs, since prosthetics is a valuable research topic in the post-war world. But in the 1970s he finally turns to humanoids. Over the decades, he continues working on robotics with a lot of influence from cybernetics, and a focus on "*making* a human." He develops a distinctive engineering approach to (philosophical) anthropology.[42] Meanwhile, he passes his legacy on to disciples and students, including Matsumoto. Matsumoto once told me of the day, almost three decades ago, that Katō had advised him to study the "kokoro" of the robot. *Kokoro* is a Japanese word that can both designate "heart" and "mind," with additional connotations of "will" and "emotion." Katō thought that the robot can "reflect" the *kokoro* of humans. Matsumoto himself took the advice to heart and has been studying it ever since.

The veracity of the story of Katō matters less than what it indicates. Here is a scientist who weaves imaginaries of the philosophy of mind, cybernetics, and robots together with metal and plastic in post-war Japan. Not only does he develop pioneering technologies, but he himself becomes a story, at once embedded in the robots he develops, and passed onto others. The player of the string figures eventually becomes part of the imaginary he creates. The story also emphasizes that *kokoro*, or its possibility in a machine, is crucial to the Japanese humanoid robot, and maybe has been since its emergence.

3.5. Conclusion

I was fascinated by the potentials of an artificial Other long before I started doing research on robots. And I have often been frustrated by the limited and limiting ways in which they are imagined. Robots could have been anything—they still *can* be anything—but,

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[42] Katō's book *Ningenkōgaku–Kōgakuteki ningengaku* can be translated as "Ergonomics: Engineering Approach to (Philosophical) Anthropology". The Japanese term *ningenkōgaku* commonly refers to "ergonomics," however, Katō's proposed science can be more accurately represented as "human engineering": a science at the intersection of philosophical anthropology, physiology, and engineering with a focus on understanding the workings of "human" (Katō 1988, 10–13).

particular imaginaries tend to prevail over all others: the robot as laborer, care worker, slave, hero, or villain.

In this chapter, I have analyzed fictional and actual robots as made from a dynamic field of facts and fictions. I have referred to this field as comprised of materials of imagination, and described how these materials are shaped and reshaped in an ongoing, collective game of string figures. As strings are passed back and forth between players, a fictional robot might become a reference point for an actual robot, such as Astro Boy, or vice versa. At each moment, the player takes into consideration prominent imaginaries—like Asimov's view of how to manage relations between robots and humans—and adapts, prolongs, inverts, or indeed perverts them, as perhaps illustrated by Doi's canine robot laws. Moreover, as exemplified by Pepper, the robots themselves are also participants in the game; their "machinic agency" often exceeding the intentions of their creators.

As I have suggested, these processes of continuous, collective reimagining are in an important sense prompted by the liminal nature of the robot: a machine that, at least in fiction, can be very humanlike. It might be that one of the most enduring qualities of the robot—as an artificial Other—is that of inducing human curiosity. The robot, as it were, makes it possible to experiment with what it means to be human through a nonhuman medium. In Japanese robotics, this peculiar characteristic is described in terms of "mirroring," a matter of looking at robots but having *kokoro* reflected back.

It might be said that the robot combines forms of curiosity conventionally piqued by the marvelous artificial Other with other more familiar imaginaries. Just as science fiction itself, it is at once strange and familiar. Indeed, this is one reason why it matters which imaginaries are activated in imagining the robot, and which fade into background. In addition to shaping how we build, configure, contextualize and relate to robots that are supposed to transform societies and lives; how we imagine robots also matters, since it affects our understandings of human and non-human relations in general.

As Kobayashi insisted, the robot has the capacity to make its human interlocutors think about grand concepts like life or being human, but also to make them doubt what they thought they knew. Arguably, similar to Haraway's simultaneous sfs—science facts, science fictions, speculative fabulations, speculative feminisms, science fantasies, and so fars—robot imaginaries facilitate exploration of the limits of human. Differently embodied robots open up different possibilities for reconfiguring the world.

Isabelle Stengers (2019, 2) has described science fiction as a continent with a wide diversity of inhabitants. Astro Boy turned out to be highly influential in Japanese robotics *so far*, but science fiction still has rich untapped potentials for thinking differently *with* the robots; not least about what happens beyond experimental research settings. This is especially important because robotics, similar to other fields of technoscience, is also tightly connected with other already existing social, cultural, and economic systems. These days, the combination of capitalist imaginaries of labor with intensive efforts to replicate human intelligence in machines leads to experiments, ethics discourses, and, in some cases, robotic performances, that are downright disturbing. Science fictional *thought* experiments are important for allowing experimental robotics to imagine routes into other worlds, and for exploring the relations of robots and humans, not reductively, but in their "many entangled repercussions" (Stengers 2018, 31).

4

Modeled After Life Forms

> "Anthropology holds up a great mirror to man and lets him look at himself in his infinite variety" (Kluckhohn 1949, 11)

4.1. Introduction

In the mid 20th century, the American anthropologist Clyde Kluckhohn asserted that anthropology plays "a central role in the integration of the human sciences" (Kluckhohn 1949, 1). Lamenting the underdevelopment of human sciences, Kluckhohn assigned anthropology a special role in this nascent field. By exploring the differences and commonalities of humanity, anthropology could help formulate a comprehensive view of "human nature". Since then, both anthropology and the sciences in general have changed many times over. Traditional human sciences, including psychology, anthropology and sociology, have become fully established disciplines and new fields such as cognitive science, artificial intelligence (AI) and robotics are now exploring human nature from angles that Kluckhohn could not possibly have imagined. These new disciplines too explore human nature but using different "mirrors".

Indeed, as discussed in the previous chapter, the metaphor of the mirror is widely used in these newer disciplines. For example, cognitive science in the 1970s saw the computer as a mirror for studying human minds. Rather than depicting human diversity, the computer reproduces (aspects of) human intelligence in a different medium and thus helps understand its essential nature.

The philosopher John Searle pondered the fact that metaphors for the brain have changed over time. The ancient Greeks compared it to a catapult, and in Searle's childhood it was likened to a telephone-switch: "Because we do not understand the brain very well we are constantly tempted to use the latest technology as a model for trying to understand it" (Searle 1984, 42). In the late 20th century, however, the robot has gradually replaced the computer, as roboticists have come to see the robot as a mirror for the human. This premise is embedded in their research practices.

Since its inception in the realm of fiction, the robot has always been associated with the question of what makes us human. Originally seen as an artificial person, the robot has been defined by its similarity to and difference from 'natural' humans. With the emergence of robotics as an academic field, the figure of the robot has moved from the realm of fiction and become the name for machines of various forms and functions. As part of this diversification, questions of what makes something alive have also become central to the field. Initially hailing from mechanical engineering and computer science, robotics might not seem to have much to do with life; yet over recent decades, roboticists have become increasingly interested in life as a point of reference[43].

A main factor in this emerging interest concerns what the roboticists Rolf Pfeifer and Josh Bongard (2007, 34) have called "the embodied turn". In short, this refers to the birth of a school of AI research according to which intelligence requires a body. Traditional or classical approaches to AI conceived human intelligence to be similar to computer programs, as consisting of symbol processing in the brain (Pfeifer and Bongard 2007, 27). The metaphor of brain-as-computer also affected how cognitive neurosciences and psychology saw the human mind, particularly in the 1980s. In the same decade, artificial neural networks (ANNs)[44] also

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[43] See Kato's story in the previous chapter, for example.

[44] These are computational models designed to resemble human brains. They were first developed in the 1940s. Today they are used in many computational technologies.

entered the scene. In the early 1990s, the "embodied turn" was ushered in by Rodney Brooks, whose notion of embodied intelligence viewed the body as a prerequisite for the development of intelligence, seen as the consequence of interactions with the world (Pfeifer and Bongard 2007, 29).

Briefly stated, the notion of embodied intelligence brought about a gradual shift in the design of artificial agents including algorithms and robots. It also led to the formation of new research areas shading into various disciplines and relying on novel combinations of theories and methodologies. One particular impact of the embodied turn was to open up new ways of thinking about intelligence, inspired by various life forms. Among other things, an increasing amount of robotics research, which previously used control engineering to reproduce human kinematic motions, began to find inspiration in cognitive or bio-inspired fields.

On the one hand, embodied intelligence helped explore how certain morphologies play an active role in certain motions, and paved way to replicate them—such as how the body of a salmon helps it swimming in a river. On the other hand, robotics attracted a lot of researchers, such as Ichirō Katō (see previous chapter) and his successors in Japan, who have found a way to understand *kokoro*, to attempt another method for peeking into the great unknowns of the mind.

In cognitive and developmental robotics, a new generation of scholars have thus developed what is known as the "synthetic approach," which, in a nutshell, aims to understand human embodied intelligence by making or recreating it in robots (Pfeifer and Bongard 2007, 21). This located the engineering efforts to create AI and robots in the context of broader explorations of human nature. The synthetic approach entails the assumption that making more intelligent agents deepens our understanding of intelligence —or some of its aspects.

Given these changing contexts, research areas such as cognitive robotics can be placed among wider transformations of the notion of life and the scientific practices that explore it.

An example of such a point of contact is provided by the anthropologist of science and technology Stefan Helmreich's ethnographic work on the "limit biologies" of artificial lifers[45] (ALifers), marine biologists, and astrobiologists, which particularly points to the instability of the concept of "life" (Helmreich 2011, 693). As biology expands through new channels in technoscience, Helmreich showed, understandings of "life" become contested, unstable and transformable. In this analysis, he distinguished *life forms* seen as "embodied bits of vitality" from *forms of life* understood as "social, symbolic, and pragmatic ways of thinking and acting that organize human communities" (Helmreich 2009, 6). On this basis, he argued that life forms and forms of life "inform, transform and deform each other" (Helmreich 2011, 676). Life-inspired robotics, too, joins this traffic of life forms and forms of life. In a similar vein, Richard Doyle has analyzed the transformation of "life" and life sciences through hermeneutic readings of molecular biology and artificial life (Doyle 1997, 2003). In this context, various life forms inspire the designs of robots, which, in turn, inform and transform our understanding of human intelligence, as a certain generalized form of life.

In terms of my ethnography, life does not appear very universal, even within robotics research. During my fieldwork over the last few years, I have encountered many divergent views on life and practices trying to deal with it. As if corresponding to this diversity, the robots I have observed are also extremely variable both in form and function.

To analyze this divergence, I have been inspired by studies of the genesis and development of scientific facts by the German microbiologist and sociologist of science Ludwik Fleck (1935). His major work developed the notion of thought styles *(Denkstilen)*, defined as the "readiness for directed perception and the assimilation of what has been perceived" (Fleck 1935,142). While thought styles generate knowledge, they do so from within

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[45] In this dissertation ALife refers to the domain of research in sciences and engineering that aims to understand––and sometimes to create—life through computer simulations and machines.

particular “thought collectives (*Denkkollektiven*) in which practitioners interact and exchange ideas (Fleck 1935, 39). Through this process, different thought collectives gradually construct their own ways of perceiving and churning data or ideas, which in turn shapes the facts they make. The difference of thought styles in various subfields of robotics is evident in how they see grand concepts like life, intelligence, or embodiment.

This chapter is about roboticists who are inspired by life forms, in Helmreich’s sense, yet who do not see their robots *as* alive. Instead, their research practices engage with bits and pieces of different live entities. They attempt, that is, to reproduce certain humanlike or lifelike features (e.g. behavior, movement) in the medium of a robot by modeling the artifact after fragments of other life forms. The metaphorical and pragmatic relation they establish between the organic and the technological can be seen in their ways of thinking and acting within particular “computational assemblages” (Johnston 2008). As I discuss further on, modeling *after life forms* is a crucial dimension of this research practice.

In the following sections, I examine important aspects of the thought styles that guide the research conducted in Matsumoto laboratory. As I show, these thought styles shape the “computational assemblages” (Johnston 2018) through which research unfolds. In particular, this research experiments with modeling robots *after life forms*, without actually ascribing the robots themselves with *life*.

In *The Allure of Machinic Life* (2008), Johnston developed the idea of “computational assemblages” to analyze the history of cybernetics and artificial intelligence in the United States. A computational assemblage designates “a material computational device set up or programmed to process information in specific ways together with a specific discourse that explains and evaluates its function, purpose, and significance” (Johnston 2008, 8). In a sense, the notion of computational assemblages formalizes the transboundary travels of ideas around robotics (cf. Kubo 2015). That is, the concept captures how bits and pieces of discourse, imagination and artifacts are related to particular devices or algorithms that process information in specific ways. Johnston further argues that these assemblages are designed to produce what he calls “machinic life,” characterized by “mirroring in purposeful action the behavior associated with organic life while also suggesting an altogether different form of ‘life’” (Johnston 2008, 1). Along these lines, Johnston shows how various computational assemblages, including some relating to robots and neural networks, were created to produce diverse forms of machinic life, thereby contributing to further transformations and complications of the concept of life.

In this analysis, Johnston shows the importance of being equally attentive to the discursive and material aspects of robotics research. For instance, he shows that connectionist models based on the immune system and neural networks are in some ways discursively similar. At the same time, however, he makes it clear that the “respective discourses are directed toward different ends, making each one part of a distinctly different computational assemblage, to be analyzed and explored as such” (Johnston 2008, 8). Consider, for example, the difference between a companion robot and a factory robot. The first is associated with sociality and made to interpret and express emotions whereas the properties emphasized in the second are safety and accuracy of operations. In both cases, the physical bodies and technical capacities of each robot are fully entangled with the discourses and imaginations used to make sense of them.

Building on and contributing to the anthropological literature on robotics and AI, I examine how the scientific imagination embedded in roboticists’ thought styles—in particular their views on life, embodiment and intelligence—are integral to the computational assemblages they create, the models they make, and the robots they build. In particular, I emphasize that models that try to reproduce certain aspects of organic life forms are crucial to the computational assemblages of robotics research.

4.2. Embodiment in Robotics

Among roboticists, a commonly used argument for embodied intelligence emphasizes that all forms of intelligence that we know of are, in fact, embodied. Or, our understanding of intelligence is invariably in reference to embodied agents. According to Professor Matsumoto, my main informant, even mathematical concepts and equations, such as “1+1=2,” which are ostensibly not dependent on a body, are either grounded in a body, or can be traced back to one. Nevertheless, even if originally created by embodied agents, aspects of intelligence that deal with symbols are in some sense “detached from reality.” Matsumoto illustrates this point with reference to languages: a computer program that translates from one language to another does not need a human body. In contrast, movement requires a body, and movements in terms of meaningful interactions with the real world are thus indicative of intelligence. In Matsumoto’s view, therefore, even though traditional AI cannot be repudiated because it focuses on symbol processing, embodied intelligence “makes sense.”

As mentioned, Matsumoto is a leading figure in Japanese robotics and AI societies. He often points to the different perspectives on embodiment held by researchers in these disciplines in Japan, which he describes as a “gap between the worlds”. This “gap” can be seen as a significant indication of the divergence between thought collectives involved in AI and robotics in Japan. Matsumoto exemplifies the gap by noting that embodiment is a core concept for roboticists who work on intelligence, whereas for AI researchers it is merely one application among others. There is also a wide area within robotics that is simply not concerned with (embodied) intelligence. At the risk of oversimplification, the development of robots for automation that only requires the agent to produce the same movement repetitively does not depend on “intelligence” in the sense in which many roboticists refer to it. Instead, intelligence is about being able to sense changing circumstances in the environment and change movements accordingly. In my fieldwork, intelligence is thus almost always akin to adaptability, and—in Matsumoto laboratory—to learning.

What does the “body” invoked by “embodiment” refer to in this context? Robotics textbooks often skip the definition and even Pfeifer and Bongard’s thorough discussion is not explicit on this point. Following my informants’ insistence on the importance of changing movements in response to changing circumstances, however, we can at least venture that a body is a physical entity capable of flexible adjustment to its environment.

During my fieldwork, I was referred to a definition provided by Yasuo Kuniyoshi, one of the most famed Japanese roboticists of our time, for whom the body is “the invariant factor that universally restricts the interactions with the outside world such as ways of movement and reaction.” The body, Kuniyoshi further explained, is therefore “the factor that is the slowest to change in comparison to the change in interaction”[46] (Kuniyoshi 2008, 284). Noticeably, this definition emphasizes limitation; the body is a configuration that only allows certain types of movement and reaction under certain circumstances. In other words, the limits imposed by the body determine how an agent interacts with the environment. You only have to imagine an elephant with a fly on its trunk to grasp how wildly different bodily interactions and their attendant “intelligent behaviors” can be. The elephant might reach for a tree branch with its trunk, thereby making the fly take off, only to land again seconds later. The elephant and the fly both act intelligently and yet it is not possible to replicate the fly’s behavior with an elephant’s body, or vice versa. This is why the morphology and materiality of a given body is an integral part of the agent’s intelligence.

Even though embodied intelligence assumes that intelligence requires a body, it does not prescribe what *type* of body is necessary. All organic bodies have their own sets of possibilities and constraints, but there is no need for robotic bodies to be configured in the same

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[46] My translation.

way as organic ones. For instance, integrated sensors such as GPS and ultrasound provide a set of inputs for the perception of the world that no human possesses, while wheels or rotary wings are body parts that do not exist in nature. In practice, however, research is overwhelmingly influenced by the workings of existing, organic bodies, sampled from nature. Furthermore, even wheeled robots use operating systems that are modeled after the perception of human bodies. In these ways, models from life inspire robotics.

Multiple groups in Matsumoto laboratory do research on or with humanoid robots such as NAO, Nextage and Baxter.[4] In general terms, they teach the robotic systems to act in certain ways in response to certain circumstances. In most cases, the robot learns to recognize, categorize and manipulate objects with the help of neural networks. There are also projects related to symbol grounding, which, in this context, translates to coupling language with actions.

In the laboratory, Matsumoto's notion of embodiment is connected with other concepts and practices. Consider, for example, the "intelligence" part of "embodied intelligence." In an interview, Matsumoto casually told me that: "arms and hands are about intelligence, and vision [is also about intelligence]" while "legs are about movement." I was puzzled, since this explanation was quite different from anything I had read or heard before. For Matsumoto, apparently, intelligence is about manipulating objects and tools, which is a very particular way of interacting with the environment. At that point, I realized that most of the humanoid robots in his laboratory consist only of an upper-half body.

It became increasingly obvious to me that this seemingly minor aspect of the laboratory's thought style has major consequences in terms of the lab's computational assemblage and research activities: There is a particular way Matsumoto and his lab sees

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[4] NAO, as mentioned before, is a humanoid robotic platform developed by Aldebaran Robotics of Softbank (Softbank Robotics n.d.a.). Nextage is a humanoid designed by Kawada robotics, mainly for factory use (Kawada 2018). Baxter, which is also a humanoid industrial robot is designed by Rodney Brooks' Rethink Robotics (Rethink 2018). Nextage and Baxter are not traditional industrial robots as they can be trained with ANNs.

intelligence and this vision is shared by some (but not all) in the Japanese robotics thought collective. The research conducted in the laboratory and the materiality of the research practices are both compatible with *that* vision, and the computational assemblages created in Matsumoto laboratory therefore embody Matsumoto's vision, both physically (e.g. the legless NAOs) and computationally.

To illustrate how embodied intelligence can be interpreted differently by different thought styles within robotics and how that creates different computational assemblages, I can draw a comparison. In the summer of 2016, I visited Professor Howard Williams' laboratory in central Europe, which focuses on micro- and nano-scale robotics, mainly used for biomedical applications. Williams, an American professor who has worked for over a decade in Europe, is a prominent figure in this research area, nearing retirement. He gave me a laboratory tour, which was in itself extraordinary because it was the only robotics laboratory in which I did not *see* any robots –their robots cannot be seen except under a microscope. He also agreed to sit for an interview in which I got to listen to his story.

Williams told me that he wanted to "make robots under a microscope" that can be injected into a person to perform tasks in the human body. His research hit a wall mainly because developing a miniscule robot is very different from making bigger robots since "the physics of the micro- and nano-scale world operates differently." He also explained that his laboratory looked into how "nature" solved this problem. And indeed, it turns out that nature has many solutions to this engineering problem, provided by various organic bodies. Eventually they modeled their robots after certain bacteria. Williams' bacteria-inspired robots and Matsumoto's cognitively inspired humanoids are illustrative of quite different computational assemblages that reflect different understandings of intelligence, and differences in research practices including modeling.

Williams' robots replicate the way a certain type of bacteria propels itself in the bloodstream. However, while the bacteria that inspired these roboticists cause diseases in animals and humans, the robot is developed instead to deliver drugs to specified places in human bodies. In contrast, rather than accurately replicating human movement, Matsumoto's humanoids are developed to recognize objects and learn what to do to them: for instance, to recognize a coffee mug, learn how to hold it, and apply that skill to mugs of various sizes and shapes. These humanoids cannot sense the environment as human beings do, and their movements are fairly limited in comparison to an able-bodied human. It is clear, however, that cognitive robotics puts an emphasis on object recognition, decision-making, and similar higher cognitive functions, which are not a concern for micro- and nano- scale robotics. As this shows, the robots of both labs are modeled and designed differently, and their envisioned purposes—working *in* human bodies and working *with* human bodies, respectively—make them as dissimilar as the life forms that they partly represent.

During our conversation, I also asked Williams where he draws the line when it comes to intelligence. He replied that that even "viruses have intelligence even though they do not have a single neuron." Compared to Matsumoto's hands-and-vision-centered understanding of intelligence, Williams' take is evidently broader. Centrally, it indicates how greatly understandings of intelligence vary within robotics. The robots they develop as computational assemblages differ not only in terms of form and function; they also embed different views of the traits they attempt to replicate (i.e. intelligent behavior).

Despite their significant differences, Matsumoto and Williams both highlight the importance of embodiment. This suggests that, across subfields of robotics, embodiment in reference to interaction with the real world is widely perceived as a requirement for intelligence. Yet the particularities of interaction are understood differently across thought collectives, even down to individual laboratories. At the same time, while it is true that newly emerging thought collectives, such as cognitive robotics or nano-robotics, draw ideas from other established ones (e.g. neuroscience, biology, developmental psychology), they do not adopt such thought styles wholesale. For example, even though Williams' laboratory frequently collaborates with biologists, and indeed employs some of them, their relation to biology could be described as an *à la carte* adoption of knowledge and methods. And because the mingling of significantly different thought collectives with different thought styles is often project-based, it shapes particular computational assemblages, such as the creation of bacteria-sized robots used to deliver medicine inside a patient's body in Williams' laboratory. In recent years, these kinds of multidisciplinary ventures and collaborations have become increasingly ordinary, generating a corresponding increase in the diversity of thought styles and computational assemblages. In the following section, I examine how these forms of research deal with, or refrain from dealing with, life.

4.3. Lifeless Robots

Given the recurrence of the notion of "embodiment" and the prevalence of life-as-inspiration during my fieldwork, in laboratories or at conferences, I was regularly struck by what might be called *the absence of robotic life.* Due to the previously discussed common conception of robots as an analogue for life forms, I had anticipated the robots in my fieldwork to be considered to have at least the potential of being alive. Yet while Matsumoto, Williams and others were clearly fascinated by existing life forms, they were hardly interested in trying to create alternative ones. Indeed, during my months at a laboratory desk, and while participating in every meeting and seminar, I encountered absolutely no talk of "life," —unless, that is, I specifically brought it up.

Matsumoto often described his views by comparing them with those of others, and our conversations about life took a similar form. He briefly described the major positions, first noting that if the definition of life is based on DNA and proteins, then machines cannot be considered alive. If, however, the definition is based on differentiating between self and other—on autopoiesis—or on evolution, then life can be ascribed to machines. This, Matsumoto added, is the stance of ALifers. He then told an anecdote from his graduate student years, a time when the research field of human-robot communication was still considered unusual, but which they were trying out nevertheless.

At the time, they conducted surveys about human attitudes to robots alongside their experiments, and found the results were divided into two broad groups: Some people consider robots to be lifelike and attribute emotions to them, while others see them as machinelike. Matsumoto and other researchers then tried to find common denominators that accounted for this difference, yet neither gender nor age worked. *"The criteria for people to accept life as life[like] is quite ambiguous"*, Matsumoto asserted; "people" here referring both to his survey audience and to his academic peers. In other words, since they did not know what is lifelike in a life form, they could not make their robots more lifelike. In this story, Matsumoto is distancing himself from ALife narratives. He is well aware of the popular association of robots with life, and the implications thereof. Yet Matsumoto finds "life" to be much more ambiguous than "intelligence," and thus he is keen to distinguish his own work from those who actively study the former.

Whereas Matsumoto wants to make his robots smarter, he is not concerned about whether they become lifelike *in consequence*. He has no interest in judging whether or not lifelike traits (cognitive, for example) really occur in the robots. What he *is* interested in is how certain mechanisms evolve in living beings, and for that he uses robots as a "reference." In other words, he uses his robots as mirrors to understand cognition. Furthermore, he does not think robots need to be wholly lifelike –or human; for him "it is alright that robots have limits."

This perspective is prevalent. Indeed, most people in Matsumoto laboratory see their robots or neural networks as mere tools. Robots are registered as laboratory equipment and lumped in together with other equipment such as computers, printers, etc.; and they *are*, in one sense, simply tools that allow graduate students to master machine learning techniques. At the same time, however, it is also fairly common for laboratory members to anthropomorphize the robots, for example referring to one of them as "*koitsu"* (roughly translating as "this guy/fellow"), *"konoko"* (this kid), or "*kare"* (he); but hardly ever as *"kore"* (this thing).

When my informants talk about their ANNs or their robots they may say that it's trying hard *(ganbatteiru)*; and the robots are considered clumsy (*heta)* when they fail. On the one hand, such anthropomorphic language is strikingly common in daily interactions in Japan; yet on the other hand, it is significant that only the robots and the ANNs are anthropomorphized in the laboratory. The robots and ANNs may have qualities that invoke lifelikeness, but not so much as to be taken as a potential life form. Matsumoto himself says that the robots and ANNs sometimes surprise him during experiments. In a sense this is unsurprising, precisely because they are tools meant to create surprises[47]. Nevertheless, when asked directly, my informants are clear that robots are primarily laboratory equipment for making movements.

Indeed, my informants seemed to *particularly* avoid talking about "life" when talking about their tools. Even so, they get their inspiration from, and build their models on the basis of, life forms. Thus, *fragments of life* are rather tenuously embedded into the research in the laboratory and, as I show below, this happens most prominently through modeling practices.

Professor Williams told me that he, as an engineer, likes to break the world into little boxes and write programs in them. This divide-and-conquer strategy is visible in the practices of many roboticists, and it conforms to how my informants are constantly digesting knowledge

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[47] ANNs often produce surprising results because of their complexity. Their surprises are very useful feedback for the researchers (See Holland 2014).

and methods from other disciplines, including biology and cognitive science, partially integrating it into their thought style and enfolding it in their computational assemblages. “Life” seeps into my informants’ research, despite the fact that they are not interested in creating new life forms. In consequence, their research, intentionally or not, also contributes to proliferating understandings of life.

This eclectic integration of different elements into laboratory thought styles relates to the history of robotics and AI research. From the start, robotics was an interdisciplinary research area, and new research areas and the computational assemblages they generate feed on a variety of already existing discourses. Thus, for example, the discourses of cognitive robotics and developmental robotics are entangled, respectively, with those of cognitive science and developmental psychology. Yet, to repeat, the conceptions of those sciences are not fully adopted, but only adapted piecemeal to the extent that particular insights seem relevant and can be computationally modeled. As the whole science is still emerging, the boundaries remain quite fluid. In turn, this means that there is no generally accepted roadmap to designing intelligent robots by using machine learning techniques. The consequence is that even though the robotic platform is shared among researchers, the specifics of computational assemblages continue to diverge between laboratories.

As I discuss in the following section, modeling is a particularly important way in which this differentiation occurs. The variability of modeling after life forms thus allows me to highlight that eclectic adoption of ideas is an important characteristic of these rather *fluid* thought styles, which generate equally fluid and eclectic computational assemblages.

4.4. Modeling within the Computational Assemblage

In a robotics laboratory that focuses on software rather than hardware, most of the daily practices involve sitting in front of a computer: coding, running simulations, etc. When members of Matsumoto laboratory discuss work, it is almost always in terms of a "model", which is embedded in their codes and simulations and serves as the core of their projects. I had read and been told by informants that in research areas such as bio- or cognitively-inspired robotics, the robots are modeled after organisms or their cognitive traits. Yet, the question of *how to replicate such traits of living beings within a computational assemblage* turned out to be quite complex. Modeling is where my informants' computational assemblages get tied to life forms and it is simultaneously where life-as-a-grand-concept disappears.

Models vary greatly in how they are related to the phenomena to which they are linked, as well as in how they are used. The philosopher of science Ian Hacking describes a triad of phenomena, theory, and models, in which the models play an intermediary role, sitting in between a phenomenon and the theory that "aims at the truth" about it (Hacking 1983: 217). Due to this position, he asserts that "models are doubly models" (Hacking 1983: 216) because they must necessarily at once capture important aspects of the phenomenon-under-investigation and the theory that tries to explain it.

Previously, the philosopher Max Black had similarly highlighted that "there is no such thing as a perfectly faithful model; only by being unfaithful in some respect can a model represent its original" (Black 1962, 220). Among the models examined by Black, analogue models, which aim to capture "the structure or the web of relations" of a phenomenon in a different medium (Black 1962, 222) are closest to the models that the roboticists in the lab construct.

To understand the function of models, Williams's previously quoted description of "breaking the world into little boxes and writ[ing] programs in them" is quite telling. A model of a given life form represents the target system but only in certain specified aspects. For instance, the ambition to explain bird movements can yield numerous models, relating to the flight of a single bird, or that of a flock of birds, or their migratory patterns, nesting behaviors, or mating behaviors—the list goes on. Such models can be combined, but in practice they are usually focused on representing a certain aspect of, say, being a bird. Modeling can thus be seen as an act of breaking apart and reshaping a form of life in order to create a partial reflection of the source material. Since cognition, behavior, or movement have all been understood in diverse ways since long before the emergence of robots, a multitude of models are available. The robots are modeled *after* life forms but more accurately after fragments of life forms.

As mentioned above, I constantly encountered the term "model" during my fieldwork. Just as the design of an embodied agent capable of learning and adapting depends on a particular computational assemblage, it clearly also requires an assemblage of different models and modeling practices. When my informants in Matsumoto laboratory refer to "*their* model", it often means their "(machine) learning model" *(gakushū moderu), i.e.* the structure of the neural network they are using. Yet that is not the only model involved in making an embodied agent move. Since the robot moves about in the physical world, a physical model is also necessary. This type of model, sometimes referred as a kinematic or body model, governs the hardware (the robot's body) and its interaction with the environment (the experiment setting). The humanoids are evidently modeled after human bodies. The resemblance may differ in terms of form and function; for instance, NAOs are smaller in scale than humans[48] and have very limited bodily capabilities. Yet the limitations imposed on them by their humanoid bodies, as asserted by Kuniyoshi, allow them to move in a humanlike manner which is regulated by the body model.

Furthermore, in terms of software, the neural network is itself modeled crudely after the human brain with nodes representing neurons. But not only are there several types of ANNs, many tasks also require combining multiple ANNs, which means that every architecture is different. According to my informants, the construction of a model is often a process of trial

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[48] A full body NAO is 574 millimeters tall.

and error that goes on until desirable results, such as correctly sensing the experimental setting and producing the appropriate action, are obtained. In addition, the "cognitive" aspect of robotics sometimes requires the input of a computational model of a form of human behavior or a cognitive trait, which is imported from cognitive or behavioral sciences. But since the physical and cognitive models are largely implicit, the notion of the "model" in Matsumoto laboratory is more or less synonymous with the ANN designs, which to some degree are inspired by understandings of human cognition.

Movement, perception, recognition, and learning are phenomena that have long been modeled by different research fields. What this means, *pace* Hacking's argument, is that the models that populate the computational assemblages of Matsumoto laboratory also implicitly theorize aspects of embodiment, learning or cognition in a range of different, and sometimes incompatible, ways.

Yet, while models proliferate in the laboratory and thus create complexity at the level of the computational assemblage, when it comes to individual models, Matsumoto advocates simplicity. That is, he tends to prefer the simplest models that behave like the target system with *no explicit mechanism* for the generation of the behavior. He emphasizes that he does not want the robot to be ordered to do things; rather, the behaviors should appear "as a result" – i.e. in an emergent manner. The principle is that even if the phenomena—or the behavior—are complex, the mechanism that generates them should be simple.

The reason for this preference relates to Matsumoto's awareness that phenomena are often explained differently in different fields. Yet no field has a perfect understanding of human cognition. According to Matsumoto, for example, physics and mathematics are not flexible enough to capture important dimensions of cognition. He rather favors neuroscience; however, this field has changed a lot over the last couple of decades and consensus is still lacking. The same can be said about fields including sociology, psychology and philosophy. Thus, Matsumoto's preference for simplicity can be understood in light of the fact that he is trying to design an intelligent agent without a definite roadmap, having to rely instead on many patchy and incompatible ones that furthermore keep changing.

Matsumoto is thus very well aware that practically all the keywords embedded in the thought style and computational assemblages of his laboratory originated in different disciplines and come with their own theoretical baggage. Within the thought style of the laboratory, there are traces of many different disciplines and ways of understanding. As suggested by Fleck, these entanglements of knowledge within a thought style are not the result of rational planning and selection. Matsumoto explained that he simply takes knowledge or models from different disciplines according to the particular phenomenon he is studying. If a certain behavior is explained in simpler terms by neuroscience, for instance, then he will choose a neuroscience-based model, but in another case, he might opt for a model based on behavioral sciences.

In sum, any robotic experiment to replicate a human behavior draws on models that represent selected aspects of the phenomena. We might say that Matsumoto is pragmatic and eclectic both in terms of how he organizes his laboratory and research and in his grab-bag approach to foreign concepts. The robots emerge from the bits and pieces of life, machines, data, models, theories, and practices that make up Matsumoto's laboratory.

4. 5. Conclusion

Robots today are technologies marked by their likeness to us. Although they all resemble us—humans and non-human life forms—to a degree, some robots are specifically developed to mirror us, to show us what we are like. In this chapter, I have examined how roboticists who work to achieve such mirroring conceive of and operationalize embodiment, intelligence and life. Doing so, I have described how their thought styles draw upon a range of ideas from adjacent disciplines, which are combined in a piecemeal manner for particular research purposes such as replicating certain cognitive traits or behaviors in robots. The fluidity and variability of roboticists' thought styles are a consequence of partial adoptions and eclectic mixture of ideas from fields including neuroscience, behavioral sciences, and biology. In turn, these thought styles shape widely differing computational assemblages; made of silicon, metal, scientific facts, theories, models, and discourses, as well as lots of 1s and 0s. It is in these assemblages that the process of mirroring occurs. As mirrors, they reflect everything that is put in to make them: particular fragments of life forms as well as working practices and knowledges, temporarily patched together by a thought style.

Since researchers borrow inspiration and practices from various disciplines, whether life sciences or behavioral sciences, what they replicate in their robots can be completely different. Even in the case of a specific behavior, there are multiple ways to recreate it in a robotic body. On the one hand, then, thought styles locally determine how roboticists perceive the target organism and how they replicate them. On the other hand, the lack of a generally accepted roadmap for design means that both thought styles and computational assemblages proliferate and diverge.

Existing forms of life not only provide insight into concepts such as intelligence and embodiment, but also offer practical solutions to engineering problems. The end result—a robot—is expected to behave somewhat like the organism that it is made after. While roboticists thus integrate fragments of life forms into their robots, they themselves also add to the multitude of existing understandings of life.

Yet, rather than seeing robots as either alternative or artificial life forms, my informants view them as offering *depictions* of life. As for life itself, or even humanlike intelligence, these goals seem too elusive to pursue. Indeed, Matsumoto, who has been working on replicating human cognition for over 25 years, claims that he will not see human-like artificial intelligence in his lifetime, adding: “Do not underestimate human [intelligence]”.

Interlude

Workers and Lab Tools

In March 2018, shortly after I return from my main span of fieldwork, I accepted a side job to work as an interpreter in an automobile factory for two weeks. In talks about the job, I told the staffing agency that I am an anthropologist working on robots, and they placed me to the most heavily automated section of the factory: the body division. Here, the machines and humans put together pressed metal sheets in order to form the bodies of the cars.

The body division was situated in an immense building. While in production, it was very loud, not only with the noise from heavy machinery, but also with the announcements and melodies played on loudspeakers by a signboard that signal problems in processes. There were streets in between processes where vehicles carried car parts, which were fed into the assembly lines that went through the gigantic factory complex.

The most fascinating sight for me, however, were the robots. While in production, there were hundreds of gigantic robotic arms, moving in their work stations welding, pressing, carrying automobile body parts. There were grand motions with sparks flying and car doors being passed around; there were tiny motions where the arms got within centimeters from each other without impeding each other's movements. When in motion, the robots were both awe inspiring and intimidating—unlike the cute and clumsy humanoids of the lab. At that moment, after years of working on robots I thought, "So *these* are robots." There was precision and strength in their movements —no excess, no lag.

The starkness of the contrast was what hit me at first: I had spent a lot of time with robots, some of which were designed as industrial robots (i.e. factory robots), yet nothing I'd seen thus far had prepared me for that sight. They were huge robotic arms that were joined together at the spatial/work unit called the "process (*koutei*)". They either had been equipped with clamps that hold and lift the metal sheets, welding machines, rollers, or nozzles that apply adhesives.

The processes that I mainly observed began with a human worker placing metal parts on a station and with the push of a button starts a mechanical process that involves 8 to 10 robotic arms that make the metal sheets into the shell of a car door. The robotic spaces were covered with a transparent but heat resistant fence. The worker can only intervene in the robotic space through a couple of work stations which are guarded with photoelectric sensors. The robotic motion stops if anything triggers the photoelectric sensors. And reasonably so, as the robotic space can be deadly for human bodies with each robotic arm is longer than 2 meters, some weighing tons, also carrying sharp metal sheets or are equipped with welding machines.

The difference between the robotic processes of the factory and the laboratory experiments is multifold. First, the movements of the factory robots are strong, swift, and precise whereas the laboratory robots' *seem* the opposite: weak, slow, clumsy. Factory robots movements are awe inspiringly fast yet exact. Most robotics experiment videos are sped up multiple times to bring the robot's movement to a humanly normal speed. The factory robot's movement capabilities are limited, the arms do the same thing over and over again. The laboratory experiments are designed to adapt to the robot's movements to certain changes in the task.

Second, factory robots require everything else in the process to be exact. Every piece of metal should be placed in their nooks, nozzles, and welding tips need to be kept pristine. Temperature and humidity should be kept in control so that the materials behave the way they are supposed to. Robots in the laboratory, on the other hand, are made to "learn". We will see in the next chapter that while there is a lot of control involved in the experimental settings, there is diversity in the movement. The factory robot acts without adequately sensing the environment; the laboratory robot interacts.

Third, the lack of sensing in the factory robot creates boundaries between the human workers and the robotic process. There is a spatial separation between the two and the interactions are totally controlled as described above. The photoelectric sensor that detects movement in robotic space is admittedly the most important sensor in the factory robots I observed, they can go on working if a nozzle is not applying adhesive properly, but they instantly stop if something triggers the photoelectric sensor.

Perhaps not surprisingly, the human workers that are stationed in the process do not consider them as "robots" and they do not know much about those machines. When there is something wrong with the automated process, the workers call on the maintenance team who oversees the whole factory complex. In comparison, the laboratory robots are designed to share the space with humans, which is embedded in their bodies. For example, the Nextage in the laboratory—an industrial robot—has two arms, but it cannot lift those arms laterally to not hit a human accidentally when it works on the assembly line next to a human worker.

The whole comparison that I was able to do because of my not-so-fieldwork observations at an automobile factory made it clear to me that new robotics bases their robots on different design principles which create different more-than-human relations. Roboticists are not merely working on attempting to replicate human cognitive functions, they are also recreating relations of various sorts, including those between the human and the machine, the child and the toy, the master and the servant, and the mouse and the labyrinth, etc. In the following chapter, I aim to examine the particularities that distinguish the robot in the laboratory from the industrial robots and end-user entertainment robots, tied strictly to laboratory practices.

5

Laboratory Reproductions

5.1. Introduction

In this chapter, I am going to focus on research practices in the laboratory, in order to further elaborate how robotics and AI make the bold claims of "understanding human". One of the main challenges in robotics is making robots more humanlike in intelligence or movement, which requires tackling emergent traits of complexity in these not-as-complex computational assemblages. Exemplified by Matsumoto's "do not underestimate human [intelligence]", the more advanced robots get, the more puzzles there are posed by the complexity. Emphasizing the contrast between the complexity of "human" and rarefaction[49]—as Isabelle Stengers puts it—in experiments, I aim to critically analyze the robot's role as a laboratory tool.

First of all, complexity is not used here as the state of being complicated, but as a system which is more than the sum of its parts, and where the parts do not necessarily follow the same rules. John H. Holland, a truly multidisciplinary researcher and a prominent figure in the study of complexity, distinguishes it from complicated by the existence of emergent properties and a hierarchical organization where each level is governed by its own rules (Holland 2014, 4).

According to Annemarie Mol and John Law (2002), "There is complexity if things relate but don't add up, if events occur but not within the processes of linear time, and if phenomena share a space but cannot be mapped in terms of a single set of three-dimensional coordinates." (1) It is important to emphasize that the study of complexity has become a multi-

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[49] Stengers (2018, 2019) uses rarefaction to refer to the elimination of all that is not directly related to the thought experiment at hand.

disciplinary endeavor that can be put to use in many aspects of life, including ecological modeling (Morita and Suzuki 2019), arms race (Mayer-Kress 1991), earthquakes (Tang 1991), etc., as many of those are complex systems. While robots as computational assemblages exhibit some complexity (simply explained by binary codes producing movement), it is not on the same level as the human.

In her illuminating book *Artificial Unintelligence,* journalist Meredith Broussard carefully examines the limits of artificial intelligence in its current and possible future applications (2018). In a chapter about a study on standardized tests in the American school system, she states: “Engineering solutions are ultimately mathematical solutions. Math works beautifully on well-defined problems in well-defined situations with well-defined parameters. School is the opposite of well-defined. School is one of the most gorgeously complex systems humankind has built” (Broussard 2018, 61–62). Indeed, the complex phenomena that are sought to be replicated in robots are the opposite of well-defined, too.

In current robotics and AI, as I discussed previously, there is a significant and thick inspiration from sciences that study the human mind, such as neuroscience, behavioral sciences, cognitive science, etc.; as well as other life sciences such as biology, ethology, etc. The objects of study for all of these are complex systems. The human brain, for example, is not nearly well understood. Not to mention the rather abstract, hard to define concepts such as intelligence, consciousness, are all traits of complex systems. Furthermore, the physical world that we live in is and has a variety of different complex systems, such as the ecology and the society. So, how does the robot fit in all that? How do roboticists simulate, or reproduce, a piece of this complexity in their experiments?

This chapter starts with a basic introduction and dissection of the terminology in robotics, positioning robotics amongst sciences that aim to understand human. Following that, I explain experimental systems with the inspiration from historian Hans-Jörg Rheinberger. And finally, I consider robot and roboticist relations created in the laboratory through experimental practices.

5.2. What Does the Laboratory Robot Do?

In the previous chapters, I discussed the mirror metaphor used by the roboticists, according to which, the robot *reflects* the *kokoro* of the human. Roboticist Minoru Asada tackles the vagueness of the concept of the robot by suggesting to define it as the "artifact that reflects human (Asada 2010, 22) by way of which one can explain the existence of factory robots reflecting the "function" of humans and the entertainment robots reflecting the "form" thereof. [50]

The mirror analogy that is fervently used in conceptualizing robotics, particularly in Japan, is carving a role for this technology as something more than a laborer. In laboratory practices, however, it is not "reflecting" that is commonly utilized by practitioners: they talk about reproducing.

The robots are primarily devices that move, therefore they do not produce static reflections of humans, instead they are used in "reproducing" human cognitive traits or behaviors. In Japanese, the term that is used is *saigen* (再現) which can mean "reproduce," "replicate," or "*re*-present"—with the emphasis, as for "representation" in its usual meaning of "standing for," another term (*hyōgen* 表現) is used.[51]

Reproducing or replicating—in this context—does not necessarily mean making an exact replica of the target system, it usually is used in the field to indicate producing similar

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[50] In a December 2018 public talk, Asada makes a distinctive note regarding *kokoro.* In his slides, he explains, the general concept of (or human) *kokoro* is written by its Chinese character "心," but when he refers to robotic or artificial mind he uses the katakana version of the word, spelled as "ココロ." It is an interesting note, though it does not necessarily develop into an extensive argument.

[51] In Natasha Myers' laboratory ethnography *Rendering Life Molecular (2015),* she takes up the term "render", similarly originating from and contextualized within the field.

effects. Drawing an analogy, a reproduction of an ecosystem in a botanical garden aims to create the same climate conditions of the said ecosystem in a closed-off section with as much as the same flora and some fauna in it. Yet in the way my interlocutors are discussing reproduction, a dynamic model or an interactive video game of the ecosystem, or even a terrarium can be considered as reproduction. It is not in the same medium, neither it is a complete exact rendering. (cf. Black 1962)[52]

Discussed in the previous chapters, the synthetic approach that relies on robotic reproduction is what distinguishes robotics from other experimental sciences, which utilize more so the analytical approach. Pfeifer and Scheier describe the synthetic methodology at the intersection of empirical sciences (such as biology, psychology) and synthetic sciences (cognitive science, AI) (Pfeifer and Scheier 1999, 22). According to the authors, the synthetic methodology is complementary to the analytical approach that is rather used in traditional empirical sciences that deal with intelligence and aspects thereof (22).

STS has so far been mainly concerned with experimental sciences that focus on their objects of study and attempt to make causal relations, hence those with the analytical approach. Take, for instance, Bruno Latour's work on Louis Pasteur (Latour 1983). Anthrax in the 19th century was a complex problem that involved the intervention of farmers, veterinarians, the state, as well as the famous microbiologist. An infectious disease, without enough knowledge, can seem as obscure, complex, and intimidating phenomenon as cognition. However, Pasteur was able to make causal relations between the microbes in the laboratory and the disease out there. According to Latour, Pasteur only succeeded in solving that puzzle by playing with scale (149). Inside Pasteur's laboratory, anthrax was in a petri dish—which is according to Latour

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[52] In addition, it is important to note that reproduction in Japanese, the word *saigen* does not have the meaning of breeding, hence a lack of nuance in my interlocutors. Not that they discuss (or perhaps even think) of these nuances extensively, to most of them the reproduction would be close enough to make a difference, in fact close enough to represent some aspects of the biological system, but inherently different, too.

an interpretation of the disease (155)—hence allowing the maximization of the microbes that cause the disease while minimizing the epizootic aspect of the disease (163).

It is known that there is no *anthrax bacillus* to cognition, in other words, no single agent that might explain the thing we call cognition. Hence, there is a multitude of disciplines and practices to tackle the mysteries of cognition and they all contribute to the understandings we have thereof. Given these circumstances, with the wide variety of disciplines from anatomy to anthropology that deal with all things human, what can be the contribution of robotics? Do we really need synthetic approach to understand human? My view is that sciences such as robotics and AI, i.e. those with the synthetic approach, offer the unique position to deconstruct and then reconstruct the human in a completely different medium. Therefore they allow a certain separation that sciences with the analytical approach do not: to look at human from the position of a designer or a builder. It bears repeating that robotics, even in my fieldwork sites, does not *only* concern with elucidating human mind—roboticists want to make better robots. However, the synthetic approach is an integral part of trying to make robots more human: it is crucial to understand in order to replicate.

Let us break this down by way of an example. Attention is a cognition-related phenomenon seen in humans and animals. We all have an idea what attention is, and it is, like anything else related to cognition, a very attractive object of study for many disciplines. Of all the experimental sciences among those who study attention, there are some, such as neuroscience and experimental psychology where the experimentation might likely use human test subjects. Ethologists would experiment with their respective animals, be it non-human primates or cetaceans. There are of course some disciplines such as medicine and some branches of psychology that experiment on “model animals”, i.e. animals such as the mouse or the monkey which “represent” humans. Roboticists, AI researchers, and computational cognitive scientists work mainly on algorithms and robots: technologies that are, by themselves, not capable of attention. Where neuroscientists and others will try to experiment on humans to understand attention, roboticists and others will attempt at building an agent that is capable of attention.

In simpler words, the analytical approach is the archetypal putting-under-a-microscope whereas synthetic approach tries to build from scratch. Therefore even in the study of the same phenomenon, the approaches differ quite a lot in their knowledge making practices.

Historian of science Rheinberger has a distinction between what he calls “epistemic things” and “technical objects” (Rheinberger 1997, 2011). Rheinberger’s epistemic things (or objects) are the objects of scientific inquiry: things embodying concepts (Rheinberger 1997, 14). He describes them as “that hardly definable something for the sake of which the whole experimental enterprise exists and around which it revolves. “(Rheinberger 2011, 312) Technical objects on the other hand embody the given scientific knowledge in a field, he more likens these to the experimental conditions and gives examples such as model organisms, instruments, theorems, etc. (Rheinberger 1997, 29). Rheinberger asserts that there can be transformations between them, and he puts models as a go-between the two (Rheinberger 1997, 110). An epistemic thing, once elucidated, can be a technical object with which other epistemic things are researched (Myers 2015, 78).

Leaving Rheinberger’s distinction of science and engineering aside, when we think of the robot as a whole, the distinction between epistemic things and technical objects becomes obscure. Intelligence and aspects thereof clearly are epistemic things, but the robot embodies both characteristics of epistemic things, technical objects, not to mention their models.

Hence it is important to look into what experimental systems produce in robotics. Even though robotics as a discipline takes a lot of inspiration and knowledge from disciplines that are directly observing cognition-related phenomena, such a robotics research primarily has robotic movement for output: a robotic movement that reproduces human behavior or cognitive traits. Hence if we think of the robotic movement as the epistemic thing, it has this double meaning in terms of a successful learned behavior and the reproduction of a human behavior. The robotic body, in this sense can remain as the technical object whereas the movement, the behavior produced by the body—*the performance*— is the epistemic thing.

Referring back to the mirror analogy, roboticists mainly focus on polishing the mirror than poking and pinching their own faces. Biology or medicine do not have this sort of mirror metaphor—the most similar element in their research practices are the model animals such as mice. Although there are parallels between the mice and the robots, the mice are not thought to *mirror* the human, nor do they hold the potential to become more humanlike. This open-ended potential of the robot characterizes robotics in regards to other experimental sciences that work on "understanding human".

So, what difference does it make? Generally, basic sciences are considered as different than engineering (cf. Rheinberger 1997) though these new disciplines aim to blur those differences. In regards to sciences' relations to what they study there have been long discussions in both sciences themselves and social sciences thereof, starting from realism, to social construction of science and eventually to performativity.

I have discussed performativity in detail in my previous work (see Kemiksiz 2016) but in general terms, performativity in STS (see Pickering 1994, Barad 1999, 2003) outlies an approach to science and technology, that both rejects the representational approach to science (sometimes referred to as "realism") and social construction of science. Realism, or representative idiom in Pickering's words, indicates that sciences are merely representing the nature, they are illuminating what is out there. Anthropologist Natasha Myers states that the representational approach "assumes the world has a fixed ontology that preexists its encounter with the scientist" (Myers 2015, 129). The approach that had initially been an answer to that was that of constructivism, where the nature is in constructed by scientific practices.

Performativity, adapted to STS from linguist John L. Austin (see Austin 1962) and Judith Butler (1997), somewhat constitutes the middle ground: the knowledge that comes out of scientific practices is neither free of the discursive elements (theories, discourses, culture, etc.) that relate to it, nor is merely constructed by it. In the performative approach, it is co-constituted by the discursive and the material (see Barad 2003, 822).

This is even more obvious in technoscientific disciplines such as robotics, where the applications of the technology matter even more so than analytic disciplines. Robots can never be completely separated from the discourses about them, as exemplified by the string figures of Chapter 3. Technoscience and discourses thereof co-constitute each other, and they co-produce stories and computational assemblages featuring robots.

The robot is a performative artifact, it *performs* human (cf. Kemiksiz 2016, Borggreen 2015) both outside and in the laboratory. In the laboratory, the robot is experimented upon to move in a more humanlike manner, to learn like a human; which entails a type of expected performance envisioned through the understandings the researchers hold regarding the human. Moreover, since it is the artificial Other, marked by its assumed humanlikeness, it is made to present itself as humanly as possible within the expectations of the society—which can mean doing a variety of things from having a discussion with a human being or caring for the elderly. It is therefore possible to critically *read* the robot's performances for all the meanings they hold, as I did in Chapter 3 and in my previous work (Kemiksiz 2016).

Roboticists work on *the mirror*, therefore the materiality is *mainly* that of the robot, not so much of the human—which makes the performativity more pronounced and begs for attention. Robotics' relationship to "the human" is much clearly performative, and a significant part of it happens through modeling. Similarly to the performativity of gender in Judith Butler's work (2010) where one becomes gendered through the performing the socially accepted gender norms, the robot can be thought to become more humanlike through culturally accepted norms of how to behave and how to look like. Humanlike behaviors and traits (including physical traits) are embedded into robotic systems through models.

As mentioned in the previous chapter, philosopher Max Black has contributed to our understanding of models: among the model types he proposed, "analogue models" can explain the robot in regard to the human, though there are also mathematical models and theoretical models in the making thereof. Max Black states that "[a]n analogue model is some material object, system, or process designed to reproduce as faithfully as possible in some new medium the *structure* or web of relationships in an original." (Black 1962, 222) Therefore, the reproduction of complex systems regarding the human in the medium of the robot will require quite a lot of simplification and abstraction that happens in the experimentation process.

In *How We Became Posthuman* (1999), Katherine Hayles discusses the analogy between human and machine extensively. The machine (here robot) as an analog for human is not necessarily a ground-breaking observation even then, yet based on her meticulous reading of cybernetics she illuminates the implications of such an analogy. One is that the linkage is there, whether the research works or not: "By suggesting certain kinds of experiments, the analogs between intelligent machines and humans *construct the human in terms of the machine*. Even when the experiment fails, the basic terms of the comparison operate to constitute the signifying difference."(64, italics in original) She illustrates that with the example of mathematician Claude Shannon's electronic rat[53], where both the electronic rat and human are goal-seeking mechanisms that reach a stable state through corrective feedback (65). Even though certain experiments fail, the assumptions have already been established.

Hence there exists the analogous relationship between the human and the machine in these disciplines for a long time, stemming from the imaginaries that I discussed earlier. I

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[53] Mathematician and electric engineer Claude Shannon developed his electronic rat (1950), modeled after a rat solving a maze, is one of the important artifacts of early cybernetics according to Katherine Hayles (1999).

would like to take my time to explain how this relationship is put into laboratory practices for which I must first explain the general outline of scientific experimentation, which I discuss in the next section, followed by the details of experimental practices in section 5.4.

5.3. Experimental systems

In this dissertation, taking inspiration from the historian of science Hans-Jörg Rheinberger (1997), experimental systems refer to systematized practices of scientific experimentation including the material and discursive elements thereof. They are crucial in validating knowledge making practices. Rheinberger describes experimental systems as "smallest integral working units of research" (Rheinberger 1997, 28) that are set up to "give answers to we are not yet able to formulate clearly" (Rheinberger 2012, 92). He states that they are "hybrid constructions: they are at once local, social, technical, institutional, instrumental, and epistemic settings," yet he continues that "they do not respect macrolevel disciplinary, academic, or national boundaries," (Rheinberger 1997, 34) insofar as they guide research practices.

Rheinberger's views are important for understanding experimental sciences. He describes them as "material contrivances" that stand the test of time (Rheinberger 2011, 309). Hence, experimental systems have their historicity, they may develop a level of independence depending on the skills, or the virtuosity of the researcher (Rheinberger 2012, 89). Rheinberger is indeed quite inspired by the thought styles of Ludwig Fleck described in the previous chapter; he further zooms the focus on the materiality of the experimental practices.

Rheinberger's formulation of epistemic things is central in understanding experimental systems, as they exist first and foremost for knowledge making. Indeed, alluding to French biologist François Jacob, considers them as "a machine for making the future" (Jacob 1988, 9 quoted in multiple Rheinberger texts, e.g. 1997, 44). Newness, therefore, is an integral part of experimental practices. Once the epistemic thing stabilizes into something we know, the experimental system must open up new potential unknowns to move on to, or, according to Rheinberger, the system stops being a research system (Rheinberger 2012, 94). In other words, if one knows what the outcome of the experimental system and there is nothing left to explore, it becomes a tool to standardize, a testing mechanism, instead of the research vessel it should be.

This movement from stabilizing to destabilizing is what Hans-Jörg Rheinberger calls “differential reproduction”: difference and reproduction as the two important axes upon which there is a continuity in the scientific process (Rheinberger 1997, 75). Rheinberger uses reproduction with a connotation of evolution: as in keeping “alive” the experimental conditions through which it remains productive (75).

Anthropologists Kim and Mike Fortun also discuss the differential reproduction in their work on toxicology (Fortun and Fortun 2005) stating that “[w]hereas an experimental system must be reproductive, drawing on and contributing back to particular genealogies, so to speak, it also must facilitate shifts and displacements that allow something new to emerge. It must articulate and dislocate, stabilize and reorient “(46–47).

The unknowns are one of the main concerns of my interlocutors, as they constantly try to make robots more humanlike, most traits they attempt to replicate in their experiments remain elusive. Matsumoto told me in an interview that the more he learns about the human the more remains to explore. The robots of sf might appear as the “end goal” of humanoid robotics, however, as I explored with string figures before and as supported by the open-endedness of experimental systems due to differential reproduction, we do not have a clear view for what kind of knowledges and machines will these “machines for making the future” will produce along the way.

As I have mentioned before, roboticists such as Matsumoto often reminded me that there is no roadmap to making humanlike robots. Furthermore, robotics is quite different than biology and other experimental sciences in the accelerated rate of the change in their technical objects. New techniques, platforms, processing capabilities show up quite so often that they have to deal with new technical objects frequently. When I was in Matsumoto laboratory, the members were often testing different tools (from game engines to robotic platforms) to integrate into their experiments. On the one hand, this abundance of new technologies provides a certain ease for designing experiments; while on the other hand, it adds to the difficulties particularly younger members are facing. With way less experience under their belts, and new techniques they have to keep up with every day, the students find themselves lost on how to design their experiments.

Interestingly, Rheinberger likens the experimental systems to labyrinths: "A labyrinth that deserves the name is not planned and thus cannot be conquered by following a plan. It forces us to move around by means and by virtue of checking out, of groping, of *tâtonnement* (74)." Despite the fact Rheinberger's analogy lacks any reference to the fast-paced technoscientific changes that concern my interlocutors, they would concur with his point. It is rather an unacknowledged norm that the first try at an experiment will yield no results. There are quite a variety of unforeseen hurdles in building experimental settings, and not only because of the complexity of the reproduced behavior or cognitive trait. The "noise" from the environment can also impede on the experiment. In a situation where not many things the researcher aims at works at the first few tries, it becomes important to create a carefully delimited experimental setting.

When philosopher of science Isabelle Stengers talks about thought experiments in sciences (such as the brain in a vat) she asserts that those experiments create fictional rarefied worlds "where everything that can blur the consequence to be dramatized has been eliminated" (Stengers, Jensen, and Thorsen 2019). In laboratory experiments, too, a lot has to be eliminated.

As it is with most of the experimental sciences, robotic experiments take place in simplified locations, labs, where the complexity of the world is reduced to a degree the robot can handle, it is quite a *controlled* environment.[54] Let us consider a fictional experiment[55] where the robot's task is to spot and grab an apple on a table. Let us add that the robot will solely use machine vision to do so, and the robot does not have tactile sensors on its fingers. The experiment will take place in a well-lit room, where the temperature and humidity will be ideal, and of course, safe from the weather conditions outside. The table will be clear of clutter if that is not a condition of the experiment. The apple itself is more likely to be replaced by a plastic prop if the robot is not strong enough to hold it in its hand. Replicating this experiment in another laboratory will require similar ideal conditions, adjusted to the new experimental system if necessary.

Replicability is a crucial facet of scientific practice. As sociologist Harry M. Collins states, replicability or repeatability of observations and experiments constitutes the main pillar of the validity thereof and it happens through experiments (Collins 1985 18–19). Resonating with the "differential reproduction" of Rheinberger, Collins states that "[a] confirmation, if it is to be worth anything in its own right, must be done in an elegant new way or in a manner that will noticeably advance the state of the art." (19)

In robotics, replication is made easier with widely used robotic platforms such as NAO. Laboratories that develop and safeguard their own robotic platforms trade replicability for

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[54] There are indeed experiments that take place outdoors, which generally are experiments *for* outdoor movement, such as walking on uneven terrain. Even those kind of experimentation starts in the laboratory and only taken outside after it shows significant success in the laboratory.

[55] I use fictional experiments in order to protect the identities of my interlocutors, in line with the ethical guidelines of Osaka University. In robotics, even a simple description of experiments makes researchers easily identifiable. I mainly change the actions and the objects in the tasks to offer a general depiction of how experimentation works in my field.

product development. For example, trying to replicate an experiment designed for a 170 cm bipedal robot in a 35 cm upper body of another robot might be akin to replicating an ethological experiment previously done with macaque monkeys to be replicated in mice, which cannot be done with all experiments, and if possible, requires a lot of change in the variables..

In any case, the experimentation as one might see is tailored to the robotic platform that is used. In Matsumoto laboratory, there is a special focus on machine learning technologies which requires a special involvement of the roboticist in the learning process by way of training. I discuss these practices in the next section, which tend to be more technical, but helpful to understand how the robot is used as a tool and how robots and roboticists relate in the laboratory.

5.4. The Education of A Robot

Figure 6. A tall can of Tully’s Coffee (Photo by Author)

It is important to take a detour and further explain how a robot "learns", because it is the main challenge of robotics research. I remember an interview I had with Matsumoto, where he explained what kind of challenges there may be. A tall can of coffee stood on the table between Matsumoto and me. Matsumoto picked it up, brought it forward, and started to explain:

> *"I would like to think about seeing things with a subjective context. Today's Deep Learning prepares all of the possibilities as to this might have been read as labels; such as "coffee", "black", "Tully's", "cap", etc. The probability of it being perceived as coffee as 50%, as Tully's is 30%, it shows as such. But really, this is a lie. When I see this now, it cannot be anything but coffee. Well it is alright if I called it Tully's. Or to some, it might be important that it is black. But to me, at this moment, it is just coffee. Someone else might see it as an empty can, and would want me to throw it away. So the meaning, the meanings others have of this might be diverse, but to me, at this point it is just one. Who sees it is important, and the timing. There's still some coffee in this, so it is still coffee, but the moment I finish it, it becomes trash. It is really important to see the one meaning among all the potentialities. Deep Learning does not think about this. It holds all the potentialities. It does not lie, saying this is orange juice. But it has to say every possibility with the percentages. It also cannot tell all the possibilities because there is no end to it. No end to it. (Laughs). Humans prepare the correct labels for the training, for the system to recognize. That is deep learning. But humans are different, when they see things, the meaning is only one."*

Sitting across the table from Matsumoto, I was fascinated by the canned coffee. Until he brought it forth, it existed but that did not register with me. I may have noticed it, as he drank from it from time to time, but did not even note its existence down on my green notepad. It was irrelevant, it occupied the dissolving edges of my attention. When he pushed it to the center stage, my cognition went along with Matsumoto, evaluating the possible labels, the canned coffee no longer irrelevant.

Possibilities may "lie", as perception is subjective. It is imperative to impose limits when designing the ANNs to create something that works in a world that is full of possibilities––or lies. Matsumoto and his laboratory do a lot of work regarding tying vision to action and that offers a solution: possibilities narrow down in action. Yet still, what comes naturally to biological agents, such as seeing coffee at times and seeing garbage at times, has to be taught to the robot.

And it is not just the endless potentials that pose a problem for the researcher. Journalist Meredith Broussard describes and demonstrates the many tricks of the trade in artificial intelligence. For instance, she explains an "open-secret" of the big data community; that "*all data is dirty*" (emphasis author's, Broussard 2018, 103). She states that all data is made either by people or by sensors that are made by people; hence the noise, the missing parts, the mistakes, etc. She then says that as dirty data does not compute, "in machine learning, sometimes we have to make things up to make the functions run smoothly" (Broussard 2018, 105). Despite their shortcomings, these relatively novel technologies produce the best results, and to understand why, it is important to look into how they are used in embodied agents.

As I have already discussed, the traditional approach to AI posits the mind in the brain, and treats it as a symbol-processing system. This approach, also known as the GOFAI (Good Old Fashioned Artificial Intelligence) is still used for a variety of purposes and is valid. What was brought to limelight with the embodied turn was a new approach to designing intelligent agents, one that distributes the intelligence to the body. As discussed in Chapter 4, the embodiment is an integral part of how my field sites design their experimental practices.

Now, not all embodied agents are designed in this novel way, such as the factory robots I discussed in the Interlude. Philosopher Andy Clark talks about three different grades of embodiment: mere embodiment, basic embodiment, and deep embodiment (2008, 42). According to Clarke, the mere embodiment is when a creature or robot has a body and sensors, "able to engage in closed-loop interactions with its world, but for whom the body is nothing but a highly controllable means to implement practical solutions arrived at by pure reason" (42). The factory robots I witnessed and their highly controlled movements indicate a mere embodiment. The basic embodiment takes it one step further, where the body becomes a resource for action. Passive dynamic walkers (See Clarke 2008, 8; EUCOG n.d.), for instance, are often simple bipedal robots that exploit their body morphology to walk. The earlier versions of passive dynamic walkers had no control system, no sensors, they just used their body and an incline on the ground to walk; but the Toddler Robot Clarke features in his book can learn a variety of new tasks such as changing speed. Yet, as Clarke points out, basic embodiment does not allow agents to react or interact "on the fly".

Deep embodiment, finally, is how most biological agents operate: they make use of their body and the world when they act and they can adapt to the changes or any novelty. This is not something that we can easily see in robots but perhaps we can see glimpses of it. For Clark, the body here is "critically important and constantly negotiable" (42), which reminds me of the beautifully monstrous starfish robot of Josh Bongard, Victor Zykov, and Hod Lipson.[56] These roboticists ventured out to design a self-modeling robot, that is a robot that does not know what itself is like, it has no internal model of itself. Through random movements and exploration, it develops a rudimentary model of itself, finding out that it has four legs with a body resembling a starfish, and it teaches itself to walk. This process is unsupervised, as in, post initial design, the modeling is done through the robot's own interactions (though limited)

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[56] For further information see https://www.creativemachineslab.com/evolutionary-self-modeling.html

with the environment (further explained later). The roboticists designed the starfish robot to have *continuous* self-modeling, which was tested by damaging one of its legs. The robot adapted to the change and taught itself to move again. It is of course incomparable to how, for instance, a chimpanzee interacts with the environment, yet it offers an example to how a deeply embodied yet thoroughly simplistic artificial agent might be. [57] In Matsumoto laboratory, however, with the added pressure of humanoid robots achieving tasks that involve dexterity, the roboticists often are more involved in how the robot learns (see Chapter 4).

Robotics' core drive is to create deeply embodied agents and the output it seeks to produce, as mentioned before, is the robotic movement. This can be the distinguishing factor from research in other disciplines (AI, cognitive science, etc.) who utilize similar techniques such as machine learning. The robot is supposed to move in the "real world", not just recognize its environment but to interact with it. Hence even simulations of robots involve movement, though in a digital environment. It is through the development of deeply embodied robots that robotics can make bold claims of understanding human: as their performances read more and more humanlike, they can be of better use to explore epistemic things, which manifest here in terms of behavior or cognitive trait.

The robot by itself does not know what it sees, or how to move. In most experiments, the robot has to be "trained" to recognize the target of its task and learn what to do with it. I would like to ruminate some more by returning to the fictional experiment with the robot and the apple—the forbidden fruit. Let us say that the task is to recognize apple, pick it up and bring it to its mouth as if to eat it. This movement is simple enough for a toddler to do, but not for a robot. The robotic platform does not "know" what an apple is, what it is for, what the action of grasping is, or even what a mouth is. As Matsumoto's explanation above elucidates,

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[57] Philosopher Andy Clark has written about the mind for his whole career and his scope of mind has expanded throughout the years. In *Supersizing the Mind* (2008), he defends an extended mind, in contrast to the mind in the brain *and* the embodied mind. He is profoundly influenced by the embodiment arguments but he puts his focus on the boundaries of the body, and that they are constantly negotiated.

it does not distinguish *by itself* between the many things an object could be in given circumstances. At the end of the experiment, it may learn to execute the task, but it still will not have a concept of eating an apple. [58] However, the execution of the task in an experimental setting will provide an understanding of the underlying mechanisms of either recognition or the movement regarding the eating of the apple.

To start, making the robot recognize an apple will require a similar process to what most of the currently ubiquitous face recognition technologies utilize, artificial neural networks that are fed countless images by massive databases. Yet, as mentioned before, in the task is not only recognizing what an apple is, it is to pick it up and to bring it to its mouth. In this sense, the robot is not just to be trained in recognizing the apple, but also in what to do with it. Therefore, the robot must learn to both recognize and act. [59]

In broad terms, there are three main methods used in machine learning: supervised, unsupervised, and reinforcement learning. Supervised learning involves a teacher and correct answers to the questions that are posed. The system is corrected if it makes mistakes. This is generally used in image recognition. In unsupervised learning, the system is left to itself to find patterns, and even though this takes a longer time than supervised learning, it can produce some unconventional, therefore innovative results. In reinforcement learning, there is again human intervention but not the same way as supervised learning, as reinforcement is generally used in tasks that require a sequence of decisions. Much like an animal in a cognition experiment, there are rewards involved to promote a certain action (i.e. to teach).

It depends on the experiment and the experimenter what kind of learning techniques are to be used and therefore what kind of intervention by the experimenter will happen in the

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[58] This requires a lot more than what is included in the experiment. Further discussions can be found in Harry M. Collins' *Artifictional Intelligence: Against Humanity's Surrender to Computers.* (2018).

[59] In behavioral sciences, even if a model animal is trained for an unfamiliar task, it is coupled with familiar experiences such as a reward. As a rule, there is nothing familiar to the robot, so if similar tactics are to be used a reward or a punishment requires to be defined as such in the software. The robot is blank in comparison to living organisms, it can be molded into whatever the experimental system requires.

experiment. What I mean by intervention is not just by code, but also by bodily interactions with the robot. In the forbidden fruit experiment, for instance, the preferred movement might be put into code in terms of 3D coordinates of body parts. And as it might be obvious, the 3D coordinates are relevant to the body of the robot, the object with which it is supposed to interact as well as other variables in the experimental setting. Yes, the robot is supposed to learn and generalize in many of the experiments, however, oftentimes there must be a baseline upon which the robot will learn.

There are numerous ways of teaching the robot to do something. The rather low-tech way would be to manually pose the robot a certain way and input the coordinates from there. This is rather easier with smaller, softer robots. For example, if a robot is supposed to learn to point at directions uttered by a human subject, it can first be posed prior to the experiment to get the necessary measurements.

There are several technologies that can be used for rather complicated motions or bigger robotic platforms: 3D mice, motion capture technologies, teleoperation technologies are among those I have heard in the laboratory. These are different techniques that do not require human contact with the robot. In motion capture, there is “reverse kinematics” involved where human movement is broken down and translated to robot movement. As mentioned before, humans have a lot more degrees of freedom in comparison to most robotic systems therefore their movement cannot be applied directly to the robot.

There is an important matter to be underlined here. The reason why the robots in the factory (see Interlude) are spatially separated from human workers is that they are dangerous, in the sense that they are powerful machines that move. That applies to laboratory robots as well. Particularly bigger robots would hurt the roboticist if they accidentally hit them. Smaller robots such as NAO are not risky in that sense, my interlocutors told me that it does not hurt even if they get hit in the process of experimentation. The risk of hurt is thence important in how the robot is trained.

The materiality of the robot is also important in designing the experiment. Many robotic platforms are customizable, one can find replacement parts required for different tasks. One can also design the experiment to fit the bodily affordances of the robot. For example, holding a real apple is impossible for the little NAO, but it can point at the apple.

It might be rather obvious that different robotic platforms foster different robot–roboticist relations, as well as human–robot comparisons. Social psychologist Steve Brown discusses the preference of Wistar rats—a strain of albino rats—as experimental animals in behavioral psychology (Brown 2011). In regards to Isabelle Stengers' (2011) discussions of comparison as a matter of concern, Brown propounds that the comparison of Wistar rats to humans, the experimental practices that allow the former to represent the other, has constituted current behavioral psychology, wondering how different it would have been have it took bees instead as the matter of concern (76). For cognitive and developmental robotics, the matter of concern is robotic movement; yet like their counterparts in analytical sciences, they use the robots to paint a picture of behavior or cognition—similarly to Wistar rats of behavioral psychology.

Claudia Castañeda and Lucy Suchman, in their impressive paper "Robot Visions" (2014), discuss the figures of the primate, the child, and the robot as model organisms. They refer to STS scholars Rachel A. Ankeny, Sabina Leonelli's work on model organisms where the main characteristic of a model organism is that "the organism can be taken to represent a larger group beyond itself and, more specifically, that the model organism represents a relatively simplified form of 'higher level' organism, usually of the human (Ankeny and Leonelli, 2011, 318)."

Castañeda and Suchman use “almost mind” to describe the figures of primate, child, and robot and the politics thereof. They can serve as a model organism precisely because of they are *almost minds*, close enough to establish an analogous relationship yet inferior in terms of complexity. I can concur with Castañeda and Suchman on their reading of robotics, and further add that the “almost mind” figures also have a tool aspect to themselves and it is deeply embedded in robotics.

Yet in contrast with Wistar rats, or other preferred model animals, there is a certain tone of pragmatism within robotics when it comes to what type of robots represent humans better: there is no obvious common preference. Most laboratories will work with whatever is in their budget and make do. However, laboratories that develop their own robotic platforms indeed prefer to work on bettering them. There is a certain motivation to make the next best robotic platform in many roboticists, including Matsumoto, notwithstanding the competition that already exists in the field.

As it is with experimental animals in behavioral sciences, there is education involved with the robotic experiments and it creates relations that result in the robot being a *different* tool. A tool with open-ended potentials, something which in principle can become more similar to what it is used to study. As discussed before, roboticists in the field often use anthropomorphic language referring to their robots or their digital creations (simulations, ANNs, etc. See previous chapters). They still consider the robots and the software as tools, but not exactly the same way as, for example, their keyboard.

5.5. Conclusion

In this chapter, I focused on the robot in the laboratory through a series of comparisons and a breakdown of experimental practices in the laboratory. To begin with the aim of robotic experiments, particularly in my field, is reproducing higher cognitive traits or behaviors in robots. This is made possible by the analogy of mirror, stemming from the imaginaries and the historicity of automata and robots, deep embedded in the discourses of my interlocutors.

Robotics' approach, i.e. synthetic approach, is different than some other sciences such as medical sciences or biology in regards to the human: it entails making. This provides some advantages, such as the looking at the human from a designer's perspective rather than other disciplines that working on understanding its mysteries. However, it also might overlook some socio-cultural biases and perpetuate certain understandings of the human, therefore the robot, as discussed in Chapter 3.

In a research field where robotic movement comes as the research output, and that output simultaneously holds meaning regarding what is reflected by it—the behaviors and capabilities of human—it becomes important to analyze what sort of tool the robot becomes in experimental practices. As mentioned before, the epistemic things (robotic performance that reflects human) are embodied by the technical object (robotic bodies) in this type of research, hence the boundaries between the two may be blurred.

Experimental systems in these disciplines evolve in relation to the complexity of the human, in alignment with differential reproduction, wherein the better the robots get, the more mysteries emerge that are to be solved—to be reproduced in the robot.

In doing so, the robot becomes a unique tool, a unique technical object in Rheinberger's terms, that occupies the limbo between human and machine, where its journey is not only important for the researchers that work on it, but also impactful for our understandings of human. The roboticists working on the robot create their own human-robot relationships that differ from how people outside of the laboratory view them. As they can see what is inside and they can tinker with the robots themselves, their relationships with the robots diverge from the mainstream fascination with robots but also from the kind of relationships they have with their other research tools.

In the conclusions of this dissertation, I discuss the meanings such robot-roboticist relations hold in addition to the overall denouements of this research.

Conclusions

In this dissertation, I offered a look into novel disciplines within a relatively new science: robotics. Roboticists, taking inspiration from disciplines such as neuroscience, cognitive science, and developmental psychology, use their robots to make them more "humanlike", a term deeply elusive and performative. There are rather implicit norms regarding what is humanlike in a given time and place, though as Matsumoto's experiment described in Chapter 4 exemplifies, people do not seem to agree on it when asked outwardly—it has always been a point of discussion for quite a lot of academic work and arts though it remains difficult to define. Their use of robots as tools is not only to make robots better technologies, but also to understand the human traits that they are trying to reproduce in robots.

This dissertation initially discusses the multiplicity of the robot. The robot is inherently multiple, as we call the extremely humanlike figures of sf and the new-generation vacuuming machines the same thing. The history of the robot, with the automaton as the precursor, suggests that there is an underlying curiosity to making such machines, to see if "human" can be made in materials other than flesh and blood. Testing the limits of the machine also means testing the limits of the human, the more that have been deemed essential seems to be replicable in a machine, the less enchanted the human becomes. The robot thence becomes an enchanting object, only one of the incarnations of the artificial human, the artificial Other.

Enchanting to whom, though? I have discussed that the robots are enacted differently in the laboratory and outside of it. A person who goes to see ASIMO perform in the technology museum Miraikan has a different encounter with the robot ASIMO than those who had conducted research on it. I would say that the person in the audience and the researcher in the laboratory are both enchanted, albeit differently. In the public understanding of robots and AI, sf and popular imaginaries play a significant role, as the string figure games in Chapter 3 illustrated. The children in the audience may be enchanted because ASIMO sings a song to them and hits a ball; the researchers, on the other hand, can be enchanted by the potentials of this technology, by what else they can make the robot do, and what the robot does to them.

When Dr. Ryōji Kobayashi told me about the robot making people questioning their own assumptions (see Section 3.4.), I felt that the robot still manages to evoke a sense of wonder despite the lack of "machinic life" in the laboratory. Similarly, I have met with a lot of scientists, including Matsumoto and Kanai, who are following their career in these high-tech disciplines because of an interest in solving the mysteries the hard-to-define concepts such as intelligence and consciousness through the developing humanlike technologies. I was told by multiple interlocutors that they are not fazed by robots because they can see or they know what is inside.

Sometimes knowing what is inside, or knowing what the "real robots" are like as Masahiro Mori expressed it (Mori 2014), may create a view close to what John Law calls One World World. Researchers in robotics and AI are aware of how humanoid robots are enacted, encountered, known outside of the laboratory. They know of the fears and hopes, the hype, and all the associations that are made in regards to the robots. To make use of this multiplicity is a very common phenomenon within robotics. For instance, some of the most fear inducing and well-known robotics demonstrations come from Boston Dynamics, where humanoid Atlas and quadruped Spot are often shown to perform highly complicated motions including a somersault (Boston Dynamics n.d.). Each time they release a demonstration video the internet roars with reactions of doubt, surprise, awe, and fear. It is not as well-known that since 2017, Boston Dynamics is owned by Softbank—the same telecommunications giant that developed the emotive and cute humanoid Pepper. Both are humanoid robots with quite different discourses attached to them, or in other words, they are quite different computational assemblages. It is rather difficult to imagine the towering Atlas to read my fortune, which Pepper had done.

Similarly, it is different to imagine Pepper to be an agile search-and-rescue robot. Softbank is simultaneously offering them to the world, though it must be noted that Pepper is mainly used in Japan, and Atlas is developed in the US (Atlas is not an end-user product yet). The attention brought upon by the associations made in the public is in fact quite important for companies like Softbank and even academia, as it translates into impact which translates into revenue or funding.

The porous boundaries of the laboratories, open to be affected by the popular imaginaries have been discussed in my earlier work (Kemiksiz 2016) as well as Chapter 3. I also initially discussed the underlying curiosity that works through replicating human traits. The robot as a mirror metaphor has been discussed in Chapters 4 and 5. There is a certain historicity for the robot to be such a tool, a mirror that shows us ourselves, present from early on in precursors to the robot such as the automaton. Now, though it is expressed as robot being a mirror, or robot having a *kokoro* in Japan, a similar use of the robot is there in robotics globally. I use the term "synthetic methodology" in this dissertation, influenced by the roboticist Rolf Pfeifer, which is used in similar disciplines to indicate knowing by making.

The replicability of human traits is a core challenge in synthetic methodology. I discuss partly in Chapter 4 and Chapter 5 the practices of replication. It is important to emphasize that most traits or behaviors that roboticists try to replicate are emergent phenomena, they belong to complex systems. Hence, roboticists need to tackle complexity, which is never an easy task. In the laboratory context, robotics experiments are made in highly controlled, "rarefied" settings, and all that is uncontrolled (such as the human interaction) is reduced to a degree that the robotic system can handle. The phenomenon is also simplified to a minimum degree; as roboticists such as Matsumoto are not trying to embed the complexity of human beings into the robot in their practices, they are instead simplifying phenomena and aiming for the somewhat complex algorithms (artificial neural networks) to produce emergent behavior.

They are doing so by practices of modeling, which is practiced similarly across disciplines of technoscience. Modeling is speculative practice, it involves potentialities of what may a phenomenon be, and works sometimes not in the way the target phenomenon does but affects our understandings thereof. In robotics, particularly, the environment also turns into an agent with which the robot interacts, and sometimes roboticists leave the modeling of the world to the robot itself?. In all cases, replicating human traits means experimentally constructing the human traits in these silicon and metal computational assemblages, where ones and zeroes replace the massively complex networks of neurons and cells.

All in all, a mirror is an apt metaphor for the robot, as the mirror is both a tool to see what one is, and the image of one's self: it can be clear, obscure, warped, broken; it will reflect an image regardless. When you do something, the image in the mirror does the same thing. Furthermore, it is also not merely the visual image that the mirror reflects, instead it is an image loaded with meaning. Yet I have been suspicious of how efficient of a mirror the robot is.

There is an attraction called "the house of mirrors" in traditional carnivals or amusement parks; constructed of many mirrors sometimes with differing surfaces, designed to confuse and entertain the visitor. I would like to think current robotics as a house of mirrors, filled with robotic reflections, though they are many, they are understandably not consistent: they reflect not a uniform human, as there is none, and they can only reflect bits and pieces. In the same time, a house of mirrors is an attraction for humans, and in robotics too the human enters the loop as the spectator, the enactor, and the interpreter. The many mirrors in the house of mirrors of robotics therefore also replicate the relations between the human and nonhuman, the human and the machine, and the human and the *almost* human.

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