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Inventing Japan's 'robotics culture': The repeated assembly of science, technology, and culture in social robotics

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Abstract

Using interviews, participant observation, and published documents, this article analyzes the co-construction of robotics and culture in Japan through the technical discourse and practices of robotics researchers. Three cases from current robotics research – the seal-like robot PARO, the Humanoid Robotics Project HRP-2 humanoid, and '*kansei* robotics' – show the different ways in which scientists invoke culture to provide epistemological grounding and possibilities for social acceptance of their work. These examples show how the production and consumption of social robotic technologies are associated with traditional crafts and values, how roboticists negotiate among social, technical, and cultural constraints while designing robots, and how humans and robots are constructed as cultural subjects in social robotics discourse. The conceptual focus is on the repeated assembly of cultural models of social behavior, organization, cognition, and technology through roboticists' narratives about the development of advanced robotic technologies. This article provides a picture of robotics as the dynamic construction of technology and culture and concludes with a discussion of the limits and possibilities of this vision in promoting a culturally situated understanding of technology and a multicultural view of science.

Keywords

culture, co-construction of culture and technology, Japan, robotics, social robots

The notion that robots hold a special place in Japanese culture is well established in popular discourse and receiving increasing scholarly and critical attention. In the 1980s, Japan was named the 'Robot Kingdom' (Schodt, 1988) to mark its global leadership in

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industrial robotics and a seemingly unique propensity to accept robotic companions and partners. Today, Japan is referred to as a place where people are 'loving the machine' and robots are 'priceless friends' (Hornyak, 2006). Some scholars point to specific cultural factors, such as Shinto animism and favorable media representations of robots, to explain the predominantly positive popular image of robots in Japan (e.g. Geraci, 2006; Kaplan, 2004; Kitano, 2006). Cross-cultural research on people's perceptions of robots, however, challenges the assumption that the Japanese public is peerlessly accepting of robots (e.g. Bartneck et al., 2005; MacDorman et al., 2009). Furthermore, critical studies of robotics in Japan suggest that the presentation of robots as endemic to local culture is the product of continuing efforts by the government, industry, and academia to encourage popular acceptance of robots (Ito, 2007; Wagner, 2009), and that such efforts reproduce conservative social values obscured by technologically advanced visions of robots in society (Robertson, 2007, 2010). This article seeks to further our understanding of the co-construction of robotics and culture in Japan by analyzing how robotics researchers, as sociotechnical 'imagineers'[1] (Rossini in Robertson, 2010: 28), explicitly invoke the notion of culture in their technical discourse and practices, and how they situate their research within a local cultural frame while participating in the global development of robotic science and technology.

Culture and technology in 'the age of robots'

From March to September 2005, Japan's Aichi Prefecture hosted the World Expo – the first world fair of the 21st century – in which the Japanese government, companies, and scientists displayed their 'future imaginaries' (Fujimura, 2003: 176) of technology in Japanese society. Held in Aichi Prefecture, the hub of Japan's automotive industry, and visited by over 22 million people (including myself), the Expo featured approximately 100 different robots and functioned as a large-scale field test of life 'in the robot age'.[2] The ubiquity of robots at the Expo, where visitors could see them cleaning, giving directions, providing security, and taking care of children, reflected the Ministry of Economy, Trade, and Industry's (METI) plan to develop 'partner robots' for the general public as a key growth industry for 21st-century Japan (Kusuda, 2006: 11). The Japanese Robotics Association (JARA) and the New Energy and Industrial Technology Development Organization (NEDO) developed special safety guidelines for the event so that visitors would not experience any mishaps that might 'hinder a healthy penetration of robots into human lives' (Hara, 2005). The Aichi Expo therefore represented both a conceptual blueprint and partial materialization of Japan's developing 'robotics culture'.[3]

Along with presenting robots as part of everyday life, the Expo emphasized the necessity of grounding the development of technology in local cultural values. Aichi was built to represent a 'global laboratory' for reconnecting technology with the positive essence of local tradition in a 'site alive with the spirit of the ancient arts' and freed from the 'unthinking pursuit of efficiency and economic rationality', where 'ancient tradition ensures that the new art of life arising from the marriage of technology and culture is already part of everyday life here'.[4] Several *karakuri ningyo*, mechanical dolls developed during the Edo period (1600–1867), were displayed prominently at the entrance to the Expo's Robot Pavilion as precursors to contemporary robots, representing the

(a) (b)

Figure 1. (a) The seal-like therapy robot PARO fuses natural inspiration, advanced technology, and socially beneficial application befitting (b) *Nipponkan*, where it was the only robot on display.

continuity between Japanese history and its robotic future. The Japan Pavilion (*Nipponkan*), powered by renewable energy sources and housed in a traditional bamboo structure from the Edo era woven into a modernist pod-like shape (see Figure 1), presented a fusion of 'traditional techniques' and 'cutting edge technology' in service to society.[5] At the entrance to the pavilion, visitors could interact with PARO, a socially assistive robot resembling a baby seal and used in eldercare (see Figure 1). Inside, the social and technical changes Japan has undergone in the past 50 years were presented in photographs juxtaposing the country's rural history with its urban present, a collection of household appliances from decades past, alluding to shifts in living circumstances, and on-screen visualizations displaying increases in transportation, migration, and electricity consumption. Although technologically optimistic, the Expo's message cautioned that the societal benefit of technology depends on its fit with the natural and social environment. The event represented Japan as a place in which technology is in harmony with cultural values and traditions[6] without explicitly referencing the societal and ecological upheaval that has accompanied technological development in the Japanese archipelago.

The Aichi Expo's fusion of advanced technology, cultural tradition, and future projection exemplifies a broader 'foundational schema'[7] (Shore, 1996) in Japan, which legitimizes the development and adoption of emerging technologies through association with traditional practices and cultural continuity. The resulting discourse about robotic technology and society interweaves, present, and 'future anterior' – a space in which how we define the associations between past and present sets up the structure and experience of 'what will have been' (Fortun, 2002) – to create a cultural logic supportive of current sociotechnical developments. This has led to the construction of 'invented traditions'

(Hobsbawm, 1983) that present today's socially desirable institutions, ideas, and technologies as age-old phenomena 'handed down from generation to generation' (Vlastos, 1998: 3). For example, the affiliation between *karakuri ningyo* and robotic technology, despite contemporary claims to the contrary, is relatively recent – the mechanisms had fallen into relative obscurity (Wagner, 2009: 511) before resurfacing in the 1960s as counterevidence to assertions that Japanese technological development was driven by innovations produced elsewhere (Ito, 2010). Similarly, popular images of robots in the 1930s showed threatening machines coming to Japan from abroad, in contrast to the friendly robots that are described as the cornerstone of Japanese robot culture today (Ito, 2010). While the aim is to inspire optimism and feelings of safety through the semblance of cultural continuity, these associations between invented traditions and advanced technology suggest underlying concerns about the potential negative consequences of emerging robotic technologies and their applications in society. At the same time, the depiction of technological development as the natural continuation of existing cultural practices obscures such concerns from view and obviates their public discussion.

Recognizing the broader social and cultural context in which robotics is developing in Japan, this article analyzes on analyzing how robotics researchers co-construct Japanese culture and robotic technology through their discourse and practices. Interviews with social robotics researchers in Japan and participant observation in the field provide empirical sources for three cases from current robotics research – the seal-like robot PARO, the Humanoid Robotics Project (HRP)-2 humanoid, and '*kansei* robotics'. I present these cases as examples of robotics culture in the making, in which robots are defined as culturally situated artifacts in ways that contribute to the societal fit of robotic technology in Japan. By examining the origin story, fabrication process, and design philosophy of the therapy robot PARO, I show how the production and consumption of social robotic technologies is associated with traditional crafts and values, and how tradition is redefined to include new technological materials and practices. I analyze the design of the HRP-2 humanoid and its performance of traditional dance to portray how roboticists negotiate among social, technical, and cultural constraints while attempting to create a humanoid for everyday use. Finally, the case of *kansei* robotics, in which robots are designed not only to appear to have emotion but to evaluate the world subjectively, displays how Japanese robotics researchers co-construct humans and robots as cultural subjects by referencing culturally specific notions of intelligence and interaction. All three examples give insight into how the cultural roots of Japanese robotics are being defined locally as well as in the international scientific community.

Conceptually, I focus on the various ways in which roboticists integrate and construct 'cultural models' – practices, artifacts, and concepts shared by members of a culture that provide an interpretive filter through which the world is meaningfully perceived and can be acted upon (Shore, 1996) – in their research. Cultural models can be studied 'both as public artifacts "in the world" and as cognitive constructs "in the mind" of members of a community' (Shore, 1996: 44); this article refers to robotic technologies that can be observed firsthand and ideas about robots and their relationship to society that can be inferred from the practices and statements of researchers. I argue that by specifically relating the applications and interactive capabilities of their robots to practices, beliefs, and social norms they consider to be culturally normative, robotics researchers 'repeatedly assemble' (Caporael, 1997) cultural models of cognition, sociality, human relationships with technology, and technology's role in society. The notion of repeated assembly calls attention to the dynamic mutual constitution of human ideas, beliefs, and practices, and to technological designs as expressions of and affordances for cultural reproduction. The normative cultural meanings and practices robotics researchers use to situate their work are in turn redefined through embodiment in new types of human–machine interactions and relationships (Suchman, 2007; Turkle, 2011). These repeated assemblies are mutative, rather than identical, reproductions; they do not produce simple copies of existing cultural and technological forms, but represent the recursion of core cultural models as they dynamically change and adapt to fit contemporary circumstances. This framework is particularly apt for analyzing the development of robot cultures in Japan because it allows us to interpret culture not as an unchanging factor, which in the terms of the dominant foundational schema 'precedes and frames technology, informs its ideology, grants it power, and, alternatively, generates contests over its own meaning' (Najita, 1989: 5), but as a series of cultural models developed through the dynamic co-construction of robotic technologies and related practices, values, beliefs, and interactions.

In the study of science and technology, self-reflective or explicit cultural interpretation is generally a critical move applied to technoscience from the outside, rather than an internal discourse constructive of the field such as the one being developed by roboticists in Japan.[8] Scholars of 'nascent robotics cultures' (Turkle, 2006: 2) have focused on reconfigurations of the human/machine boundary in the development of social and interactive robots to critique the dominant ways of thinking about humanity, intelligence, and sociality in the artificial intelligence and robotics communities (Robertson, 2007, 2010; Suchman, 2011; Turkle, 2011) and to rethink existing social and cultural norms regarding embodiment, sociality, and humanness (e.g. Alač, 2009; Castaneda, 2001; Castañeda and Suchman, 2014; Suchman, 2011).[9] This article expands on existing interpretive studies of robotics by analyzing the explicit ways in which roboticists define 'Japanese culture' and use it to make sense of and legitimize their research. I describe the explicit roles ascribed to culture in the development of robotics technologies and show how multiple cultural models are defined and materialized through robotics practice. I also discuss how cultural work performed by robotics researchers defines behavioral and conceptual norms that constrain interaction with and around robots and the future possibilities for emerging robotic cultures. Finally, I analyze the construction of robot cultures as an analytical category through physical and discursive presentations of the relationships between technology, culture, and society and with particular attention to the social values, beliefs, and attitudes that are integrated into robotics research.

Methodological approach

This article is based on data collected starting in the spring of 2005, when I spent four months in Japan as a visiting researcher at the Intelligent Systems Institute in the National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba, Japan. My aim as a participant observer was to study how roboticists design socially interactive robots and define sociality in their research. I was hosted by the PARO laboratory, where I participated in daily research tasks with other lab members. I also interviewed and observed the researchers working on HRP-2, a humanoid robot designed to assist people in construction, dangerous environments, and home, and traveled to visit 16 other social robotics labs in Japan to interview 25 researchers about their work. Since then, I have been professionally involved in the social robotics and human–robot interaction communities, and continued my participatory studies of social robotics through interviews with roboticists and participation in conferences and other public events relating to robotics. I am currently working on a collaborative project with Dr Takanori Shibata, PARO's designer. The insights presented here therefore include information gleaned through my initial interviews with roboticists in 2005, as well as in later conversations and activities I had a chance to observe, up to the present.

The discussions and interviews I report in this article were performed in English; the research participants, established researchers in academic, government, or corporate laboratories, were all conversant in the language. Being an English-speaking researcher functioned as an unspoken prompt for learning about the cultural underpinnings of Japanese robotics, cueing my interviewees to describe in detail what they saw as the specifics of their culture and its relation to robotics. Interview questions included basic demographic information, as well as queries about the person's early knowledge and impressions of robots, applications of robots they saw as important, societal issues related to robotics, and more specific discussions regarding projects the participants worked on. I did not specifically ask or prompt interviewees to talk about culture in the interviews; roboticists themselves generally initiated the discussions concerning cultural aspects of robotics described below in the course of our interviews. The interview participants were aware that I was doing a comparative study of social robotics in the United States and Japan, and that I would therefore be interested in discussing cultural differences. While this might suggest that the connections being made between culture and technology were part of a cultural performance put on by the interviewees, the additional information gained through long-term participant observation and examination of robotics publications and other documents confirms that concerns with the cultural aspects of robotics occurred outside of the interview context.

After transcribing the interviews, I openly coded the interview data, my notes, and other documentation to find recurrent themes. In this article, I present instances in which roboticists specifically discuss and embody 'culture' in robotics research and unpack how the notions of culture and robotics technology are used and defined in the process. The three main examples in this article – the robot PARO, HRP-2, and *kansei* robotics – represent cases for which I was able to collect the most thorough data on the way in which robotics researchers associate cultural factors with their work, as two robots were situated in the institution in which I was doing participant observation, while the third topic was the subject not only of interviews but also of presentations and publications produced by robotics researchers.

Crafting robots

The socially assistive robot PARO (Figure 1) was designed by Dr Takanori Shibata to resemble a baby harp seal and is used in a manner similar to pet therapy, primarily with older adults. PARO is currently in use in 30 countries around the world and has been

(a) (b)

Figure 2. (a) The seal-like robot PARO displayed on top of a locally woven silk cloth in the Nanto City silk museum next to local mascot NANTO-kun and (b) PARO's 'birth certificate'.
Photo credit: WL Chang

commercially available in Europe and the United States since 2009, and in Japan since 2005, where about 2000 PAROs have been sold. Contrasting with PARO's global reach, Dr. Shibata's description of the robot's design emphasized its grounding in the craft traditions of his hometown, Nanto City.[10]

I traveled to Nanto City with Dr Shibata in June 2012 during a series of site visits for our collaborative study on the therapeutic uses and user perceptions of PARO in the United States and Japan. The 2-week Japan-wide tour included visits to nursing homes, hospitals, a children's home, and group homes and temporary shelters for survivors of the 2011 tsunami, all of which either already had or planned to obtain PARO. In Nanto, we visited sites involved in the robot's production, including the headquarters of Intelligent Systems Co. Ltd., the company behind PARO's commercialization, and the factory where PARO is manufactured. Dr Shibata also took us to the Suganuma and Ainokura villages to learn about traditional silk and gunpowder production, the town museum to see elaborately decorated Hikiyama festival floats, an Etchu Gokayama Washi paper studio, and *inami* wood carving shops where we observed local artisans at work. During the trip, Dr Shibata explained not only the technical aspects of PARO's construction but also the broader social and cultural significance of its design and use.

Each PARO unit is delivered with a birth certificate (Figure 2), styled after a Japanese family registry document and designating Nanto City as the robot's birthplace.[11] The local authorities reciprocally celebrate PARO's place in the local economy. The robot is prominently displayed in the Nanto silk museum, which documents the silk weaving industry as a mainstay of the regional economy over centuries (see Figure 2). The factory where PARO robots are produced is housed on the site of an old silk manufacturing plant, built when the industry switched from manual to automated production methods. The robot therefore both materially and symbolically represents Nanto's economic development and its potential to attract and support new high-tech industries. Our visit to a local nursing home which had been using PARO for over 9 years displayed how PARO's design reflects local social issues as well. The Nanto region, where adults over 65 years of age comprise 30 percent of the population, is seen as a model and testing ground for the future of Japan's aging society. Nursing home staff described the many challenges of their work, particularly the lack of sufficient manpower to provide person-centered care and enable elders to age in place, and gave examples of how they used PARO in their daily activities to entertain older adults who were too weak to do physical exercise, or to curb wandering in cognitively impaired residents. Nanto City is therefore a prime site for observing the ongoing development of a robot culture that can support PARO's adoption and use in society.

The focus on quality in PARO's production process provides a further bridge between local economic traditions and new manufacturing technologies. In our discussions, Dr Shibata compared the workmanship involved in producing PARO to a long tradition of local craft making. While visiting Suganuma and Ainokura villages, we learned that the area's saltpeter (an ingredient for gunpowder) was of such high quality that the governing Maeda family allowed villagers to use it instead of rice to pay part of their taxes; the Imperial family is said to purchase locally produced *washi* paper. In the PARO factory's conference room, Dr Shibata pointed out a set of circuit boards in a glass case and mentioned they were produced in a strict quality-controlled process and used in luxury cars. PARO's microcontrollers are fabricated in a similarly quality-controlled, fully automated process that can handle components 'too small for the human eye to see'. Two workers then manually assemble individual PARO units from a collection of over 200 parts, which include pieces contributed by companies around the world as well as those produced in Nanto City. As a finishing touch, workers manually attach and trim each PARO's fur covering, giving every unit a unique appearance noticed by long-term users. Attention to detail and quality is further exemplified by the sustained work that Dr Shibata has done on PARO's design, which has been perfected since 1993 in more than eight iterative versions.

Along with the emphasis on production quality, PARO's design also invokes specific cultural models of consumption, which value the high quality and longevity of artifacts above the article's price (PARO costs approximately 35,000 Yen in Japan and US$6000 in the United States). As we watched an artisan carving intricate flowers from a piece of wood in a small Nanto City *inami* shop, Dr Shibata explained that many local residents purchase such pieces for their homes despite their high cost because they can appreciate the skill and time that goes into their creation. A few minutes later, in front of the Betsuin Zuisenji Temple gates laden with *inami* carvings, he compared people's ability to value such woodwork with their appreciation of PARO. This suggests that PARO's design assumes a particular type of user – one who can recognize and afford high-quality products and expects to use technology for the long term, rather than relying on cheap disposable goods. In the documentary film *Mechanical Love* (Ambo, 2007), Dr Shibata described PARO the robot's longevity to a women who had bought the robot for domestic use, 'It was made with solid materials and will probably live for 10-20 years'. In Japan itself, about 60 percent of PAROs have been sold to domestic users, while the other 40 percent have gone to caregiving institutions and museums. Purchases in other parts of the world are largely made by institutions, suggesting that different cultural models of consumption and of relating to robotic technologies might be at work.

The cultural and social grounding of PARO's design and use suggest an increasing awareness of the socially situated nature of robots and their effectiveness in everyday applications of robotics in Japan.[12] As an example of repeated assembly, PARO's design embodies cultural models of skill, quality, relational construction of value, and appreciation for local tradition in emerging robotic technology. These values are constructed with reference to new materials, such as PARO's antiseptic fur and silicon processors, novel processes of automated production and new modes of personal interaction with technology. While the automated process of producing PARO's circuits enhances the robot's quality, the hands-on human labor needed to assemble and personalize each unit also relates PARO's production to the unique human capabilities that define craft making. Dr Shibata's specialized expertise as a designer of interactive mechanical systems further extends the notion of craftsmanship from that of a hands-on process of creation to the ability to assemble globally distributed networks of human and nonhuman actors into a meaningful cultural artifact. Users also play a crucial role in the successful implementation of PARO, the design of which assumes that all the necessary functions are not included in the robot itself, but that 'interaction will enlarge the number of functions'.[13] Dr Shibata emphasized that people come to realize PARO's worth, despite its high price, through such locally constructed interactions. The robot's interpretive flexibility allows people to relate to the robot in different ways depending on the cultural context. PARO, in turn, is able to represent a local craft that draws on traditional values of production and consumption. A global product, constructed from parts developed all over the world, conforming to various national standards, and used on three continents, and a new category of 'subject/object' (Suchman, 2011)[14], PARO is a research platform, a therapeutic tool, an honorary citizen, and a social actor with which people build personal relationships. PARO's cultural significance is therefore constructed by a diverse network of actors, including roboticists, factory workers, machines, craftspeople, and users, all of whom contribute to new local and global robotics cultures through the repeated assembly of their daily practices, beliefs, and locally constructed meanings.

Performing robot culture

In the spring of 2005, I stood along with other visitors in the Humanoid Robot Group's lab at AIST watching the HRP-2 robot swaying to the sound of the *aizu bandaisan*, a Japanese folk dance (see Figure 3). The result of a collaborative project between scholars from AIST and the University of Tokyo and funded by Japan Science and Technology Agency's Core Research for Evolutional Science and Technology program (JST-CREST), the performance demonstrated the use of robots to 'preserve [traditional practices] forever', particularly in the event that there are no longer any human 'inheritors' that can carry them out (Kudoh et al., 2008: 1). HRP-2 also played the *kodo* drum and performed the Japanese martial art Bojutsu during the 2005 Aichi Expo. Along with protecting the country's tangible and intangible cultural heritage as the foundation of Japan's 'future cultural growth and development', (Yamamoto, 2007), such projects linking culture, art, and new technologies are expected to give the public 'a deeper

(a) (b)

Figure 3. (a) HRP-2 dancing the *aizu bandaisan* and (b) the cover of a Patlabor comic.
Photo credit: http://news.nationalgeographic.com/news/2007/08/070814-dancing-robot.html

understanding and awareness of science and technology' and to improve their adoption and acceptance in society (Government of Japan, 2006: 61–62). HRP-2's folk dancing therefore not only embodies traditional practice in a new medium but also seeks to make robots more acceptable to the public through their association with familiar cultural forms. For the scientists involved, the HRP-2 project as a whole and the folk dancing application more specifically involved negotiation between social and technological needs and existing cultural models to construct a robotic platform for use in everyday interactions.

The roboticists I interviewed showed a pragmatic interest in developing the culturally specific folk dancing application as a way to construct more advanced and robust technology. The Humanoid Robot Group's main aim is quite general: to create a platform for developers with an open architecture that will allow scientists to build various applications, or as one researcher working on the project said, 'a computer with arms and a head'. The robot should be able to 'go anywhere a normal human can go';[15] it 'must be able to pass through a door, go up and down stairs, or crawl on the ground'.[16] Promotional photos show HRP-2 working in construction sites and other dangerous environments, as well as helping people carry heavy objects, serving tea, and washing dishes. Current technological capabilities, however, do not allow humanoids to operate in such physically taxing and open-ended situations. Roboticists see folk dancing as the 'first step' to solving the hardware and software challenges of a general purpose humanoid: 'If we cannot make a robot for entertainment, we cannot make a robot for hazardous environments. So we can train our robots for five years, and then later come up with new applications'.[17] The development of HRP-2 as a generic humanoid platform that is adapted to different uses presupposes that the humanoid robot can be conceptualized and constructed separately from its specific behavioral and interactive capabilities, shifting the performance of robotics from robotics researchers to corporate clients and eventually to users.[18]

From the outset, the development of an application-oriented humanoid platform was defined as a way to address societal issues (Tanie, 2003), fitting AIST's policy of performing 'full research' from basic science to application in society (Yoshikawa, 2006).[19] This was a departure from the largely technological focus of prior robotics research. The search for a viable application for the HRP-2 robot was also necessary for Kawada Industries, the researchers' corporate partner, to continue working in robotics, and for the researchers, who needed an advanced platform for 'stay in the major league' of humanoid science and development.[20] The task of finding appropriate humanoid applications turned out to be more challenging than making the humanoid itself. The researchers spent 2 years making the platform and 6 years unsuccessfully testing out different commercial applications with industry partners; Kawasaki Heavy Industry suggested 'teleoperated humanoid driving machinery', and Hitachi developed a hospital patient care humanoid, but these ideas were not 'interesting to customers in the future'.[21] Although unlikely to support a major market, the folk dancing application had some initial success when a 'group of hotels offered to buy HRP-2 as a dancer. They are located in the countryside and there is no attraction there and they thought they could have more visitors if they have a robot show'.[22] Although roboticists may see folk dancing as just a convenient application for technological development, this corporate buy-in to the image of the humanoid as cultural performer suggests that robots as artifacts adapted to Japanese traditional practices have some popular acceptance.

The researchers also needed to develop a robotic body that would be amenable to a variety of uses, for which they combined existing cultural models and technological capabilities. AIST's humanoid group had previously used Honda humanoids, which were not open enough to allow them to pursue the software and hardware developments they desired. Working with the Advanced Step in Innovative Mobility (ASIMO) platform, however, taught the roboticists that 'how the robot looks'[23] was important for societal acceptance of the research. When they were developing their own humanoid platform, the HRP group decided to invite an anime artist, Yutaka Izubuchi, to design the robot. Izubuchi was known for his work on Patlabor, an anime series featuring robots performing municipal and industrial jobs similar to those envisioned for the HRP platform (see Figure 3). The HRP group had also considered the widely popular Astroboy as a possible model for the new robot; Astroboy's blueprints hang on the wall of one group member's office marked with the title HRP-X (Figure 4).[24] Along with being technically inappropriate for Kawada's development process, however, the roboticists saw Astroboy as having cultural connotations that were at odds with the aims of the HRP project:

> The project [funding] was supposed to terminate in March 2003 and [Astroboy] was born in April. We were wondering whether to have the final demonstration on his birthday. But we found it too challenging … The shape is challenging, the round shape, the robot is very slim, so we would need more space to put in the parts. In the case of HRP-2's design, the shape is

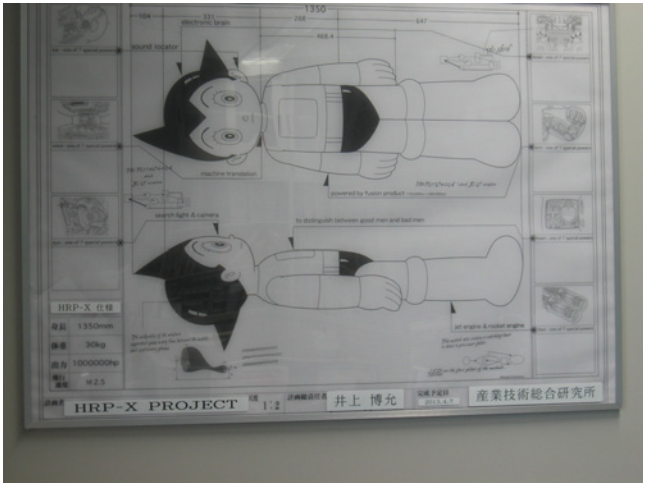


Figure 4. Blueprints for Astroboy as HRP-X, a possible template for the HRP platform.

> supported by the external structure. Using that method it is very difficult to develop an Astroboy shape. And if we employ [the Astroboy] design, the robot should be exactly like this, because many people have an image in their mind. But with Patlabor, it was a Japanese design, but it is still a new robot … Another problem with a robot like Astroboy is that we cannot make him work, since he is just a boy. We were afraid that people would complain that we cannot let a boy work. That was seriously a problem. But the main reason was technology. Because Kawada has experience in developing the type of structure which is supported by the exoskeleton, but the other type of robot is very different.[25]

The roboticists' vision of how to accomplish their technical goals explicitly included expectations about the likely social and cultural interpretations of robots outside of the laboratory, while material and technical possibilities posed limitations to certain cultural figurations. The final choice came down to a preference for what the roboticists saw as the combined technical and social realism of Izubuchi's robots:

> From the viewpoint of mechanical engineering Astroboy is not interesting, it's not realistic … On the other hand, with Izubuchi-san our feeling is that he knows much about technology and has a vision of future machines … Patlabor … is a quite realistic world where humanoid robots are used in society.[26]

This notion of realism is defined by roboticists' extensive technical knowledge and the kind of social practices they saw as compatible with technologically feasible robot designs. Modeling HRP-2 on Patlabor therefore materialized not only what the researchers thought would be a technically workable robot, but also what they understood to be appropriate social roles for robots and interactions between people and robotic technology.

The ongoing negotiation between technical possibilities and cultural models that resulted in the HRP-2 design shows that, to cross the boundary from fiction to reality, cultural traditions and notions about robotics need not only be popular but also technically compelling and feasible. As a result, the *aizu bandaisan* may persist in its robotic embodiment while activities less amenable to computational reduction are lost to posterity, and Astroboy may eventually be forgotten while Patlabor-style robots become ubiquitous. Cultural needs also motivated roboticists to push the limits of technical capabilities. While folk dancing was easily amenable to computation and software development, the researchers admitted that dancing was 'too much' for HRP-2's hardware – 'The speed of the motion is too high. It destroys the robot … Then when we try [to do] some experiments, it falls down'.[27] Pushing HRP-2 to the point of breakdown displays the tension roboticists experience between the need to provide a socially and culturally acceptable application for robotic technologies and the constraints posed by technological capabilities.

As a cultural performance, HRP-2's *aizu bandaisan* dancing presents a further tension between notions of culture as the rote repetition of a computationally defined set of behaviors and as a finished product to be viewed, and the idea that cultural traditions are co-constructed with the audience as they are performed. Repeated assembly suggests that the continuation of culture requires it always to be transformed and adapted in the process of transmission. While HRP-2 materializes to the public the roboticists' interpretation of culture and robotic technology's place in it, it does not provide an opportunity for the two-way communication between performer and the audience through which such traditions gain a cultural meaning that shifts with their circumstances. In addition to bringing up issues regarding the lack of public participation in the construction of new technological and cultural forms, this way of reproducing traditional performance poses questions about the relational authenticity of cultural experience being simulated through mechanized means. According to Sherry Turkle, the automation and mechanization of interpersonal relationships reduce human values to appearance, as people are ready to accept a machine's simulation of emotional and personal understanding as sufficient for establishing a relationship. She claims this creates a 'crisis in authenticity' (Turkle, 2007: 501–503, 514) and produces questions about the value of 'interactions that contain no understanding of us and that contribute nothing to a shared store of human meaning' (p. 515). HRP-2's rote reproduction of tradition may similarly be interpreted as unwittingly replacing the ongoing construction of cultural meanings and practices by people with the mere semblance of cultural knowledge and competence performed by machines.

Engineering cultural subjects

When the dancer whose movements were computationally analyzed to produce HRP-2's movements saw the robot's *aizu bandaisan* performance, she reported 'she could "feel" her style in the dancing of the robot'.[28] HRP-2 project members claim they did not consciously aim to portray a specific personal style in their robot's performance. Waseda University researchers working in the field of '*kansei* robotics', however, work on deliberately including such subjective elements into robotic programming. Researchers in *kansei* robotics suggest that human–robot communication requires the machine to engage the world with sensitivity, sensibility, feeling, aesthetics, emotion, affection, and intuition (Hashimoto, 2006). Shuji Hashimoto, a member of Waseda's Humanoid Robotics Institute, proposes *kansei* robotics as a new paradigm in robot design defined by

> sensitive data processing … [that is] not about dealing with signals any more but about laying down our feelings on data processing's cutting board. As opposed to … data processing types which [sic] were looking for an objective reality, sensitive data processing aims for subjectivity. (p. 11)

Kansei roboticists contrast their approach to more rational and logical definitions of intelligence that have so far dominated robotics research. In order to achieve *kansei*[29] feelings and make subjective sense of their environment, Waseda University roboticists describe their robots as including an internal '*kokoro* function', named after the organ that generates *kansei. Kokoro* – which can be translated as heart, spirit, or mind and is posited as a foundational aspect of humanity in Japan (Katsuno, 2011) – defines subjective values and interpretations as necessary to robot intelligence. A Waseda University professor compares applying *kansei* to robotics with prior approaches to enabling a robot's actions in the world:

> There is a typical subject of robotics field, obstacle avoidance … I want to study *why* the robot avoids the obstacle. Conventional researchers just look at how to avoid the object … [I believe] the motion should be determined by the sense of values or the meaning of the environment, [which will] be calculated from the experience of the robot … based on the *kokoro* function …[30]

Defining the subjective properties of action and experience computationally poses challenges to customary methods for programming robots, as exemplified by Waseda roboticists' work to design a violinist robot, exploring the notion of *kansei* as 'the relationship between playing expression and the music and individual sense of value'.[31] In designing the robot, researchers first tried to develop *kansei* by analyzing the physical properties of a human player's movements, such as force and velocity, along with the properties of the musical score and sound, but 'found it impossible to translate subjective experience into an objective measure'.[32] They felt they were able to model what it means to 'play with feeling' only once they included in their analysis listeners' comments on the violinist's performance along with the motion data. This defined appropriate movements for *kansei* expression, thereby using subjective human impressions as a resource for the robot's subjectivity. The researchers also strive to enable the robots to develop 'evaluative criteria and their own emerging function' for behavior through interactions with their environment (Sugano and Yabuno, 2004: 19). One example is a robot that develops variable responses to people depending on its experiences with them; it can be attentive to the requests of a person who maintains the robot regularly and disregard those of a stranger, who is 'meaningless' to the robot. Or a robot could learn to respond differently to a battery that it can use to charge itself (compared with what cake might mean to a person), or to a piece of metal, which can cause the robot to discharge (described as rotten meat in human terms) (Sugano and Yabuno, 2004: 19). In these examples, the robot's behaviors are relationally defined through its experiences. Similarly, using human evaluations to develop the robot's ability to play music 'with feeling' suggests that *kansei* is a property of the relation between the robot's action and people's perceptions, rather than a characteristic of the robot itself.

Robertson (2010) refers to this relational approach to robot design as 'active incompleteness', and suggests it is a unique characteristic of robots built in Japan, inspired by a culturally specific view of the self as relationally defined (pp. 14–15). This relational conception of robotic intelligence contrasts with 'autonomous, rational agency', which Suchman (2007) suggests is 'the prevailing figuration of Euro-American imaginaries' (p. 228). Robotics researchers themselves claim that the definition of intelligence as rationality is a Western conception and that the Japanese understanding of mind is more holistic – the reference to broadly defined 'Western' values was made by the robotics researchers I interviewed, who compared Japanese culture with a homogeneously defined Western culture. A Waseda University roboticist described the difficulty of presenting *kokoro* to foreign colleagues:

> There is almost the same term in English – mind, feeling – but it is difficult to think that *kokoro* and mind are the same word. It is difficult because we consider that *kokoro* is the integration of emotion, intelligence, and intention. So it is also the origin of the intelligence and emotion, all the behavior of human … [In English], when someone is behaving irrationally, foolishly, people can say they are 'out of their mind'. But in Japan we define such crazy behavior as also resulting from the *kokoro* function. There is no way we can say 'out of *kokoro*'.[33]

Designed to embody *kokoro* and a culturally specific understanding of cognition, *kansei* robots as 'model (in)organisms' (Suchman, 2011: 121–123) represent ideas about uniquely Japanese cognitive processes. A Waseda University professor describes a conversation about *kokoro* in the following way:

> At the plenary session of an AI conference I attended, I presented about the WAMOEBA project[34] and the *kokoro* function … After I finished speaking … some guy from Europe asked us – no, he told us – we were wrong. We should not consider mind as *kokoro*, emotion … It is a very difficult topic … In Japan, we have a strong animism idea … so we can consider that mind can be in artificial things or in natural things, in stones, trees. Many people in Europe and America cannot think about that. But in Korea and China and Japan it is easy for us to consider that. It is a big difference, just from the culture.[35]

The emphasis on culturally specific concepts of consciousness and agency as the foundation for robotics serves to define a regional scientific community of East Asian robotics designers and users conceptually distinct from 'the Rest'. This kind of differentiation may be important for legitimizing scientific approaches developed outside the traditional centers of scientific production in Europe and the United States, even in the case of Japan, a leader in robotics development and research. It is notable that these culturally specific formulations of robotic affect do not reference emotional robots in the United States and Europe, which similarly purport to overturn dominant ideas about machine intelligence by incorporating affect into computation (for a critique, see Suchman, 2007: 232–234). Cynthia Breazeal's (2002) Kismet, for example, displays emotion and uses emotional drives to govern its own behavior and modulate people's interactions with it. Through this omission, the cultural framing of robots reinforces cultural boundaries between scientists in different geographies, further enabling roboticists to create a national context and a potential market for robotics in Japan and other East Asian countries.

Waseda University professor Takanishi Atsuo goes further in ascribing the acceptance of robots in Japan to the culturally unique cognitive abilities of the population, involving differences in the perception of sounds and reactions to objects between Japanese and Western populations.[36] Takanishi suggests that these cognitive abilities, coupled with the rich onomatopoeic expressions in the Japanese language, allow Japanese people to develop relationships with objects, which can be extended to robots:

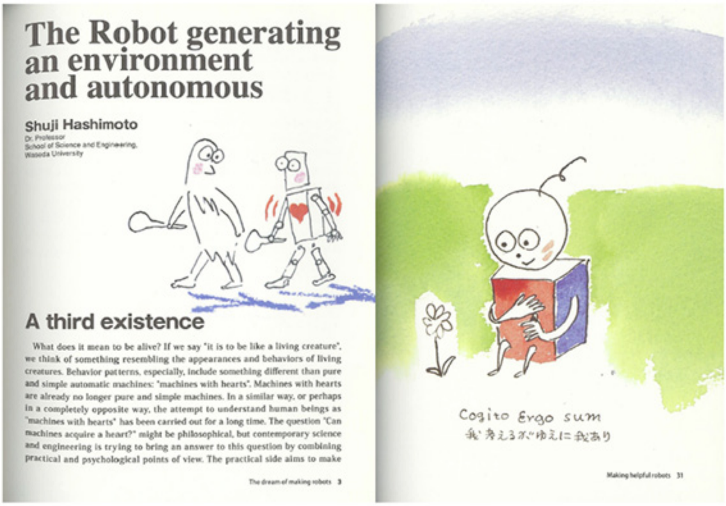
> Japanese treat anything in the universe as if it has a soul inside, which may have strong relations to the fact that Japanese use the left brain for natural sound recognition and have a large vocabulary of onomatopeias. We cannot treat robots and other artifacts less worthily (rudely/roughly/impolitely) or even too-worthily (too-goodly/too-muchly) because we are no more than they are and even some of them become a god … [This] makes the society to be highly ecological and highly friendly to anything, including artificial ones.[37]

Robotics researchers refer to animistic beliefs and practices to suggest that Japanese people are particularly susceptible to interpreting robots as companions and to legitimize the creation of robots that perpetuate an anthropomorphic view of technology. As roboticists seek to construct human cognition by developing *kansei* and *kokoro* in robots, the psychology of the normative Japanese subject is interpreted and redefined through the designs and prescribed uses of these new technologies.[38] In critique of this culturally essentialist perspective, Wagner (2009) suggests that techno-animism is a much more globally present phenomenon and that people outside of Japan also interpret and interact with advanced technologies in human-like ways.

Viewing robots through the lens of Buddhist or Shinto belief and designing them to have subjective experiences of the world opens up the possibility for imagining a new ontological category represented by robots in society. *Wabotto no Hon*, a book series written by roboticists from Waseda University to introduce humanoids and their research to the public, refers to robots as 'a third existence … between that of a living creature and that of a nonliving creature', 'machines with hearts' that are 'no longer pure and simple machines' (Hashimoto and Yabuno, 2003: 1; see Figure 5), while 'human-shaped robots are considered as having a life similar to that of human beings' (Toshio Ojima in Miwa and Yabuno, 2002: 25). The ability to evaluate the world subjectively allows robots to be more than tools; they can be 'machines that almost have a life' and can 'attain enlightenment' (Hashimoto, 2006: 27). In the 1980s, Japanese robotics pioneer Masahiro Mori similarly stated that 'robots have the Buddha-nature in them' (Mori, 1981: 13).

The notion of a third existence suggests that robots can coexist as social agents alongside humans, although not necessarily as their social equals. Roboticist Takahashi Tomotaka, speaking at the Japanese Cultural Center in New York City, explained that robots are similar to 'live-in exchange students' and like them need time to learn how to take part in Japanese culture:

> When we accept an exchange student a lot of trouble occurs … from the difference of culture. A robot is just like that – it can't do what we can do, but it can do what we can't do … But it's still family and there is an emotional feeling, and then the robot becomes better and better and they do a lot more work. They can handle much more things and our lifestyles will change.



(a) (b)

Figure 5. Depictions of Wabot as a 'third existence' in (a) *Wabotto no Hon* volume 2 (Hashimoto and Yabuno, 2003) and (b) volume 5 (Sugano and Yabuno, 2004).

This quote anthropomorphizes robots not as Japanese subjects, but as bumbling, disruptive foreigners, who can become useful to society only once they can emulate local customs. Robots are often depicted as being preferable to immigrant workers, who might have more trouble assimilating to the local culture:

> People's age is going up little by little, so workers are decreasing. We have to get some workers somehow. In the US, people come from other countries, but in Japan it is very difficult. In US there are many different cultures, many nationalities, but in Japan it is almost just one nationality so it is difficult to bring in people from other nationalities, it makes people nervous. In Japan the robot system is successful, one reason is the problem of nationality.[39]

Where cultural difference and change is described as a major threat to the well-being of Japanese society, culturally trained robots are presented as a possible solution to this social challenge and a way to conserve Japan's assumed cultural homogeneity. Robotics therefore becomes part of a conservative social agenda (see also Robertson, 2010).

Robots as a third existence are also expected to provide social connection in an increasingly individualized Japan. Katsuno (2011) suggests that the attribution of *kokoro* to humanoid robots in Japan by robot designers and users alike is a response to the social alienation people feel in postmodern society. The Wabot books similarly represent robots as social mediators for humans; Wabot is described as a 'director of hearts' and a 'bridge of the heart and the heart' (Miwa and Yabuno, 2002: 12). Other researchers have suggested that anthropomorphic robots can provide a 'human presence' in future society.[40] Turkle has criticized the vision of robots as relational artifacts by pointing out that social interaction with machines may leave people even more socially isolated (Turkle, 2011:

103–125), a concern echoed by other scholars analyzing the use of robotics in caregiving applications with elders and children (e.g. Sharkey and Sharkey, 2010, 2012; Sparrow and Sparrow, 2006). As we have seen in the discussion of *kansei* robots above, such robots also embody normative visions of culturally appropriate behavior toward people and technologies. Focus on robotics design as a process of cultural repeated assembly therefore calls for reflection on how the cultural models embodied by and embedded in robots affect people's evolving sense of their relational and cultural selves.

Assembling robot cultures

Robotics in Japan has become identified with a vision of robots as social agents and personal technologies that will be easily accepted by society. In the development of this vision, scientists incorporate and adapt traditional themes and cultural values into advancements in robotic technology to suggest cultural continuity and support technological development. The examples of PARO, HRP-2, and *kansei* robotics present robots as cultural products, performers, and subjects and show how robotics researchers use their cultural standpoint to provide epistemological grounding and social justification for robotics. Novel technological capabilities and relationships between humans and nonhumans are defined in relation to familiar social roles, interaction patterns, and cognitive models, which are in turn redefined to include new technological artifacts and the interactions they enable. Such repeated assemblies of cultural models and technology play a variety of functions: justifying specific design choices for consumer-oriented robots, including presumed societal interests in researchers' technical agendas, situating robotics and their social consequences within a narrative of cultural continuity, modeling appropriate attitudes toward robotics technology, and defining the uniqueness of Japanese robotics in the international scientific community and national and global markets.

The definition of emerging robotic technologies as continuations of existing cultural models and invented traditions can be seen as a 'modern trope' constructed in response to social and cultural change (Vlastos, 1998: 3) and used to provide a sense of security in a society going through 'constant change and innovation' (Hobsbawm, 1983: 2). Tradition was invoked in depictions of robots as an alternative to immigrant workers in solving Japan's labor shortage, in comparisons between PARO and traditional crafts, in the use of HRP-2 to preserve cultural practices in danger of being lost due to lack of human interest, and in the construction of normative practices and cognitive models for Japanese subjects to position Japanese robotics within global science. The articulation of robotics as the continuation of Japanese culture, therefore, seeks not only to normalize new technologies as they enter into daily life and to reinterpret culture in ways that support their use and further development, but also to contend with the continuing changes in culture itself.

Science and technology studies scholars know that scientists are always historically, geographically, culturally, and socially located; Japanese roboticists, however, use their cultural positioning to establish the social and scientific significance of their work in a striking departure from the dominant culture-neutral language of science. In this way, Japanese roboticists question the necessity of supplanting local traditions with 'universal' values for the sake of progress (Brown, 2007; Feenberg, 2010; Fujimura, 2003).

Feenberg (2010) suggests that Japan's framing of technological development as a cultural issue creates an 'alternative modernity' that includes values as fundamental components of all scientific and technological production (p. 107). Such alternative imaginaries of modern society are seen in the Aichi Expo's claim that conservation should replace mass production and consumption,[41] in the focus of *kansei* robotics on subjective rather than objective experience, and in the expectation that PARO's users will recognize and value the artifact's quality and craft-like uniqueness. As recognized world leaders in robotics, Japanese roboticists' culturally situated approach to the development of science and technology raises awareness of science and technology as socially negotiated 'local knowledge systems' (Harding, 1998) within the broader robotics community. The use of cultural models as frameworks for new robotic technologies suggests a rising understanding among robotics researchers that technologies need to fit into and be supported by appropriate cultural and social structures.

The cultural view of science and technology proposed by Japanese researchers, however, falls short of providing a culturally reflexive understanding of robotics and the social values that are repeatedly assembled in robotics projects. Studies have noted the opportunity for robotics research to create new possibilities for redefining the boundaries and relationships between and among humans and machines (e.g. Castaneda, 2001; Suchman, 2011; Turkle, 2006, 2011); researchers have also pointed out that the actual practices of robotics often serve to re-entrench existing social stereotypes and hierarchies rather than to contest them (e.g. Robertson, 2007, 2010; Suchman, 2007). The cases analyzed in this article present a similar dynamic, in which new robotic platforms and social visions of robots in society are related to roboticists' assumptions about cultural values and practices, without critical reflection on their broader meaning or desirability for other social actors. The comparison between PARO and traditional craft making readily replaces handmade crafts with industrial production and transfers local consumption practices to a global market; the use of HRP-2 to conserve the cultural practice of folk dancing suggests a static notion of culture; and the use of culturally specific conceptualizations of cognition as a basis for robot design in *kansei* robotics defines normative Japanese and robotic subjects assuming the existence of a homogeneous cultural heritage. Such notions of culturally unique technology can lead to re-entrenchment of specific conservative values, creating robots as 'retro-tech' (Robertson, 2011: 28) that uses the veneer of technological novelty to obscure conservative social policies. Cultural definitions of science and technology are also prone to essentialism, stereotyping, and exclusion reinforced by technological means. The associations between robotics and Japanese culture have led to perceptions of Japanese people as robotic (for a critique, see Fujimura, 2003), as well as to a Techno-Orientalism (Morley and Robins, 1995) in which Japan is seen as the harbinger of technological development while continuing in its role as 'other' to Western society. Scientists themselves are caught up in reproducing cultural stereotypes, such as notions of Japan's cultural homogeneity, assumptions that Shinto beliefs will make the public accepting of robots, and patriarchal representations of gender roles in the design of humanoids (Robertson, 2010).

Robotics has been criticized as a field that provides 'technological fixes' for social problems (e.g. Robertson, 2007), and the examples discussed in this article show that introducing the notion of culture into robotics discourse and practice does not automatically resolve this issue. While robotics researchers in Japan have brought attention to culture as part of technological development, their framing of culture in robotics largely relies on untested and unquestioned cultural assumptions, as robots have yet to be broadly commercialized and adopted by users in ways that will allow those users to contribute to robots' cultural meanings. A more critical view of the development of 'robotics culture' as a process of repeated assembly suggests that future research in and on robotics will need to engage explicitly in 'cultural fixes' (Layne, 2000) – revealing and questioning common assumptions, exploring alternative meanings situated within particular cultural contexts, and reflecting on changes in cultural meanings – to identify and resolve contemporary sociotechnical problems and develop socially beneficial and meaningful applications for robotic technologies.

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Notes

1. As part of their work, scientists in many different fields create 'technoscientific imaginaries' that describe the relationship between society and technology and the resulting social order and common norms, beliefs, and desires (Fujimura, 2003; Suchman, 2007). Imaginaries can motivate knowledge production and give legitimacy and meaning to the results of research (Taylor, 2004). In developing new knowledge and technologies, researchers reproduce cultural assumptions about social roles and interactions and reiterate common cultural, social, and political tropes (e.g. Edwards, 1996; Forsythe, 2001). Robotics researchers produce not only technological artifacts, but 'visions of future possibilities' in society that provide shared goals and narratives for developing 'national and transnational identities, notions of culture, new institutions, and future realities' (Fujimura, 2003).
2. Aichi 2005 Expo website, http://www.expo2005.or.jp/en/robot/index.html (accessed 22 September 2013)
3. Sherry Turkle (2006) posits the development of a 'nascent robotics culture' shaped by 'the possibility if not the reality of robots in the form of relational artifacts' (p. 2) and prompting a reimagining of humans and their relationships to technology. Other scholars have discussed popular discourse about robots (Ito, 2007) and new institutional visions of society including robots (e.g. Robertson, 2007) as important components of developing robotics science and technology in society. References to 'robotics culture' in this article refer to the co-constitution of robots and humans at the levels of philosophical concepts, personal experience, organizational practice, and institutionalized discourse, including and going beyond Turkle's conceptualization.
4. Aichi Expo website, http://www.expo2005.or.jp/en/whatexpo/theme.html
5. Aichi Expo website, http://www.expo2005.or.jp/en/venue/jz_b.html
6. Ministry of Foreign Affairs of Japan's statement on Aichi Expo 2005, http://www.mofa.go.jp/j_info/expo2005/j-message.html

7. In 2007, the National Museum of Nature and Science in Tokyo organized an exhibition titled 'The Great Robot Exhibition: Karakuri, Anime and the Latest Robots', relating history and contemporary culture to advanced robotics research. Japanese multinational corporations have similarly invoked history when presenting robots to the public: Mitsubishi's flagship robot Wakamaru was named after Ushiwakamaru, a famous 12th-century general, and resembles a samurai in formal wear (*hakama*) (Robertson, 2007), while Dr Tomotaka Takahashi's Murasaki Shikibu robot is named after and inspired by the author of *The Tale of Genji*, a Japanese classic and one of the world's first novels.
8. Epstein (2008) identifies a variety of approaches to the study of culture and technoscience in science, technology, and society (STS) literature: the analysis of science as a cultural practice (e.g. Knorr-Cetina, 1999; Pickering, 1992); a focus on the cultural significance and meaning of science in a broader sense (e.g. Harding, 1998); investigations into the relationship between science and broader 'culture' (e.g. Bowker and Star, 2000; Fujimura, 2003); and studies of different science 'cultures' (e.g. Gieryn, 1999; Haraway, 1997; Traweek, 1992). STS scholars have also shown that technology can 'embody a culture or a set of social relations' (Wajcman, 1991: 149) and that the cultural and historical resources in our social environment shape our ways of viewing and imagining the world (Suchman, 2007) and designing for it (Šabanović, 2010a).
9. Lucy Suchman (2011) suggests robots can be seen as 'model (in)organisms' in the development of artificial intelligence and the study of human cognition, which allows us to use the study of the design and development of these robots to explore how the relationships between humans and nonhumans are being reconfigured (pp. 120–121). Alač's (2009; Alač et al., 2011) works display how robots and their perceived agency and sociality are created through interaction with a larger social context; she shows how the embodied actions of the robot and researchers are dynamically co-constructed through the process of developing human-like capabilities for robots (Alač et al., 2011). Castañeda (2001) suggests that robotic artifacts designed to experience touch breach 'the human/non-human divide' and create possibilities for a feminist reimagining of human–machine relationships and embodiment. Castañeda and Suchman (2014) pull a number of these themes together in conversation with Donna Haraway's work.
10. Personal communication with Dr Takanori Shibata, June 2012.
11. This origin story makes no reference to the multiple sites in which PARO's development has taken place since the project's start in 1993, which include National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba, where Dr Shibata is a senior researcher, as well as Massachusetts Institute of Technology (MIT) and the University of Zurich, where he was a visiting scholar, and the many field sites in which PARO has been tested and evaluated. We can infer that the location of the PARO factory, or of the cultural sources of Dr Shibata's inspiration for PARO's design as described in this article, is seen as defining the robot's origins.
12. The social situatedness of robots is widely discussed by social science scholars studying robotics (e.g. Alač, 2009; Alač et al., 2011; Kidd et al., 2006; Šabanović, 2010b, 2010c). Dr Shibata and his longtime collaborator Dr Kazuyoshi Wada have developed initial guidelines by analyzing their experiences observing PARO used in various health-care contexts that people can use to scaffold the robot's sociality and to ensure its therapeutic effect (Wada et al., 2010).
13. Dr Shibata, speaking at Japan Society in New York, NY, June 2007.
14. In contrast to the robotic researchers portrayed here, Suchman (2011) problematizes the notion of a robotic subject by analyzing how the 'sameness and difference' of humans and machines (p. 121) are materialized through various contemporary robotic projects, including Kismet,

Mertz, and Robota. She points out that one of the dangers of the co-definition of humans and machines is that existing conceptions of 'model humans' and instrumental machines will be unreflexively reproduced without broadening the space of possibilities for both humans and robots.

15. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
16. Interview with robotics researcher 2 from AIST Humanoid Robot Group, April 2005.
17. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
18. Personal communication with Lucy Suchman, July 2013.
19. Interview with robotics researcher from Tokyo Metropolitan University, April 2005.
20. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
21. Interview with robotics researcher from Tokyo Metropolitan University, April 2005.
22. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
23. Interview with robotics researcher 2 from AIST Humanoid Robot Group, April 2005.
24. Astroboy is often discussed by roboticists and scholars studying robotics as a symbol of the friendly image of robotics in Japan (e.g. Ito, 2010; Robertson, 2011; Wagner, 2009), and the Japanese government has widely used its image to broaden public support for the development of robotic technologies (Ito, 2007).
25. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
26. Interview with robotics researcher 2 from AIST Humanoid Robot Group, April 2005.
27. Interview with robotics researcher 1 from AIST Humanoid Robot Group, May 2005.
28. Interview with robotics researcher 1 from AIST Humanoid Robot Group, April 2005.
29. *Kansei* is a Japanese concept that has been difficult to define concretely. Harada (1998) found that researchers refer to the term in a variety of ways: as 'a subjective and unexplainable function', 'the cognitive expression of acquired knowledge and experience', 'the interaction of intuition and intelligent activity', and 'the ability of reacting and evaluating external features intuitively'. Lee et al. (2002) describes it as a cognitive function that inspires creativity through images that result in affective responses, in contrast to *chisei*, which creates knowledge and understanding through verbal descriptions and logical facts.
30. Interview with robotics researcher from Waseda University, April 2005.
31. Interview with robotics researcher from Waseda University, April 2005.
32. Interview with robotics researcher from Waseda University, April 2005.
33. Interview with robotics researcher from Waseda University, April 2005.
34. The Waseda Artificial Mind on Emotional Base (WAMOEBA) project, started in the mid- to late-1990s and continuing until 2007, includes a series of robots designed to develop emotions using an internal control system modeled on humans to adjust to their embodied experience and sensing of the environment and which were evaluated in interactions with humans (e.g. Ogata and Sugano, 1998, 2000).
35. Interview with robotics researcher from Waseda University, April 2005.
36. In a talk given at the Roboethics workshop held in Rome during International Conference on Robotics and Automation (ICRA) 2007, Takanishi cited controversial research by Tadanobu Tsunoda (1985) that purports to show that Japanese research subjects show activity in the left – 'linguistic', logical, and intellectual – side of their brain when listening to nature sounds, in comparison to Western subjects who respond with the right side of their brain as they would to mechanical sounds, noise, and music. Tsunoda relates his results to the animistic interpretation of nature in Japanese culture.
37. Slides from Takanishi Atsuo's talk at ICRA 2007 are available at http://www.roboethics.org/icra2007/contributions/slides/Takanishi_icra07_ppt.pdf (downloaded on 31 October 2013)

38. *Kokoro* is not the only way in which robots are designed to reproduce Japanese cultural values; the design of the Gynoid android's face as a composite of female Japanese physiognomies provides 'a topographical map of national ethnic identity' (Robertson, 2010).
39. Interview with robotics researcher at AIST, May 2005. The interviewee had participated in the development of a Ministry of Economy, Trade, and Industry (METI) plan on future growth of robotics.
40. Interview with a robotics researcher at Osaka University, May 2005.
41. Aichi Expo website, http://www.expo2005.or.jp/en/whatexpo/theme.html

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