Moving Android: On Social Robots and Body-in-Interaction

Morana Alac

Social Studies of Science 2009; 39; 491
DOI: 10.1177/0306312709103476

S|S|S

ABSTRACT Social robotics studies embodied technologies designed for social interaction. This paper examines the implied idea of embodiment using as data a sequence in which practitioners of social robotics are involved in designing a robot's movement. The moments of learning and work in the laboratory enact the social body as material, dynamic, and multiparty: the body-in-interaction. In describing subject–object reconfigurations, the paper explores how the well-known ideas of *extending the body with instruments* can be applied to a technology designed to function as our surrogate.

Keywords embodiment, gesture, human–technology extension, laboratory studies, multimodal semiotic interaction, social robotics

Moving Android:

On Social Robots and Body-in-Interaction

Morana Alač

Studying 'embodied' technologies designed for 'social interaction' is a chance to re-examine our modes of relating to them and to each other. The description of those engagements raises a host of questions: How is the body of a social actor articulated in a course of action and interaction with technology? How do we talk about embodiment with respect to the details of such action and interaction? I anchor these questions in the concept of the *body-in-interaction*, using as data an interactional sequence in which social roboticists are involved in designing a robot's movement. While potentially engaging a larger discussion, the argument is aimed at addressing specific assumptions in the discourse of *social robotics* concerning the body and embodiment. I want to examine the conception of embodiment by focusing on how our bodies are articulated in interaction.

Social robotics is a fast-growing research field geared toward the design and study of 'autonomous' robots that are expected to engage in social interaction with humans. The goal of the field is twofold: to develop practical applications for everyday use, and to model human cognition (see, for example: Dautenhahn, 1995; Brooks et al., 1998; Scasselliti, 2001; Breazeal, 2002; MacDorman & Ishiguro, 2006; Ishiguro, 2007; Tanaka et al., 2007). Social roboticists foresee the practical applications of the robots in domains as diverse as tourism, mass media, health services, and education. They expect their robots to be capable of directing people through museums and supermarkets,

Social Studies of Science **39/4 (August 2009) 491–528**

ISSN 0306-3127 DOI: 10.1177/0306312709103476

broadcasting the latest news, providing comfort and care to the elderly, and guiding children in learning foreign languages. At the same time, the social robots are conceived as testing platforms for theoretical models of human cognitive abilities. Thus, while the domain of *human–humanoid interaction* can be understood as a parallel endeavour to *computer-mediated communication*, *human–computer interaction*, and *'post-human' cyborgization* (Zhao, 2006: 402), humanoid social robots are also designed as experimental models to be employed in studying properties of natural subjects (Riskin, 2003: 605).

By using the social robot as a model for human cognition, the research field aims to point out the interdependencies between the mind and the body. Unlike other computational systems designed for the study of human cognition, social robots must have a physical body; the researchers maintain that in order to interact successfully with humans and other robots, the system needs certain motor and sensory abilities. This position has theoretical affinities with the current trend in cognitive science that goes under the name of 'embodiment' (see, for example, Clark, 1997; Nunez & Freeman, 1999). Embodiment questions the principles of *cognitivism* and the *physical symbol system hypothesis* (typically assumed in *artificial intelligence* research) by arguing for the centrality of the human body for cognition (see, for example, Clark, 2001). It is believed that human cognition cannot be adequately approached without considering the role that the body plays in memory, perception, learning, and reasoning. Accordingly, thinking is not merely the abstract manipulation of symbols according to rules, but a process grounded in the sensory–motor capacities of an individual human body and its exchange with the world.[1] As roboticists suggest:

> Recent trends in artificial intelligence, cognitive science, neuroscience, psychology, linguistic and sociology are converging on an anti-objectivist, body-based approach to abstract cognition. Where traditional approaches in the fields advocate an objectively specifiable reality – brain-in-a-box, independent of bodily constraints – these newer approaches insist that intelligence cannot be separated from the subjective experience of a body. The humanoid robot provides the necessary substrate, for a serious exploration of the subjectivist-body-based-hypothesis. (Brooks & Stein, 1994: 7)

While sharing the interest of social roboticists in embodiment and social interaction, I will further engage the problem by examining the work practices of social roboticists. The paper will describe specific instances of learning and designing in a social robotics laboratory to trace how the conception of the body as a discrete and unified entity disintegrates through practice. The moments of learning and work in the laboratory enact the social body as dynamic and multiparty – what I will call the 'body-in-interaction'. In this respect, my account will run parallel to Lucy Suchman's (2007) and Alison Adam's (1998:155) argument concerning the absence of the social situatedness in artificial intelligence and social robotics. I will show how social situatedness is deeply rooted in our bodies as they are implicated in interaction. In this sense, being situated is not only about being able to sense the environment and be responsive to it. Similarly, being embodied goes beyond having a physical body through which we interface the world.

Related research on robotics has been done in the domains of *human–computer interaction* and *computer-supported collaborative work* (for example, Luff et al., 2000, 2003; Kiesler & Hinds, 2004; Kuzuoka et al., 2004). However, because I am concerned with the field of social robotics and issues of scientific theory and practice (focusing less on the problem of practical application of humanoid social robots), I ground this work in *laboratory studies* (Latour & Woolgar, 1979; Knorr-Cetina, 1981, 1999; Lynch, 1985). Similar to other laboratory studies, the argument draws on fieldwork conducted in places where social robots are designed and built. Ethnographic work in artificial intelligence laboratories (see, for example, Forsythe, 2001) has largely been a part of the 'second wave' of ethnographic studies that addresses questions of culture and power in science and engineering. While drawing on that literature, this paper attempts to open up the field of social robotics, especially its theoretical aspects, to discussion while also re-appropriating some of the concerns of the earlier laboratory studies – primarily epistemological issues foregrounded in the study of local research practices. While discussing scientists' ordinary work and their interaction with technology, this paper focuses on practitioners' *embodied know-how* (see, for example, Dreyfus, 1979). I approach the problem of the body from the perspective of the practitioners' skills learned by experiencing how things act and how we can interact with them and each other in specific moments of practice. In particular, I address the experiential ways in which practitioners deal with the world by attending to the visible, public deployment of multimodal semiotic means: gesture, gaze, body orientation, talk and facial expressions (see, for example, Goodwin, 1994a, 1995, 2000; Ochs et al., 1996; Hutchins & Palen, 1997; Heath & Hindmarsh, 2000; Suchman, 2000).

Understanding the social nature of material objects and the situated character of human bodies involved in scientific practices can not be complete until we are willing to carefully observe the richness of everyday activities (including our own actions/reactions as we study those of others) in the environments in which the bodies of social actors are designed and enacted (for a discussion of the approach see, for example, Cicourel, 1974; Lynch, 1993). This paper approaches scientists' practices at the level of gestural enactments in acquisition and employment of skills. Using video records as data for studying scientists at work, I draw on the growing body of research on the social and interactional organization of multimodal human conduct (see, for example, Goodwin, 1994b, 2000; Heath & Hindmarsh, 2002). The aim is to take forward the research in laboratory studies by directing attention to gesture and embodied aspects of laboratory work.

Extending the Body

Rather than programming the robot in advance with all that it needs to know, roboticists design the robot's body so that it can be used for data-gathering. The embodied character of the robot's body includes both its physical traits (its head, arms and torso, for example) and its capacity to learn by acquiring information through sensory input. The robot's sensing is accomplished through various devices, such as microphones and video cameras, located in its environment.

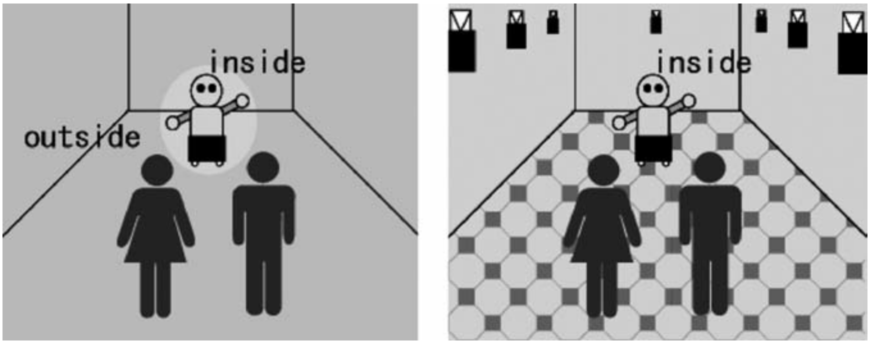
The fieldwork described in this paper was conducted in a leading laboratory of social robotics located in a Japanese university. The laboratory members are greatly concerned with the role of the robot's body in social interaction.[2] To design a robot that could 'sustain relationships' and 'communicate' with people, they proposed a research framework where the robot's body is 'unified with the environment'. Consider the two figures taken from the laboratory website (see Fig. 1). The laboratory members explain:

> In Figure 2 [Fig. 1 in present paper], in the conventional robot system, it is thought that the inside of the system is the robot's self and the outside consists of all things existing in environment. In other words, the system recognizes an outside state with it's own sensors and calculates itself and acts. Against that, in Figure 3 [Fig. 1 in present paper], 'the robot unified with human' system doesn't have the boundary between the robot's self and outside. This is new framework that isn't prepossessed with the physical restriction of the robot's body. In other words, this system can use sensors that are dispersed in the environment and equipped on the robot's body without distinction. Using data from every sensor makes the range of support and communication vary widely. Since 'the robot unified with environment' has 'Perceptual Information Infrastructure', the system can recognize the state of a large area exactly. So it can support and communicate with humans and so on, with using conclusion of recognition [sic.].[3]

The robot's body is connected to the sensor networks diffused throughout the laboratory space. Accordingly, the robot's 'self' and the 'outside' function as a distributed system: through the sensor network the robot can recognize human actions.

The roboticists' attempt to distribute the body across the environment is appealing. The robot's body is not bounded by its 'skin', but has its 'eyes' and 'ears' allocated across the laboratory space so that it can collect and thus process a large amount of data, and also capture elements of social interaction such as talk, gestures, body postures, and gaze of its interlocutors. This kind of embodiment allows the robot to 'learn' as it changes through time. In the present paper I will further explore the idea of embodiment by turning attention to laboratory work, focusing on how scientists coordinate with robots and their human colleagues. While agreeing with roboticists' stance that in order to

FIGURE 1
'Figure 2' and 'Figure 3' from the laboratory website



understand embodied actors the boundary between the 'self' and the 'outside' needs to be reconsidered, I want to investigate what this extension of the body consists of, particularly when the embodied and multimodal interaction (also of interest to the laboratory members) are taken in account.

Grounding my analysis in mundane activities and daily practices of the laboratory, I argue that no matter how powerful and extensive the processes of collection and recognition of data computed by the machine may be, such processes do not allow an understanding of how the human body 'extends' through human and non-human bodies engaged in a common task at hand. Thus, rather than arguing for the 'distributed' body, I will talk about the 'body-in-interaction'.

I will explore this phenomenon in reference to the well-known idea of *dwelling in technology*, proposed by Michael Polanyi's (1958, 1959) philosophy of science. The concept can be tracked back to Heidegger's (1962 [1927]) and Merleau-Ponty's (1962 [1945]) notions of embodiment, in which perception is extended through an artifact or instrument (classic examples are the hammer, the blind man's stick, and the feather in a woman's hat – see also Ihde, 1990). Polanyi, in explaining personal knowledge in science, focused on the inarticulate manifestations of intelligence and skillful doing and knowing to point out how such knowledge requires scientists to extend themselves into tools and probes, while having only subsidiary awareness of particulars that compose the whole. Skillful performance in science requires practitioners to be embodied in their instruments, making such instruments a part of the practitioners' bodies involved in the work project:

> Our subsidiary awareness of tools and probes can be regarded now as the act of making them form a part of our own body. The way we use a hammer or a blind man uses his stick, shows in fact that in both cases we shift outwards the points at which we make contact with the things that we observe as objects outside ourselves. While we rely on a tool or a probe, these are not handled as external objects. We may test the tool for its effectiveness or the probe for its suitability, e.g., in discovering the hidden details of a cavity, but the tool and the probe can never lie in the field of these operations; they remain necessarily on our side of it, forming part of ourselves, the operating persons. We pour ourselves out into them and assimilate them as parts of our own existence. We accept them existentially by dwelling in them. (Polanyi, 1958: 59)

I will show how humanoid social robots, when considered from the perspective of laboratory work and interaction, often function as a way for scientists to extend their bodies, partaking in the embodiment of the practitioners. This is not to say that scientists build the robots to reflect themselves in technology (Marantz-Henig, 2007), but that they become one with the technology in accomplishing their laboratory work.

Humanoid social robots, however, exhibit important dissimilarities in comparison to the simple hand-tools and instruments used as classical examples of human–technology extension. It is important to realize that these technologies are intended to function as human counterparts. In cognitive science, robots are seen as potential models and test-beds for the study of human cognition and interaction. Karl MacDorman and Hiroshi Ishiguro, for example, explain the advantages that they see in robots that closely resemble human beings:

> An experimental apparatus that is indistinguishable from human being, at least superficially, has the potential to contribute greatly to an understanding of face-to-face interaction in the social, cognitive, and neurosciences. It would be able to elicit the sorts of responses, including nonverbal and subconscious responses, that people typically direct toward each other. Such a device could be a perfect actor in controlled experiments, permitting scientists to vary precisely the parameters under study. (MacDorman & Ishiguro, 2006: 298)

The quote expresses an imagined future where the robots will take the role of human experimental subjects as they converse with other humans.

To tackle the complexities of such technologies, I will describe how practitioners of social robotics work with the instrument which functions as their model.[4] I will further broaden the metaphor of human–technology extension to foreground the reconfigurations of the human body that the technologies framed as our 'others' or 'quasi-others' entail. In describing how robots are handled, experienced, and referred to in the laboratory, I will point out that interaction between scientists and the robotic technology is not just about subjects projecting their phenomenal bodies through the instrument. Instead, the embodiment of robotic technology involves trying to attain a bodily sense for what a machine can and should be doing. This 'getting into' the body of the machine fashions the human body in terms of the machine, while, at the same time – by aiming to design and further tweak the robot's body – articulates the robot's body in resemblance to the human body. What do these bidirectional projections and reconfigurations of the human and machinic body imply for the idea of embodiment?

In contrast to a notion of embodiment based on data-gathering procedures, I will describe the body as a dynamic arrangement that, rather than simply mapping one entity onto the other, concerns context-sensitive, hybrid formations enacted across the human/non-human boundary.[5] In this sense, I use the term 'interaction' in the expression 'body-in-interaction' to indicate: (1) that I focus on the body while it is involved in social interaction (thus, as a material, phenomenal as well as semiotic body); and (2) that such a body should not be mapped onto a single, physical body (the body of the scientist or the body of the machine), but rather that it emerges across subjects and objects as a dynamic and interactive phenomenon.

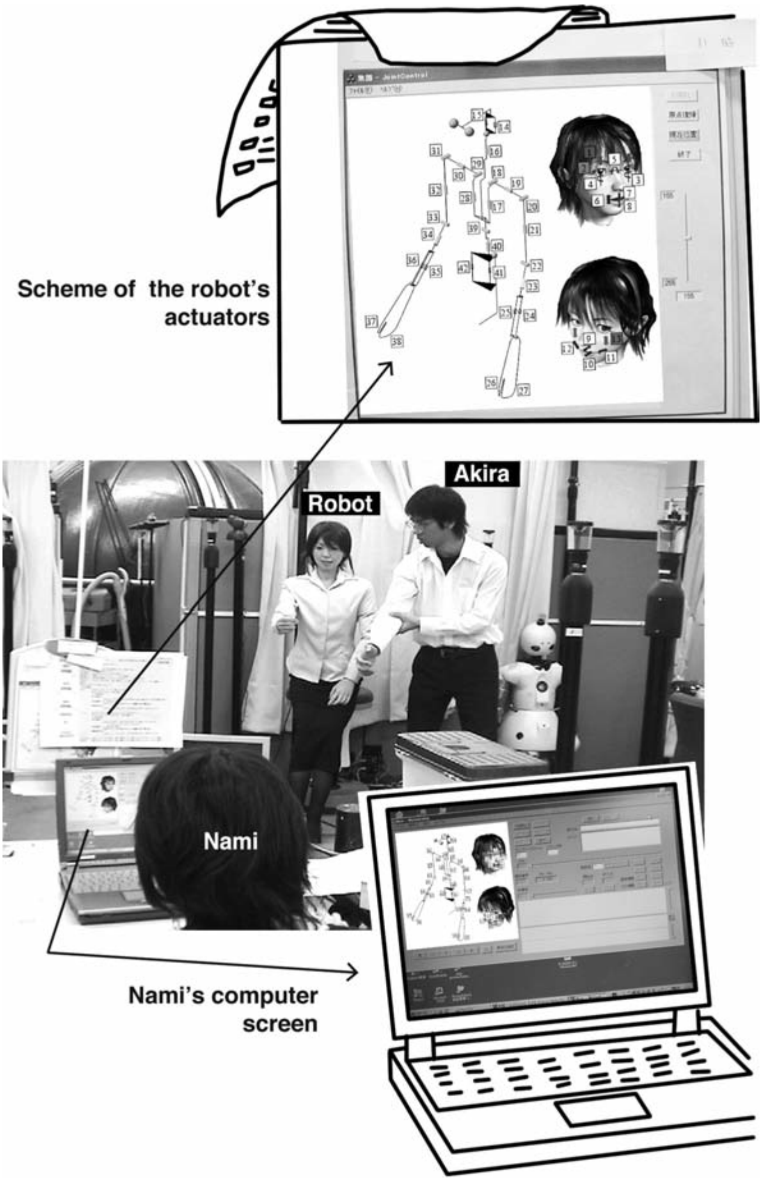
I will first describe some of the complexities in the modelling of the human body in a robot. Such modelling, by requiring the human body to become 'articulate' (rather than withdrawing from direct experience, as intended by the original idea of 'dwelling in technology'), recovers a production of the human body at work. As the 'becoming embodied' of the 'social' machine regards the involvement of the practitioners' bodies (the robot acquires its body through the involvement of the scientists' bodies), the human body reveals itself to be situated in relation to a world of 'other' bodies (the scientists talk about and understand their bodies not simply through direct perception, but also via the body of the machine whose anatomy they try to get a sense of). The details of gestural 'intra-actions' (Barad, 2003, 2007) between human and machine challenge the idea that the human body primarily belongs to a single individual who exchanges information with the external world, as implied by the 'distributed body' and the concept of embodiment proposed by contemporary cognitive science and social robotics. Rather, the practitioners' interaction with their colleagues and their engagement with technology show peculiarities of the human body in interaction. Such a body expands and contracts while its dynamic, multiparty configurations change with the context and participation framework.

Designing an Android's Movement

During my time in the laboratory, the practitioners were involved in the design of an android. To get a sense of the android's appearance, consider Figure 2, which shows a practitioner (at the center of the image facing the viewer) and two robots. On the practitioner's right-hand side is the android robot, while behind him is a small humanoid robot. The body of the small robot has some human characteristics – we can recognize its hands, head, and so on – but its physical resemblance with the human body ends there. The android, on the other side, is 'human-like' in as much as it aims to be a particularly accurate replica of an individual. The laboratory members believe that the robot's human-like appearance is fundamental for successful interaction with humans (MacDorman & Ishiguro, 2006; Ishiguro, 2007). At the same time they are also convinced that the robot's humanness – the impression of autonomy and intentionality that the robot generates – importantly depends on the movements of its body. By designing and implementing elaborate movements, the roboticists aim to overcome the repulsive response that a robot perceived as an 'almost human' but 'not yet human' may generate (Mori, 1970). While the movements should help foster the impression that the robot's body is moved 'from within' (see, for example, Dobbyn & Stuart, 2003), the design of the robot's movement, however, recovers the publicly available and dynamic configurations of bodies and technology. These configurations involved in generating the sense of human body redirect our interest from the body as grounded in the subject, to the body as relative to a multiplicity of 'operations' (de Certeau, 1984). In other words, they prompt us not only to wonder if the robot's movements can at all be managed 'from within', but also to consider if they could consist only of data collection and recognition, as implied by the idea of distributed body invoked on the laboratory's website.

The present paper deals with these questions by describing how the practitioners mapped the robot's movements through computational schemas that could subsequently guide the execution of its movements.[6] This was done by means of a software program that set the duration of the movement as well as the values (from 0 to 255) for the 42 pneumatic actuators (that is, 42 degrees of freedom) implanted in the robot's upper body. The design of each movement was part of a larger project where a list of movements was pre-programmed to be executed by the robot's body. To specify a robot movement, practitioners had to operate the computer software (designed by one of the laboratory members) while imagining a movement executed by the robot's body. Because the movement of a single actuator determines the behavior of the surrounding actuators, the process of design required a great skill from the practitioner. To render the robot's

FIGURE 2
Participants involved in the robot's movement design



movement as human-like as possible, practitioners needed to know what the particular human movement they intended to represent would look like, and how such a movement could be executed by the robot's body.

To describe the details of such activity, we shall focus on three instances of interaction between the practitioners and the robot. Each concerns a moment of laboratory work when the robot's movement needs to be computationally specified so that it can be implemented in the robot's body. At the same time the process is an apprenticeship practice: the newcomer (Nami) is guided by an advanced student (Akira) in the acquisition of laboratory skills and competencies. Nami learns how to use the software to specify movements and thus become a competent member of the community of practice. During the activity Nami is seated in front of a laptop facing the robot so that she can monitor its behavior while working on the computer (Fig. 2). The computer screen is divided into three fields: a visual representation of the robot's upper-body featuring the 42 actuators, a graph of the time and joint value, and a menu where the sampling time, joint value, and the step number can be selected. Above the computer, on a clipboard toward the left, is another representation of the robot's actuators.

The transcriptions of the excerpts are followed by brief descriptions of the activity and a discussion. To argue that the bodies-in-interaction not only 'recognize' each others' gestures, but also are dynamically co-constructed through gestural interaction, I will organize my argument around the following questions: How is the human body implicated in the design of the robot's body? How is the coordination between the practitioners and the technology enacted through work and interaction and what effects does it generate? What does this mean for our ways of talking about the human body involved in social interaction and interaction with technology?

Dynamic Co-construction of Bodies

The excerpts from interaction are transcribed following conventions developed for conversation analysis (Sacks et al., 1974; Jefferson, 2004):

=	Equal signs indicate no interval between the end of a prior and start of a next piece of talk.
(0.2)	Numbers in brackets indicate elapsed time in seconds and tenths of seconds.
(.)	A dot in parentheses indicates a brief interval within or between utterances, of less than one-tenth of a second.
(( ))	Double parentheses contain transcriber's descriptions and remarks.
°°°	Degree signs are used to indicate that the talk they encompass is spoken noticeably quieter than the surrounding talk.
.,?	Punctuation markers are used roughly to indicate intonation, prosody, and stress.

To deal with the English translation of the interaction among Japanese speakers, each turn of talk is divided into four lines.[7] The first line reports the Japanese text; the second line (italics) shows a Romanization of the Japanese text; the third line is a word-for-word translation; and the fourth line (bold) is the free English translation. The word-for-word translation uses the following abbreviations:

ACC – accusative marker.
COP – copula.
EMPH – emphasis.
GEN – genitive case marker.

INJ – interjection or fillers.
NOM – nominative case marker.
P – particle.
Q – question particle.
TOP – topic marker.

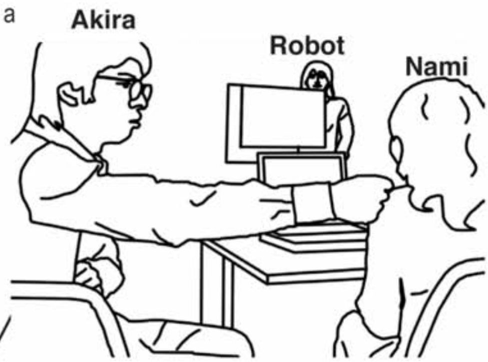
Excerpt 1

1 Akira: ((Akira looks at the computer screen and then at the robot))

2 Robot: ((The robot performs a movement))

3 Akira: ° もー回やってみて. °
° mo ikkai yatte mite°
again once do try
° Should we try it again. °

4 Robot: ((The robot performs a movement))



5 Akira: °難しい°
°muzukashii°
difficult
°It is difficult°

6 ここをこう.
koko wo koo
here ACC like
Here like this.
((Akira performs a movement))
((Akira looks toward the robot))

7 Robot: ((The robot performs another movement))

8 Akira: もう少し曲げてみて.
moo sukoshi magete mite.
more little bend try
Try to bend a little bit more.
((Akira moves towards the computer, and then looks toward the robot))

9 Robot: ((The robot performs the movement))

10 Akira: ここをこう
koko wo koo
here ACC like
Here like this
((Akira performs another movement))

11 Akira: ((Akira looks toward the computer and then toward the robot))

12 Robot: ((The robot performs a movement))

13 Nami: ふ：：ん. ((thinking))
hu::n.
Hm.

14 Akira: ((Akira looks toward the computer, and then towards the robot))
もういっぺん (0.1) ちょ- 動かしてみて.
moo ippen (0.1) cho- ugokashite mite.
more once little move try
One more time (0.1) Try to move.

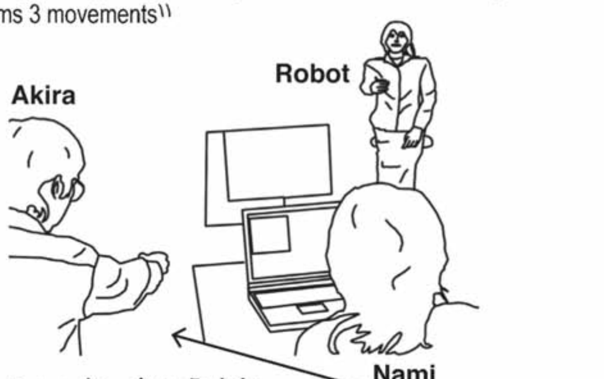
15 Nami: ちょっと待って.
chotto matte.
little wait
Just a moment.

16 Robot: ((The robot performs a movement))

17 Akira: ((Akira turns his whole body to face the robot))

18 ま、座った時点でインタビューに来てんのも：おかしいかもね.
ma, suwatta jitende intabyuu ni kiten no mo: okashii kamo ne.
INJ sat when interview to come P P strange maybe P
Well it is strange that ((she)) is doing an interview while sitting isn't it?
((Akira performs 3 movements))

19 Nami: う：ん.
u:n
Yeah.



20 Akira: 差し出すとこ：：なっちゃうよね.
sashidasuto koo:: nacchau yo ne.
stretch.out like.this become P P
When ((she)) moves ((her hand)) toward ((the interviewee)), ((her arm)) goes like this, doesn't it? ((Akira performs a movement))

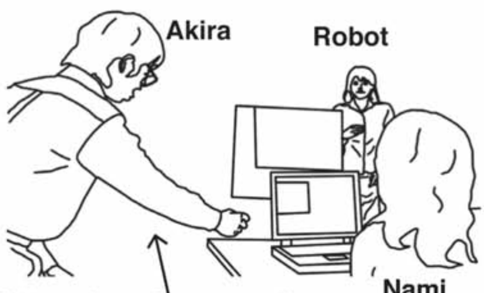
21 Nami: 変かな？
hen kana?
strange wonder
((I)) wonder if it seems strange.

22 Akira: うん.
un.
Uh-huh.

23 変かな？
suwatteru kara:,
sitting because
Because ((she)) is sitting, ((Akira changes chair))

24 こう- こう座ってるから例えば.
koo- koo suwatteru kara tatoeba,
like like.this sitting because for.example
Because ((she)) is sitting like this for example.

25 ((Akira looks toward the robot. The robot performs a movement))



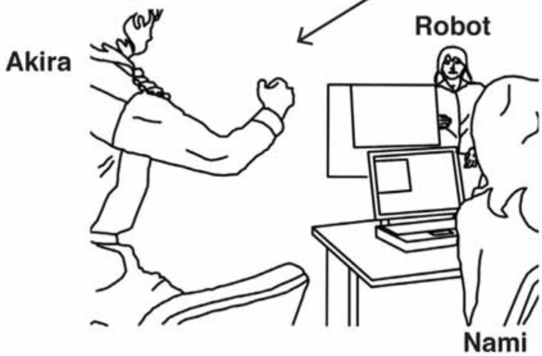
26 こう.
koo
like.this
Like this. ((Akira performs 2 movements))

27 こう- 手を：こうやって動かしてる時に：
koo- te wo: koo yatte ugokashiteru tokini:
ike.this hand ACC like do moving when
Like this- when ((she)) moves ((her)) arm like this
((Akira performs a movement))

28 ((Akira looks at the screen))
何番だっけ？
nan ban da kke?
what number COP Q
What number was it?

29 Akira: 番か、30番か.
juukyuu ban ka, sanjuu ban ka..
19 number P 30 number P
It is number 19. Oh ok it's number 30.

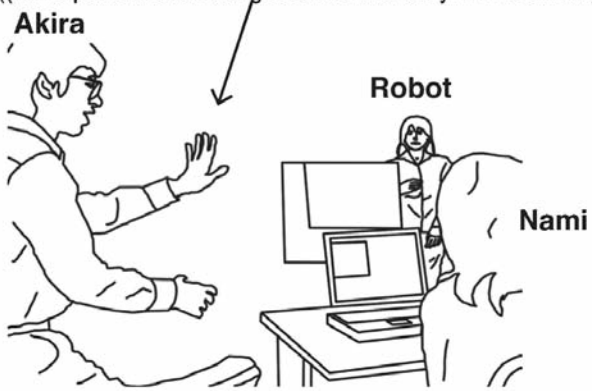
30 番を <動か：し：て> 30番だよね、動かしてるの。
sanjuu ban wo <ugoka:shi:te:> sanjuu ban da yo ne, ugokashiteru no.
30 number ACC move.and 30 number COP P P moving one
Move number 30 ((uttered slowly)) **(.) Is it number 30 that ((we)) are moving?** ((uttered rapidly)) ((Akira looks toward the robot. He performs 3 movements while touching his own shoulder))



31 動かしてる時に、姿勢自体ちょっとこう：：
ugokashiteru tokini、shisei jitai chotto koo::
moving when posture itself little like.this
When moving, the upper body ((moves)) like this
((Akira performs a slower movement))

32 そうすると首をもっと、
soo suru to kubi wo motte,
so do if neck ACC more
If so, then ((we have to move)) the neck more
((While performing a movement Akira moves his neck))

33 Nami: それに合わせて首をもっとそらないといけないのか.
soreni awasete kubi wo motto sorasanaito ikenai no ka.
The neck should be bent
((Akira performs a hand gesture of the body in movement))



34 Akira: うわ：むず：：！
uwa: muzu::!
EMPH difficult
Oh this is tough! ((Akira laughs))

The two practitioners and the robot perform a series of right-hand movements. At the beginning of the activity, Akira, the advanced practitioner, is seated next to Nami, the newcomer, while she is working on the computer. The position allows Akira to monitor the robot while being actively involved in his colleague's project. The excerpt opens with a robot hand movement (line 2). As the movement takes place, Akira promptly shifts his gaze from the computer screen toward the robot (line 1), whose movements allow him to monitor the quality of Nami's work. In line 3, he suggests that his colleague re-specify the robot's movement. When the robot executes the movement (line 4), Akira expresses dissatisfaction with what he sees by performing a more desirable movement (line 6). But before he performs the movement, Akira premises his action with an exclamation 'it is difficult' (line 5). His comment acknowledges the complexity of Nami's task, and frames his future action (line 6) as a suggestion rather than an order. Just after Akira enacts the movement, the robot moves again.

Through lines 8–16, the pattern of activity repeats three more times. By using mouse commands, Nami specifies the robot's movement. After observing the robot and monitoring what is happening on the computer screen, Akira enacts the movement to indicate the desirable improvements. Akira's enactment leads Nami to further meliorate the specifications of the movement. Her work culminates in the robot's execution of the movement, closely monitored by Akira.

After observing another robot movement (line 16), Akira turns his body toward the robot (line 17). Once he directly faces the robot, he performs an additional series of movements. While doing so, he notices the awkwardness of the robot's body position (the robot is placed in a sitting position because of the immobility of its lower body). In line 19, Nami expresses her agreement with Akira's observation. The content of her utterance is similar to her previous 'hm' in line 13 where she expressed concern with the discrepancy between Akira's movement and the computational possibilities for movement specification.

To further constrain his movement, while exposing his body to the direct sight of his interlocutor, Akira gets up from the chair on which he was seated, and moves to sit on a stool (line 23). By moving to a new seating area, he 'calibrates' the height of his seat to the one on which the robot is placed. Once seated, Akira observes the robot before performing the other two arm movements (lines 26 and 27). As in lines 6, 10, 18, Akira's movements are slow and stiff.

While Nami focuses on the software program throughout the passage, Akira does not turn his full attention to the computer until line 28. He looks at the representation depicting the robot's actuators (this can be inferred from the utterance that follows: 'It is number 19. Oh ok it's number 30') to inquire about the actuator involved in Nami's specification of the movement. When he discovers that the actuator in question is the one designated by 'number 30', he touches his right shoulder with his left hand and moves his right arm back and forth three times (line 30). While executing the slow movement (line 31), Akira suggests that the neck should be involved (line 32). Subsequently, he makes the movement visible with a hand gesture (line 33). He comments on its difficulty with another exclamation: 'Oh this is tough' (line 34).

The prominent feature of Excerpt 1 is the practitioner's embodied involvement in the apprenticeship. In the midst of computers, robots, and other technology, the human body – structured by the disciplinary expectations and the routine work practices that have developed for the accomplishment of the design task – is used as a versatile and readily available tool for thinking and communication. This excerpt, like the two that follow, shows the senior practitioner guiding his colleague's learning by only sporadically turning his attention toward the computer screen on which she is working while actively moving throughout the laboratory space, changing his seating position, approaching the robot, stepping in front and in back of it, and gesturing. To give a sense of how a laboratory member should reason about the problem at hand and advance the process of robot design, the senior practitioner engages his body into rich gestural choreographies, gradually refining his persistent movements. Thus, we see how the programming activity concerns the readily available, mundane and ephemeral movements of the practitioner's upper body, hand, shoulder and neck. Lines 6, 10, 18, 26, 27, 30, 31, 32, 33 are examples of such a process. The newcomer observes her colleague's gestures – bending his torso, protruding his right hand in front of his body, and leaning toward the extended hand – as the movements of his hand, neck, or shoulder, in conjunction with his linguistic expressions, exemplify aspects of skillful laboratory work.

The robot's body 'becomes alive' through a series of actions – material and discursive – that practitioners must produce in order to render the robot human-like. Lucy Suchman (2007) has pointed out that an understanding of the robot's functioning must take into account the human labour behind the technology. My focus on multimodal interaction in laboratory practice is a way to engage the discussion on the robot's dependence on the human practices (also see, for example, Turkle et al., 2006; Marantz Henig, 2007), as the interaction between Akira and Nami shows how gestures participate in such labour. Thus, the body of a social robot is not only about a specifically raced, gendered, and mechanized embodiment, about its image in mass media reports, and about standards, constraints, and possibilities of technology; it is also about the local, contingent, coordinated work, and the fleeting movements of gesturing bodies that populate laboratories of social robotics.

In addition to the gestures of the senior practitioner, the excerpt, however, also abounds in the newcomer's as well as the robot's gestures. Akira's gestures are embedded in the series of movements performed by the robot, as the practitioner orients to such movements with comments and directives articulated verbally or enacted through his own gestures. The interaction is 'sequentially organized' (Sacks, 1992): Akira enacts movements just after the current robot's movement has been performed. Similarly, Nami seizes the exact moments in the joint activity to make the robot move – after she observes the robot's movement enacted by Akira. In other words, the fine workings of interaction incorporate and involve a technological object: in addition to the linguistic utterances and participants' embodied performances, the movements executed by the robotic body partake in the orderliness of the social action. What is more, the robot's movements enacted through Akira's body are always contingent on Nami's work on the computer. At the same time, the execution and positioning of Akira's gestures are continuously aligned with and reconfigured by the particularities of the robot's movement that Nami articulates. The process not only includes multiple movements and their concatenation, but it also involves a co-construction of each movement by the temporally adjacent (immediately following) movements.

Importantly, the modeling of the human body through the body of the machine does not only involve a process of 'translation' and 'mimicking'; the characteristics of human anatomy are not simply translated onto the robot's body, and the practitioners do not just 'mimic' the robot's body. Rather, at stake is a multiparty process of bi-directional fashioning and reconfiguration that generates hybrid bodies as dynamic and contingent effects of local practice.

Where is the Model of the Robot's Body?

Akira actively gestures and employs his body as an instrument used by the two practitioners to grasp how the human body moves. The idea of the body as an instrument is well known in the phenomenological literature:

> We use instruments as an extension of our hands and they may serve also as an extension of our senses. We assimilate them to our body by pouring ourselves into them. And we must realize then also that our own body has a special place in the universe: we never attend to our body as an object in itself. Our body is always in use as the basic instrument of our intellectual and practical control over our surroundings. Hence in all our walking hours we are subsidiarily aware of our body within our focal knowledge of our surroundings. And, of course, our body is more than a mere instrument. To be aware of our body in terms of the things we know and do, is to feel alive. This awareness is an essential part of our existence as sensuous active persons. (Polanyi, 1959: 31)

Similar to Heidegger's (1962 [1927]) discussion of the 'ready-to-hand' ontology of tools-in-action, Polanyi explains that, while we are absorbed in our work projects, our body must function as an instrument, as though withdrawn from direct, focal experience. In the robotics laboratory, however, the body, rather than withdrawing from focal experience, is what needs to be attended. In other words, while being the means (the way to understand how the body moves), the human body is simultaneously the object of experience (the body in movement). This peculiar situation generates interesting effects.

As soon as the practitioners render the body visible as the object that needs to be looked at, such a body is configured as a multiparty phenomenon. The human body, to function as the model re-cast in the non-human body, is articulated in relation to the constraints and anatomy of the technological object. The laboratory interaction, thus, shows how the human embodied enactments materially inform and guide the programming, while at the same time it reveals how such enactments appertain to the human as well as the non-human bodies.

The interaction is characterized by the gestures that point to or *index* the body. But, which body? Interestingly, the acts of pointing do not simply individuate one body, but concern an assemblage of bodies – both human and machinic. This assemblage, however, does not involve any single body in its entirety, but integrates specific features of multiple bodies relevant to the task at hand.

Charles Sanders Peirce – who characterized the sign in its relation to objects as *icon*, *index*, and *symbol* – pointed out that every sign is a mixture of *likeness, indices,* and *symbols.*[8] Thus, every indexical sign as a complex whole has some iconic and symbolic components. Akira's gestures in lines 6, 10, 20, 24, and so on, similar to his utterances accompanying the gestures (see, for example, lines 6 and 10: 'here like this'; line 20, 'her arm goes like this'; and line 24, 'because (she) is sitting like this'), are indices directing the attention toward the practitioner's body. At the same time, they are also iconic signs of the robot's movements: they exemplify the way in which the robot should gesture. Because of their composite character, rather than 'masking or glossing their own production to render something else visible', as is usually the case with indexical gestures (see, for example, Hindmarsh & Heath, 2000; Heath & Vom Lehn, 2004), they are what is noticed and examined. The movements' of Akira's hand are the model for robot's gestures that draw attention to the practitioner's body whose movements need to be discovered.

As Akira performs the robot's expected movements, his gestures do not simply take place in the moment of their enactment. Akira's body enacts the robot's future movements, which are desired but not yet realized. These future movements are articulated by the practitioner, but they are not simply lodged in the body of the engineer. When enacting the movement, Akira tries to move specific body parts while keeping the rest of his body relatively steady, in the background. As the movements of Akira's wrist, neck, or shoulder are rendered salient with respect to the concurrent focus in the laboratory work, the configuration of his body-in-motion is a selective act in which only certain features of his body participate in the process designing the robot's body movements.

This highlighting of the relevant body parts and movements turns the practitioner's body with its quirks and specificities into an 'anonymous apparatus to be examined'. In as much as only specific features of the human body are the focus of attention, Akira's body movements are always oriented to the robot's body: his human body highlights its specific parts while, in turn, functioning as a model for the robot's body. This is not to say that something universal is at stake here; as the scientists seek to perform the universal through embodied multimodal interaction of interest is how particular actions can be performed as universal. In other words, the movements of the machinic body that need to be computationally specified are produced in the material here and now, instantiating the 'universal' and 'future' body of the robot in the particularities of the individual human body. Concurrently, the human body is fragmented and coordinated with multiple bodies and technologies across the environment of engineering practice. The focus on the details of work and interaction recovers the modeling of the robot's movement as specific, material and publicly shared acts accomplished across bodies, technologies, and moments in time.

Moving as a Robot

By definition, the movements of an android reference human movements – the robot's body is conceived as a replica of the human body. The design practice, however, indicates how the robot's body reconfigures human movements. Rather than being independent from the robotic body, the practitioners' enactments of the movement are made intelligible by the presence of the robot. Similarly, the movements of Akira's body not only index the robot's body while they perform its movements; they are also intimately reconfigured by the robot's body and its possibilities or constraints.

The machinic reconfiguring of the human body can be identified in the temporal organization of the activity and the morphology of the practitioner's movement. Before enacting the movement, Akira scrutinizes the robot's body (see, for example, lines 1, 6, 8, 11, and 14) as this close scrutiny allows him to perform movements that are carefully coordinated with the structure of the robot's body. Importantly, the movements performed by the practitioner are not just casually executed everyday movements, but highly controlled acts situated in the space of possibilities shaped by the constraints of the robot's body. The aim is to organize the movements into their constituent elements so that each element can be identified, digitally specified, and mechanically performed. When Akira performs the movements in lines 6 and 10, for example, his movements are mechanistic and 'unnatural': the movement of his torso and the protrusion of his arm are slow and syncopated. The mode in which the movements are executed is paralleled by the prosody in the linguistic form: the pronunciation of 'Here like this' (in lines 6 and 10) is elongated and rhythmic.

In lines 27–29, the pursuit of the engineering task further projects the characteristics of the robot's body onto the practitioner's body. Akira first looks toward the computer screen (line 28) to identify the numbers assigned to the robot's actuators (Fig. 2). Once this is done he sits back and repeats the number identified on the screen: 'Oh ok it's number 30' (line 29). Next, he says 'Move number 30. Is it number 30 that (we) are moving', while touching his shoulders and moving his arm forward. The actions function as if transposing the nomenclature of the robot's body onto Akira's body. Yet, what is projected from the robot's body onto the body of the practitioner is not the essence of the robot. Inasmuch as the robot's body – its possibilities and limitations – 'connote' the larger scientific community in terms of the values, attitudes and beliefs supported and naturalized by the community, while suppressing others (Barthes, 1972 [1957]), the ad hoc categorization renders the body intelligible in terms of the historic and social dimensions of the practice.

Importantly, this process of bidirectional fashioning between the human and machinic body is not an intentional and representational process. In his study of how visitors see and reflect on Gunter von Haagen's 'Body World' exhibit, Dirk vom Lehn (2006) adopted Paul Schilder's (1950) concept of body image, for the purpose of analyzing video-recordings of the exhibit visitors. The concept played an important role in Vom Lehn's explorations of how visitors 'inspect, identify and make sense of different parts of the plastinates by building up images of the bodies on display'; how they 'relate these images of the plastinates to the bodies of others and thus come to see the exhibits as "real"'; and how they 'reflect on and produce an understanding of their own bodies when they examine the plastinates' (Vom Lehn, 2006: 225). During the activity of movement design, Akira manipulates the robot through bodily expression and experience, while simultaneously fashioning his own body by watching and responding to the robot's movement. However, when discussing how characteristics of the robot's body are projected onto the practitioner's body, I do not mean to imply that Akira and his colleague somehow intentionally see, reflect upon, and acquire information about their own bodies in terms of the robot's body. In contrast to the exhibit visitors, the roboticists' overarching goal is to figure out how to develop the human model. Rather than learning about the body at the display, Akira and Nami learn about how to implement its movements in the course of implementing them. In this sense, they are acquiring an engineering skill, rather than a 'body image'. Since the process involves embodied know-how, the coordination and projections among the bodies are not necessarily mediated by an intentional content: they do not form a 'map, grid or representational reference point' as it is the case for the 'body image' (Vom Lehn, 2006: 227). The projections among the bodies, including the practitioners' experiences of the robot's body, often include non-representational actions through which the skillful body responds to and coordinates with the situation at hand (Merleau-Ponty, 1962 [1945]).

Feeling the Robot's Movements

The focus on the semiotic features of the engineering know-how does not disregard the experiential and sensory qualities that belong to the bodies involved in the design activity. The way Akira gestures is intimately related to affective and subjective experiences in the design practice, as laboratory learning and problem solving display affect at the level of multimodal semiotic engagement. Interestingly, the felt gestures, incarnated in the body of the practitioner and enacted in the publicly shared environment of practice, are *multiple* (Mol, 2002) – they are at once human and machinic. Even though such gestures are materially grounded in the human body, they do not exclusively belong to it. The movements of the hand, neck, shoulder, and upper body enable the practitioners not only to find out what human-like movements look like, but also to discover what the robot's movements feel like.

In line 10 Akira performs the movement several times while seated. To work on the specification of the robot's movements, he tries to find out how he would move if placed in the same position as the robot. Akira thus feels the awkwardness of the robot's movement: 'it is strange that (she) is doing an interview while sitting' (line 17). The felt awkwardness is publicly available – the movements are clearly marked through their abruptness, and accompanied by verbal cues. The experience of the movement guides the discovery of the possibilities (and limitations) of the body – lines 30–32. In line 30, Akira touches his right shoulder while enacting the movement. As he enacts the movement over and over again, the touching hand senses the structure of the practitioner's body, functioning as a probe involved in discovering what needs to be modeled. Through this public and experiential act of instruction and discovery, Akira can feel the place on his body where the robot's joint governing the movement in question is located. In this way, the movement is enacted and felt through coordination across multiple bodies: Akira feels the movement of the robot's body in his body.[9]

While sensing his own movement and body position, Akira recognizes potentially problematic aspects for the engineering task. For instance, as he performs the body movements and the hand gesture, Akira exclaims while laughing: 'Oh this is tough!' (line 34). Obviously, the movement itself is not 'tough'. Rather, the enactment indicates that the movement requires an involvement of multiple body parts (for example, the upper body, hand, neck), which is not immediately compatible with the possibilities for specifying the machine's embodied actions through the available hardware and software. Thus, the enactment of the movement allows the practitioner to realize that some movements that are not difficult for the human body, would be exceedingly difficult for the robot's body. The practitioner's own movement feels 'tough' in respect to the particulars of the engineering work and the future instantiation of the movement in the machine's body.

The comment 'Oh this is tough!' marks the discrepancies and re-established boundaries between the human and non-human. The process of movement co-construction is not about perfectly coordinated acts; the roboticists do not find the machinic body to be 'just like the human body'. Instead, they are eager to point out that the robot does not in fact constitute a faultless model of the human. Akira's remark is an instance of such a stance: while not showing any signs of resignation, Akira proudly displays the complexities of the task and the impossibility of ever producing a 'perfectly human' movement.

In her study on the history of automata, Jessica Riskin (2003) points out the contradiction that underlies the early history of artificial intelligence: 'that one could understand life and intelligence by reproducing them, on the one hand, and that life and intelligence were defined precisely by the impossibility of reproducing them, on the other' (Riskin, 2003: 633). By attending to the embodied enactments and the co-construction of bodies in the contemporary practice of robot design we are confronted with a parallel stand. We see the tension, rather than a process of translation, at the level of laboratory know-how. One can further wonder if Akira's movements, the probing of his shoulder, and his remark 'Oh this is tough!', give voice to the challenge faced by the contemporary social robotics community at large, while like Vaucanson and his automata in Riskin's account, they acknowledge the sameness and the incompatibility of life and machinery (Riskin, 2003: 610).

Social Management of Robot's Movements

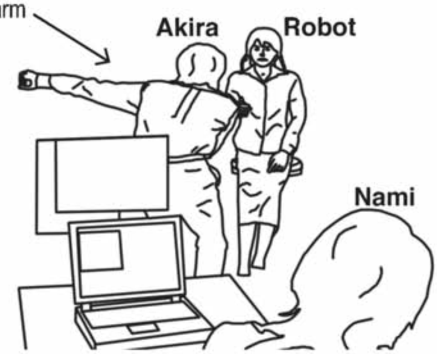
The activity reported in Excerpt 1 is followed by a few minutes of Nami's work at the computer closely monitored by Akira. Thereafter, Akira abandons his location and walks toward the robot where he can directly interact with it (lines 35–54).

Excerpt 2

35 Robot: ((Robot moves))

36 Akira: で、こっち側に開いて：、え：スタンバ-
de, kocchi gawani hiraite:, e: sutanba-
and this side open INJ stand.by
Open the arm toward this side and keep it like this ((Akira first touches the robot's shoulder and then his own shoulder. Nami moves her head to obtain a better view))

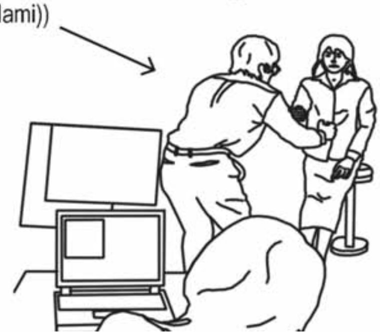
37 っち側にこういう感じでずれる感じで
kocchi gawani kooyuu kanji de zureru kanji de
this side like.this like shift like and
Make this side like this ((Akira moves his right arm and then swings with his left arm 3 times while touching his left shoulder with his right hand))



38 Robot: ((Robot moves))

39 Akira: で：もう少しこう。
de: moo sukoshi koo.
and more little like.this
Little bit more like this ((Akira observes the robot, and touches its arm. Nami moves her head to obtain a better view. The robot moves a bit))

40 ((Akira shapes his arm in the desired position. While touching his shoulder he carefully turns around 90º to face Nami))



41 Akira: ((When standing next to the robot, Akira shapes his arm again in the desired position, and looks toward the robot's arm and back))

42 そしたらこうなるんじゃない、
so shitara koo naru n janai.
so if.do like.this become right
Then it changes to this, right? ((Akira performs the movement while keeping his right wrist steady with his left hand))

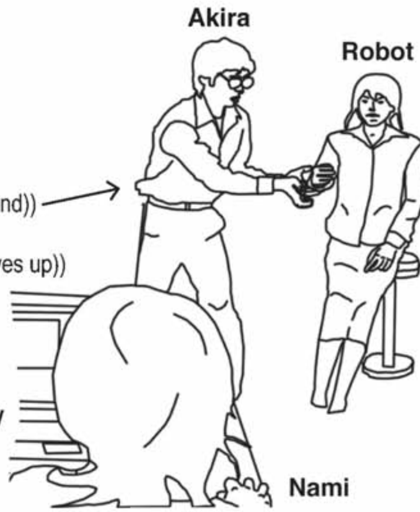
43 手に向けるから：
aite ni mukeru kara:
interlocutor to direct because
Since ((she)) will point toward the interlocutor

44 え：：と、こっち側の間接あるっしょ？
e::to, kocchi gawa no kansetsu aru ssho?
INJ this side joint have right
There is a joint on this side, isn't there?
((Akira points to the lower side of the robot's arm))

45 これを使って
kore wo tsukatte
this ACC use
Use this ((Akira places his hand next to the robot's hand))

46 これをもう少し
kore wo moo sukoshi
this ACC more little
A little bit more.

47 Akira: こうするから
koo suru kara
like.this do because
Like this ((Akira moves his hand))



48 Robot: ((Robot's hand somewhat moves up))

49 Akira: 逆、 逆、
gyaku, gyaku,
opposite opposite
The other way, the other way
((Akira moves his hand two
more times Downwards))

50 え、もう行かない.
e, moo ikanai.
INJ more not.go
It can't go any more.

51 行かない？
ikanai?
not.go
Can't go?

52 これを使ってみて.
kore wo tuskatte mite.
this ACC use try
Use this side ((Akira points to robot's upper arm)

53 方
ryoohoo
both
Both sides

54 Robot: ((Robot's hand somewhat moves))

In line 35, Nami employs computer commands to initiate the robot's movement. Akira observes the movement while standing in front of the robot. In line 36, he suggests how to improve the specification of the movement while directly touching the robot's right shoulder. He then touches his own right shoulder, and initiates a series of movements. While still facing the robot, Akira briefly raises his left arm, lets it hang back, swiftly switches hands, raises his right arm and lets it slowly and emphatically hang back for three consecutive times (line 37). The robot's arm moves (line 38). After a close observation and direct probing of the robot's body (line 39), Akira carefully brings his right arm in a position resembling the robot's left arm position. In line 40 Akira turns 90° to directly face Nami while standing on the robot's right-hand side. While turning around, Akira keeps his left hand touching his right shoulder. Once facing Nami, he looks at the robot's arm, and by scanning back and forth from the robot's arm to his own arm, he once again checks if his arm position corresponds to the robot's (line 41). Once his arm position has been closely aligned with the robot's, Akira gets involved in the execution of a series of movements performed in the immediate vicinity of the robot (lines 42–53). In line 44, he touches the robot while pointing to its arm. He then places his hand next to the robot's (line 45), and performs the movement (line 47). The robot's movement (line 48) is once again followed by Akira's performance of a more desirable movement (line 49). Immediately thereafter Nami informs Akira that the robot hand cannot move in the direction suggested by him. In lines 52–53, Akira suggests the strategy of engaging the robot's upper arm.

Excerpt 2 illustrates how the enactments of the hybrid movements are not exclusive to the relationship between the advanced practitioner and the robot, but are importantly shaped by the newcomer. Literature on the acquisition of skill in science has pointed out the significance of the master's role in apprenticeship. In this regard, Polanyi writes:

> To learn by example is to submit to authority. You follow your master because you trust his manner of doing things even when you cannot analyze and account in details for its effectiveness. By watching the master and emulating his efforts in the presence of his example, the apprentice unconsciously picks up the rules of the art, including those which are not explicitly known to the master himself. These hidden rules can be assimilated only by a person who surrenders himself to that extent uncritically to the imitation of another. (Polanyi, 1958: 53)

The interaction in the robotics laboratory follows this model of authority: the advanced practitioner guides the newcomer's learning as she acquires laboratory skills. At the same time, however, the newcomer's participation in the activity shapes the course of action. This active involvement of the apprentice is not developed only through her own semiotic body (Nami remains largely silent and immobile throughout activity), but is enacted via the bodies of the 'others'. Nami drives the process of design through the gestures of the advanced practitioner and the movements of the robot. The description of her active participation in the apprenticeship raises questions about human–technology extension and embodiment.

Akira once again participates in problem solving by articulating his own body in terms of the machinic body. In line 37, for example, he enacts a slow and exaggerated robot-like movement, while in lines 40 and 43 he constrains his moving hand to involve only those body parts that the robot could possibly enlist in its movement. This hybrid body is contingent on the temporal and spatial organization of the practice. The proximity between the two bodies – Akira's and the robot's – allows for exploration through touch. Once in front of the robot, Akira not only can sense the 'mechanical structure of his own body' (as seen in the Excerpt 1), he also can touch the robot's body. The physical proximity enhances the possibility of tight projections between the two bodies (lines 39, 44 and 52). In line 36, for example, Akira first touches the robot's shoulder and then quickly strokes his own shoulder. While indexing the two bodies the sequential touching functions as if promoting a contagion between features of both. The sequence culminates in another performance of the robot's movement enacted by Akira (line 37). A similar action takes places in lines 44–45, where the practitioner first touches the robot's body and then enacts the movement himself.

In line 37, while facing the robot and turning away from his colleague, Akira initiates the movement with his arm corresponding to the robot's moving arm. The movement maps the robot's right arm onto Akira's right arm, but he almost immediately aborts the initiated performance, alters the arm involved, and performs the movements for three consecutive times with his left arm. This mirroring makes Akira's enactment more easily readable by Nami: for Nami, Akira's arm now moves towards the same side (that is, right) that the robot's arm is expected to move. While enacting the movement, Akira utters: 'Open the arm toward this side and keep it like this' (line 36) and 'Make this side like this' (line 37). The deictic expression 'this side', while occurring in parallel with Akira's hand movement, is relative to Nami's positioning in the space of action. Even though Akira moves his left arm, Nami is interested in the robot's right arm moving toward the right. This adjusting of activity in respect to Nami's participation is also visible in Akira's altering of his spatial location in line 40. In lines 36 and 39 Nami moves her head and torso to the right to obtain a view of the robot (lines 36 and 39), as Akira spatial location obscures her line of sight. To deal with the trouble Akira turns 90° so that his right hand can represent the robot's right hand. The new location may be less convenient for him, as the position doesn't allow Akira to directly observe the robot while performing its movements, and yet it exposes both his and the robot's body to the direct gaze of his colleague. By being subtly sensitive to Nami's spatial location and her task at hand, the organization of Akira's movement exhibits 'recipient design' (Sacks et al., 1974; see also Hindmarsh & Heath, 2000). The movements, enacted by Akira's body and shaped by the spatial arrangements of machinic and human bodies, orient to Nami's positioning in the practice. Thus, the act of co-construction not only implicates Akira and the robot, but Nami as well; while acquiring the know-how of social robotics, Nami's presence in the practice is visible in the doings of her colleague, and therefore in the enactment of the robot's body.

Acting 'Through' the Movements of the 'Others' and 'Quasi-others'

Excerpt 3

55 Akira: ((Akira, seated in front of the robot, performs a gesture of movement around the robot's face with both hands))

56 Robot: ((Robot looks up and performs the movement))

57 Akira: 首の回転は、こっちを
kubi no kaiten wa, kocchi wo
neck GEN rotation TOP this ACC
The neck rotation is like this

58 Robot: ((Robot's head moves toward its right.))

59 Akira: そう：そう そう そう.
soo: soo soo soo..
right right right right
Yes yes yes yes ((Akira performs the gesture of movement around the robot's face with his right hand as if moving its face toward his right))

60 でもうちょっとこっち. これに、これを見るような感じが.
de moo chotto kocchi. kore ni, kore wo miru yoonakanji ga.
and more little this.way this this this ACC look like NOM
And move this way. As if she is looking at this ((Akira points to the robot's hand, while keeping his right wrist steady with his left hand))

61 Akira: (1.0)

62 もうちょっとこっち.
moo chotto kocchi.
more little this.way
A little bit more this way.

63 Robot: ((Robot's head moves toward its left))

Excerpt 3 starts right after Akira picks up a chair and places it in front of the robot. Once seated, he suggests how the head of the robot should be moved (line 55). He does so by executing a gesture that resembles a physical rotation of a round object. The enactment is followed by a robot movement (line 56). In line 57 Akira verbally directs the attention toward the robot's neck. In line 58 the robot moves again. The next turn (line 59) is again an example of Akira's embodied enactment of a physical rotation, this time performed with one hand only. The enactment is transformed into a deictic gesture that indicates the desired direction of the robot's gaze (line 60). The excerpt is closed by another robot's movement (line 63).

The newcomer's presence in the activity is not only visible in the embodied enactments of her colleague. Excerpt 3 shows how Nami employs Akira's conduct as well as the movements of the robot to further extend her doings. Importantly, the relationship between the co-participants is not one of mirroring, but one that sees the body of the other or quasi-other as part and parcel of the practical problem-solving.

Of particular interest are Akira's gestures in lines 55 and 59. Akira gestures as if physically rotating the robot's head. This time his gestures do not enact the movement of the robot; instead, they materialize the engineering work of his colleague. Akira's embodied enactments function as if they were a translation of Nami's work on the computer in the physical work performed around the robot's body. In other words, the rotation of the robot's head, which needs to be computationally specified, is rendered concrete through Akira's gestural enactment. The previous section illustrated how Akira's movements of the robot's body were organized by Nami's positioning in the space. Here we see how Akira's body enacts Nami's work in the shared environment of practice: Akira's gestures around the robot's head function as extensions of Nami's work performed in the publicly shared environment of practice.

The articulation of Nami's work in the environment of practice, however, is also achieved through the robot's movements. In addition to acting through Akira's embodied performances, Nami's actions are made publicly available via the robot's hand protrusions. When interacting with Akira via the body of the machine, Nami 'speaks' through the movements of the machine employing the body of the machine as a *semiotic prosthesis*. Such an apparatus allows each practitioner to see what the other is doing. While Nami can observe Akira's embodied enactments, the robot's movements are a key resource for Akira to assess his colleague's learning and her participation in the activity: he can see Nami's facial expression, gaze directions, and hand movements on the computer mouse, but he can also access her participation in the design process through the movements of the machine. This 'stretching out' of Nami's work through the robot's body is a way for 'producing collaborative action' (Goodwin, 1995: 263).

An equally intriguing example of the body as prosthesis can be found in Excerpt 2 – where we see Nami's work publicly exhibiting the robot's body while shaping Akira's actions. In line 49 of Excerpt 2, Akira twice consecutively moves his hand downward in order to perform the desired robot movement. By probing the possibilities of the robot's body, Nami expresses unhappiness with Akira's gesture (line 50). As she translates the colleague's gesture in the computer command, she notices that the robot's arm does not respond as desired: 'It can't go any more.' This projecting of her phenomenal body through the body of the machine allows Nami to explore the instrument she is using: the body of the robot enables the apprentice to get a feel of how the machine can or cannot move.

What is more, Nami's utterance provides a public display of the robot's body, even when the robot does not move, giving Akira the possibility of 'sensing' the robot's body 'at a distance'. This 'sensing at the distance' organizes the performance of Akira's movements: it reconfigures the practitioner's work in terms of Nami's actions and robot's movements. As Nami informs her colleague about the constraints of the robot's body, he proposes a different solution: while saying 'Use this side' he now points toward the robot's upper arm (line 55). Akira thus reshapes his suggestion in relation to those (absent) movements of the robot, experienced through the computer by Nami. Akira's hand tilts and his movements express close attention to Nami's work displayed via the robot's movements. In this way, through the movements of the robot, Nami positions herself in the activity as a competent practitioner. Nami designs the robot's movement so that they progressively match Akira's suggestions, presuming his authority as community spokesperson, while displaying her capacity to speak the emergent local vernacular through the robot's movements. Nami in fact resorts to talk only in the rare moments in which the robot's movements cannot 'speak' for her – when she encounters insurmountable discrepancies between the experiential possibilities of the robot's body and the present configuration of the activity. For example, in line 50 (Excerpt 2) she says 'It can't go any more' when the robot's body resists moving as required. Otherwise, even though Nami mostly remains silent and immobile, the enactments of the hybrid movements implicate her as a powerful speaker in the activity of robot design.

Recent studies of the social aspects of robotics (see, for example, Turkle, 2006) have been concerned with the affective character of our relationship with humanoid robots: we are prone to approach a robot in anthropomorphic ways, entertaining certain feelings for it. In other words, the technological object is seen as our 'quasi-other' with whom we can 'interact'. This kind of experience often takes place when a visitor to the laboratory encounters the robot (see also Suchman [2007: chapters 13, 14]). During such encounters, the visitor is prone to consider the robot to be a self-sustaining object.

In laboratory work, on the other hand, the robot more often functions as a means of extending the bodies and actions of its designers. When engaged in scientific practice, the body of the robot, as well as the bodies of the human practitioners, function as prostheses, which, rather than being replicas or models, 'extend' the body – its experienced actions and interactions. These ways of extending the body 'talk back': they reconfigure the body, which, in turn, is reconfiguring them. Perhaps this is why, unlike the visitors, the practitioners often feel *with* the robot, rather than *for* it – as they experience frustration, joy, discouragement, or a sense of achievement in the everyday work of social robotics.

Discussion

From a communication perspective, humanoid social robots are conceived as *human surrogates*, intended 'not as a medium through which humans interact, but rather a medium with which humans interact' (Zhao, 2006: 402).[10] Similarly, the role of social robots in cognitive science is framed in terms of human models. Roboticists aim to deploy such robots as computational test-beds for devising controlled, repeatable experiments to investigate questions about the nature of human intelligence (Scassellati, 2001: 145–46). In both cases, the robots are envisioned as human counterparts, to take our place in conversations and experimental procedures. In this paper, I looked at how scientists accomplish the task of designing a robot in 'their own image'. The details of interaction between scientists and robotic technology suggested a more complex picture. I addressed the issue of human–technology relationship in terms of 'bodies-in-interaction'.

The account followed two practitioners of social robotics engaged in a process of technology design and apprenticeship learning. As we joined the activity of movement specification, the laboratory space opened up as an environment articulated through the embodied actions.[11] I described how practitioners, in a place filled with state-of-the-art technologies and scientific representations, turned to their own bodies, employing them as a pivotal resource in accomplishing the engineering task. Their bodies, materially informing and guiding the programming, were employed as instruments and models for the robot, particularly apt for being brought under shared attention, manipulated, and felt.

Contrary to the everyday experiences of our own bodies, the process of robot design asks practitioners to attend to their own bodies, rendering them visible: the senior practitioner gestured to look at and display the model of the human body to his colleague. This task of 'externalization' was further assisted by employing the gesturing bodies as instruments. The senior practitioner, for example, touched his own shoulder to feel the architecture and mechanics of the human body, as he rendered his finding publicly available. The practitioner's hand, while enacting how the human body moves and should be represented, took the role of a probe engaged in providing access to the world (which, in this case, was the same body that acted as the instrument).

Humanoid robotic technologies impact how scientific work and technology design are accomplished. We are used to seeing scientists looking at computer screens or observing what can be spotted under a microscope; in the social robotics laboratory, however, practitioners also scrutinize their own bodies. Rather than just observing a reality positioned for scrutiny in front of them, they must take into account how their own wrists rotate and their necks bend. At the same time, as they turn to focus on their own experiential bodies, the subjective body is 'pushed outward', beyond the skin of an individual. In other words, the practitioners' body, aiming at becoming a general type of the human body, is displayed to be collectively observed in the shared environment of practice.

These local and embodied interventions, as they blur the demarcation line between the observed and felt, articulate the body of the machine, thus challenging the autonomy of the robot. While the claim of autonomy invests the machine itself with the ability to dwell in its own access to things, the details of practice indicate how the robot is animated through the practitioners' gestures. In this way, the machine not only extends its ears and eyes across the environment, it also dynamically adopts the hands of its designers. Rather than merely collecting information from the world, the robot, through a series of semiotic transformations, 'comes to life' by dwelling in the gestures of its designers.

Importantly, however, the process is not one of projecting where the human body is seamlessly mapped onto the robot's body. Instead, in the laboratory the robot's body reconfigures the human body in action. As practitioners use their bodies to model the body of the machine, they need to adjust such models to the constraints and possibilities of the technology. The excerpts from interaction show how the practitioner, in order to accomplish the task at hand and acquire skills of a laboratory member, moves like a robot while simultaneously feeling the robot's movement in his own limbs, neck, and upper body. Such a process is achieved through locally enacted gestures: while being configured by the constraints and the mythologies inscribed in the machinic body, the practitioner's actions are conditioned by the specific movements of the robot that precede them while projecting a certain kind of future.

In accounting for such enactments, I was particularly interested in how the two engineers dwell in the body of others and quasi-others. The examples from laboratory illustrate how the body and its interactional work may extend through the body of the robot as well as the bodies of other human co-participants. The coordination of gestural movements within the sequentially organized course of action provided a way for the practitioners to probe the body of the machine: the senior laboratory member tested the robot's capacities and its limitations through the work of his colleague. The co-construction of movements, moreover, allowed the practitioners the possibility of an interactional engagement, even when their own bodies did not display any verbal or gestural conduct. The newcomer to the laboratory was able to see the enactments of her work in her colleague's embodied gestures and spatial positioning. In addition, she conversed with him through the very robot's movements that she was trying to *understand* in a literal, embodied sense of the word. The newcomer's work was thus not limited to the computer with which she directly engaged; it also was performed through the actions of the fellow practitioner, as well as the body of the technology she was attempting to 'get into'. In this way, the body of the robot, as a semiotic and phenomenal prosthesis, rendered the work of the two roboticists open to cooperation while providing the junior practitioner with a professional voice and an embodied sense of the technology she was designing.

The description of such processes indicates how the well-known metaphor of human–technology extension may be employed and further broadened to account for the computational technologies that present themselves as self-standing human counterparts. To be designed, social robots require complex reconfigurations of human bodies, as scientists, to master the skills of social robotics and accomplish their work, employ the robotic technology as a part of themselves.

This is, however, not to deny that the complexities seen in the robotics laboratory exceed the classical examples of simple hand-held tools and instruments (such as the hammer and blind man's stick). In the robotics laboratory both the technology and the human body function as tools as well as models of each other. In this sense, the extension (implying Foucaudian layers of historically specific discourse, see Lynch, 1991: 55), is bidirectional: rather than witnessing a relationship between a subject and an inanimate object, in the social robotics laboratory we are confronted with technologies that talk back, demanding from us to reconfigure ourselves in the opening to the world. These complexities, rather than necessitating new concepts and terminology, call for 'sustained observations of daily routines in settings of research and work' (Lynch, 1993: 104–05; Garfinkel, 2002).

Importantly my account of human–humanoid relationship should not be read as a story about scientists mimicking or imitating the robots while empathizing with or nurturing sympathy for them. By observing the difficulties, imperfections, and frustrations that characterize how the skillful body responds to the situation at hand (often in a non-representational manner), I suggest that the process of human–humanoid interaction is about embodying the technology and experiencing its structure and mechanics in one's own body. Rather than projecting their bodies onto the machine and mimicking the robots, laboratory practitioners take part in enacting dynamic human–machine hybrids, as they try to make sense of the world and get things done.

Over the past two decades, social studies of science and technology have witnessed a growing interest in the 'blurring of human–machine boundaries' and the phenomenon of 'human–machine hybridization' (see, for example, Haraway 1985[1991], 1997; Turkle, 1995; Latour, 1996; Hayles, 1999; Knorr-Cetina, 1999; Mindell, 2002; Prentice, 2005). In parallel, artists – Stelarc probably being the most celebrated (see, for example, Smith, 2007) – have generated rich performances tackling the notion of 'post-humanist cyborgization'. The examples from the social robotics laboratory can be read by referring to a similar set of ideas. Yet, in the case in point, the phenomenon of the *extended*, *stretched*, and *probed* body indicates nothing but the mundane features of human action and interaction. While the encounter between two practitioners and the advanced humanoid machine takes place in a high-tech research laboratory, the extending of the body and human–machine hybridization was largely accomplished through a recurrence to the human body and its embodiment in the world. My description, in fact, is a way to think about the dynamics between human bodies and robotic technology, starting from local acts of work and multimodal interaction in the laboratory. Such an approach calls for a taming of the gap between the human and machine expressed in terms of counterparts, while it problematizes the idea of embodiment seen as a process grounded in data collection.

Conclusion

I started the description of apprenticeship in social robotics laboratory by recalling the conception of embodiment inscribed in such technologies. While defining a robot's body in terms of its humanoid characteristics (a robot may have an easily recognizable head, hand, and torso), social robotics considers embodiment in terms of the robot's capacity to change as it acquires data collected through its sensory inputs. To reflect on this idea of embodiment, I focused on the way scientists interact with the robots and each other in the midst of laboratory work. The goal of the paper was to think through the issues of body and social interaction by confronting the 'theoretical ambitions of the scientific discourse' (de Certeau, 1984) with the everyday work of the laboratory. By looking at the material practices in the laboratory, I asked: Where does the body start and where does it end? Can the body expand and contract? The turn to those questions drew attention to what the definition of the body and embodiment in social robotics misses: the ways in which the body reconfigures itself through social interaction as it dwells in the world.

The practitioners' own work and interaction suggest that the explanations of embodiment in terms of distribution, networks, representations, propagation, collection, and addition are not complete. To argue against the idea of the body as an enclosed structure, I showed how the body extends outward not only by distributing its sensors across the environment, but by dwelling in other actors (human and non-human) that comprise its world. Thus embodiment also concerns transformations and emergence in a specific situation as at stakes is a body that moves.

The distinction between the two ways of understanding embodiment may not appear substantial, but it does involve a move from the body as confined to an individual subject to a body that emerges in its opening to the world. The body-in-interaction concerns the complex and dynamic dependencies across bodies as a part of recognizable social action. I described the human body as a locally contingent, interactionally achieved phenomenon through which the practitioners acquire engineering skills, participate in the process of design, and see the robot in movement.

This account, pointing out the unstable relational configurations between human and non-humans, does not, however, argue for symmetry (see also Collins, 1990; Collins et al., 1997; Lynch & Collins 1998; Suchman, 2007). Instead, I maintain that distinctions between humans and non-humans are at play for at least as long as we envisage the technologies built as our counterparts while failing to recognize the interactional complexities at the human-technology interface.

Notes

This paper, in its various versions, was previously presented at the *Cognitive Science Workshop: Toward Social Mechanisms of Android Science*, 25–26 July 2005, Stresa, Italy; *Ethnographies of Code: Computer Programs as the Lived Work of Computer Programming*, 30–31 March 2006, Lancaster University, UK; and Society for Social Studies of Science Annual Meeting, 11–13 October 2007, Montreal, Canada. I would like to thank: Hiroshi Ishiguro, Monika Buscher, Lisa Cartwright, Nitin Govil, Val Hartouni, Yvonne Hsiung, Ed Hutchins, Jim Hollan, Charles Goodwin, Shimako Iwasaki, Michael Lynch, Maurizio Marchetti, Daisuke Matsui, Karl MacDorman, Dave Martin, Takashi Minato, Javier Movellan, Yasukazu Nagatomi, Motoko Noma, Saeko Nomura, John Rooksby, Allison Sanford, Ayse Saygin, Michihiro Shimada, Lucy Suchman, Sherry Turkle, and Rosalind Williams for their contributions to this paper.

1. For this idea of embodiment see, for example, Gibbs (2006).
2. I find this sharing of common interest with the scientists whose practices I study particularly challenging.
3. The laboratory is Japanese and this explanation is written as a second language.
4. Michael Lynch (1991: 54), taking in account Michel Foucault's (1979) problematization of any notion of extension from a naked existential ground, has pointed out that the metaphor of extension misses the transformation of embodied spatiality associated with an instrumental complex.
5. When referring to processes of hybridization, I base my thinking in *conceptual integration* or *blending theory* (Fauconnier & Turner, 2002).
6. When I observed the laboratory practices, the design of the robot's movement through motion-capture technology was largely a future plan. Motion capture, frequently used in filmmaking and animation, digitally records human movements to be used to simulate such movements by the robot. My intention is not to imply that the use of such technology would wipe out the kind of enactments described here, but to suggest that the detail of their articulation would differ.
7. For the help with the transcript I am particularly indebt to Shimako Iwasaki. I have also made frequent checks with the participants themselves in order to confirm the interpretations of their interaction.
8. C.S. Peirce defines the sign as follows:

    First, an analysis of the essence of a sign (stretching that word to its widest limits, as anything which, being determined by an object, determines an interpretation to determination, through it, by the same object), leads to a proof that every sign is determined by its object, either first, by partaking in the characters of the object, when I call the sign an Icon; secondly, by being really and in its individual existence connected with the individual object, when I call the sign an Index; thirdly, by more or less approximate certainty that it will be interpreted as denoting the object, in consequence of a habit (which term I use as including a natural disposition), when I call the sign a Symbol. (Peirce, 1906 [CP 4-531])

9. My insights regarding these semiotic and phenomenal acts are not simply informed by a conversation analytic unpacking of the talk, but are based in ethnographic understanding through which I explicate what the participants are doing and feeling (Lynch, 1985, 1993).
10. A frequent comparison is between social media, aimed at promoting information sharing among human beings while using technologies as conduit, and humanoid social robots, conceived as a mode of communication where humans interact with technology.
11. For an account of the role of embodiment in science see Lawrence & Shapin (1998).

References

Adam, Alison (1998) *Artificial Knowing: Gender and the Thinking Machine* (London: Routledge).

Barad, Karen (2003) 'Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter', *Signs: Journal of Women in Culture and Society* 28: 801–31.

Barad, Karen (2007) *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press).

Barthes, Roland (1972 [1957]) *Mythologies* (London: Vintage).

Breazeal, Cynthia (2002) *Designing Sociable Robots* (Cambridge, MA: MIT Press).

Brooks, Rodney & Lynn Andrea Stein (1994) 'Building Brains for Bodies', *Autonomous Robots* 1: 7–25.

Brooks, Rodney, Cynthia Breazeal, Matthew Marjanovic, Brian Scassellati & Matthew Williamson (1998) 'The Cog Project: Building a Humanoid Robot', in C. Nehaniv (ed.), *Computation for Metaphors, Analogy and Agents* (Berlin: Springer-Verlag): 8–13.

Callon, Michel (1995) 'Four Models for the Dynamics of Science', in S. Jasanoff, G.E. Markle, J.C. Petersen & T. Pinch (eds), *Handbook of Science and Technology Studies* (Thousand Oaks, CA: Sage Publications): 29–63.

Cicourel, Aaron (1974) 'Interviewing and Memory', in C. Colin (ed.), *Pragmatic Aspects of Human Communication* (Dordrecht: D. Reidel): 51–82.

Clark, Andy (1997) *Being There: Putting Brain, Body, and World Together Again* (Cambridge, MA: MIT Press).

Clark, Andy (2001) *Mindware: An Introduction to the Philosophy of Cognitive Science* (New York: Oxford University Press).

Collins, H.M. (1990) *Artificial Experts: Social Knowledge and Intelligent Machines* (Cambridge, MA: MIT Press).

Collins, H.M., Gerard H. de Vries & Wiebe E. Bijker (1997) 'Ways of Going On: An Analysis of Skill Applied to Medical Practice', *Science, Technology, & Human Values* 22(3): 267–85.

Dautenhahn, Kerstin (1995) 'Getting to Know Each Other: Artificial Social Intelligence for Autonomous Robots', *Robotics and Autonomous Systems* 16: 333–56.

de Certeau, Michel (1984) *The Practice of Everyday Life* (Berkeley, CA: University of California Press).

Dobbyn, Chris & Susan Stuart (2003) 'The Self as Embedded Agent', *Minds and Machines* 13: 187–201.

Dreyfus, Hubert (1979) 'From Micro-worlds to Knowledge Representation: AI at an Impasse', in J. Haugeland (ed.), *Mind Design II* (Cambridge, MA: MIT Press): 143–82.

Fauconnier, Gilles & Mark Turner (2002) *The Way We Think: Conceptual Blending and the Mind's Hidden Complexities* (New York: Basic Books).

Forsythe, Diana (2001) *Studying Those who Study Us: An Anthropologist in the World of Artificial Intelligence* (Stanford, CA: Stanford University Press).
Foucault, Michel (1979) *Discipline and Punish: The Birth of the Prison* (New York: Random House).
Garfinkel, Harold (2002) *Ethnomethodology's Program: Working Out Durkheim's Aphorism* (Lanham, MD: Rowman & Littlefield).
Gibbs, Raymond W. Jr (2006) *Embodiment and Cognitive Science* (Cambridge: Cambridge University Press).
Goodwin, Charles (1994a) 'Professional Vision', *American Anthropologist* 96(3): 606–33.
Goodwin, Charles (1994b) 'Recording Human Interaction in Natural Settings', *Pragmatica* 3: 181–209.
Goodwin, Charles (1995) 'Seeing in Depth', *Social Studies of Science* 25: 237–74.
Goodwin, Charles (2000) 'Practices of Seeing, Visual Analysis: An Ethnomethodological Approach', In T. van Leeuwen & C. Jewitt (eds), *Handbook of Visual Analysis* (London: Sage Publications): 157–82.
Haraway, Donna (1985 [1991]) 'Manifesto for Cyborgs: Science, Technology and Socialist Feminisim in the 1980s', *Socialist Review* 80: 65–108. Reprinted as 'A Cyborg Manifesto: Science, Technology, and Socialist-feminism in the Late Twentieth Century', in D. Haraway, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge): 149–81.
Haraway, Donna (1997) *Modest _Witness@Second_Millenium.FemaleMan©_Meets_Onco Mouse™: Feminism and Technoscience* (New York: Routledge).
Hayles, N. Katherine (1999) *How we Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago, IL: University of Chicago Press).
Heath, Christian & Jon Hindmarsh (2000) 'Configuring Action in Objects: From Mutual Space to Media Space', *Mind, Culture and Activity* 7(1/2): 81–104.
Heath, Christian & Jon Hindmarsh (2002) 'Analyzing Interaction Video Ethnography and Situated Conduct', in T. May (ed.), *Qualitative Research in Action* (London: Sage Publications).
Heath, Christian & Dirk vom Lehn (2004) 'Configuring Reception: (Dis-)Regarding the "Spectator" in Museums and Galleries', *Theory, Culture & Society* 2(6): 43–65.
Heidegger, Martin (1962 [1927]) *Being and Time* (New York: Harper).
Hindmarsh, Jon & Christian Heath (2000) 'Embodied Reference: A Study of Deixis in Workplace Interaction', *Journal of Pragmatics* 32: 1855–78.
Hutchins, Edwin & Leysia Palen (1997) 'Constructing Meaning From Space, Gesture, and Talk', In L. Resnick, R. Säljö, C. Pontecorvo & B. Burge (eds), *Discourse, Tools and Reasoning: Essays on Situated Cognition* (New York: Springer-Verlag): 23–40.
Ihde, Don (1990) *Technology and the Lifeworld* (Bloomington, IN: Indiana University Press).
Ishiguro, Hiroshi (2007) 'Scientific Issues Concerning Androids', *International Journal of Robotics Research* 26(1): 105–17.
Jefferson, Gail (2004) 'Glossary of Transcript Symbols with an Introduction', in G.H. Lerner (ed.), *Conversation Analysis: Studies from the First Generation* (New York: John Benjamins): 13–31.
Kiesler, Sara & Pamela Hinds (eds) (2004) '*Introduction to This Special Issue on Human-Robot Interaction*', *Human-Computer Interaction* 19(1/2): 1–8.
Knorr, Karin (1981) *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Oxford: Pergamon Press).
Knorr Cetina, Karin (1999) *Epistemic Cultures: How the Sciences Make Knowledge* (Cambridge, MA: Harvard University Press).
Kuzuoka, Hideaki, Keiichi Yamazaki, Akiko Yamaziki, Jun'ichi Kosaka, Yasuko Suga & Christian Heath (2004) 'Dual Ecologies of Robot as Communication Media: Thoughts on Coordinating Orientations and Projectability', *Proceedings of CHI*: 183–90.
Latour, Bruno (1996) *Aramis: The Love of Technology* (Cambridge, MA: Harvard University Press).
Latour, Bruno & Steve Woolgar (1979) *Laboratory Life: The Social Construction of Scientific Facts* (London and Beverly Hills, CA: Sage Publications).

Lawrence, Christopher & Steven Shapin (eds) (1998) *Science Incarnate: Historical Embodiments of Natural Knowledge* (Chicago, IL: Chicago University Press).
Luff, Paul, Jon Hindmarsh & Christian Heath (eds) (2000) *Workplace Studies: Recovering Work Practice and Informing System Design* (Cambridge: Cambridge University Press).
Luff, Paul, Christian Heath, Hideaki Kuzuoka, Jon Hindmarsh, Keiichi Yamazaki & Shinya Oyama (2003) 'Fractured Ecologies: Creating Environments for Collaboration', *Human-Computer Interaction* 18(1/2): 51–84.
Lynch, Michael (1985) *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory* (London: Routledge & Kegan Paul).
Lynch, Michael (1991) 'Laboratory Space and the Technological Complex: An Investigation of Topical Contextures', *Science in Context* 4(1): 81–109.
Lynch, Michael (1993) *Scientific Practice and Ordinary Action: Ethnomethodology and Social Studies of Science* (New York: Cambridge University Press).
Lynch, Michael & H.M. Collins (1998) 'Introduction: Humans, Animals, and Machines', *Science, Technology, & Human Values* 23(4): 371–83.
MacDorman, Karl & Hiroshi Ishiguro (2006) 'The Uncanny Advantage of Using Androids in Social and Cognitive Science Research', *Interaction Studies* 7(3): 297–337.
Marantz Henig, Robin (2007) 'The Real Transformers', *New York Times* (29 July).
Merleau-Ponty, Maurice (1962 [1945]) *Phenomenology of Perception* (New York: Humanities Press).
Mindell, David (2002) *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (Baltimore, MD: John Hopkins University Press).
Mol, Annemarie (2002) *The Body Multiple: Ontology in Medical Practice* (Durham, NC: Duke University Press).
Mori, Masahiro (1970) 'Bukimi No Tani [The Uncanny Valley]', *Energy* 7(4): 33–35.
Nunez, Rafael & Walter J. Freeman (eds) (1999) *Reclaiming Cognition: The Primacy of Action, Intention and Emotion* (Thorverton: Imprint Academic).
Ochs, Elinor, Patrick Gonzales & Sally Jacoby (1996) '"When I Come Down I'm in a Domain State": Talk, Gesture, and Graphic Representation in the Interpretative Activity of physicists', in E. Ochs, E. Schegloff & S. Thomson (eds), *Interaction and Grammar* (Cambridge: Cambridge University Press): 328–69.
Peirce, Charles S. (1906) 'Prolegomena to an Apology for Pragmaticism', *The Monist* 16: 492–546. Reprinted in P. Weiss, A. Burks & C. Hartshorne (eds), *C.S. Peirce Collected Papers (1931–1958)*, eight volumes (Cambridge: Harvard University Press).
Polanyi, Michael (1958) *Personal Knowledge: Toward a Post-critical Philosophy* (Chicago, IL: University of Chicago Press).
Polanyi, Michael (1959) *The Study of Man* (Chicago, IL: University of Chicago Press).
Prentice, Rachel (2005) 'The Anatomy of a Surgical Simulation', *Social Studies of Science* 35(6): 867–94.
Riskin, Jessica (2003) 'The Defecating Duck, or, The Ambiguous Origins of Artificial Life', *Critical Inquiry* 20(4): 599–633.
Sacks, Harvey (1992) *Lectures on Conversation*, two volumes (Oxford: Blackwell).
Sacks, Harvey, Emanuel Schegloff & Gail Jefferson (1974) 'A Simplest Systematics for the Organization of Turn-taking in Conversation', *Language* 50(4): 695–737.
Scassellati, Brian (2001) 'Investigating Models of Social Development Using a Humanoid Robot', in B. Webb & T. Consi (eds), *Biorobotics* (Cambridge, MA: MIT Press): 145–67.
Schilder, Paul (1950) *The Image and Appearance of the Human Body* (New York: International Universities Press).
Smith, Marquard (ed.) (2007) *Stelarc: The Monograph* (Cambridge, MA: MIT Press).
Suchman, Lucy (2000) 'Embodied Practices of Engineering Work', *Mind, Culture and Activity* 7(1/2): 4–18.
Suchman, Lucy (2007) *Human–Machine Reconfigurations: Plans and Situated Actions*, 2nd expanded edn (New York: Cambridge University Press).
Tanaka, Fumihide, Aaron Cicourel & Javier Movellan (2007) 'Socialization between Toddlers and Robots at an Early Childhood Education Center', *Proceedings of the National Academy of Science* 194(46): 17954–58.

Turkle, Sherry (1995) *Life on the Screen: Identity in the Age of the Internet* (New York, Toronto: Simon & Schuster).

Turkle, Sherry (2006) 'A Nascent Robotics Culture: New Complicities for Companionship', *AAAI* Technical Report Series (July). Available at <http://web.mit.edu/sturkle/www/nascentroboticsculture.pdf> (accessed 8 February 2009).

Turkle, Sherry, Will Taggart & Cory D. Kidd (2006) 'Relational Artifacts with Children and Elders: The Complexities of Cybercompanionship', *Connection Science* 18(4): 347–61.

Vom Lehn, Dirk (2006) 'The Body as Interactive Display: Examining Bodies in a Public Exhibition', *Sociology of Health & Illness* 28(2): 223–51.

Zhao, Shanyang (2006) 'Humanoid Social Robots as Medium of Communication', *New Media Society* 8(3): 401–19.

Morana Alač; is Assistant Professor of Communication at the University of California San Diego, where she is also on the faculty of the Program in Science Studies. She holds doctorate degrees in Semiotics from the University of Bologna and in Cognitive Science from the University of California San Diego.

Address: University of California San Diego, Department of Communication, 9500 Gilman Drive 0503, La Jolla, CA 92093-0503, USA; email alac@ucsd.edu