FURO at Robotworld: Human-robot metacommunication and media studies

Chris Chesher, University of Sydney, School of Letters, Art, and Media

Abstract

Over the next few years, the robotics industry is aspiring to introduce more 'service' robots into shopping centres, hospitals, schools; elderly-care facilities and other public places. But what happens when people come face to face with actual robots? How do they establish and sustain connections with their new autonomous friends? The imaginary representations from science fiction and popular culture are no guide. Interactions with even the most advanced current robots are generally quite rudimentary. Formal studies of Human-Robot Interaction (HRI) are now common in engineering, design and social robotics, seeking technical solutions to enhancing robots' social skills. However, these typically follow instrumental strategies rather than understanding the situated dynamics of interaction. In this paper I ask how approaches in the broad tradition of media studies might help analyse robots as media, and particularly how humans and robots establish the conditions for communication through metacommunication. I will argue that Robot Media Studies *will challenge both robotics and media studies itself.*

Approaching a new robot, people will seek cues to help establish what kinds of relationship they might form with it. Is this a social actor or a machine? What is this body capable of? This inquisitiveness is necessary in processes of 'metacommunication', which Bateson explores in the classic work of cybernetic media psychology and anthropology, Steps to an ecology of mind (1972). Metacommunication is communication about communication. It helps regulate communication between animals, humans, and (I will argue) machines.

Everyday human-to-human interaction is characterised by subtle metacommunicative events that indicate, for instance, that the next message is mimicry; irony; aggression, a cry for help, etc. Sometimes such shifts in the frame of meaning are indicated with verbal codes, such as literally saying, 'Here is a joke…' More often this modulation is signalled through paralanguage and kinesics: tone, volume, movement, facial expressions, and non-verbal codes (Bateson, 1977; 411–425). These situated analogue meanings mainly work to establish a change in relationships (Bateson, 1977; 412).

Metacommunication is not exclusive to humans. Bateson traces the genesis of his work on the metacommunication concept to a visit to Fleishhacker Zoo in San Francisco, where he noticed two young monkeys play-fighting.

> What I encountered at the zoo was a phenomenon well known to everybody: I saw two young monkeys playing, i.e., engaged in an interactive sequence of which the unit actions or signals were similar to but not the same as those of combat. It was evident, even to the human observer, that the sequence as a whole was not combat, and evident to the human observer that to the participant monkeys this was 'not combat'.

> Now, this phenomenon, play, could only occur if the participant organisms were capable of some degree of meta-communication, i.e., of exchanging signals which would carry the message 'this is play' (Bateson, 1972; 179).

The signals that define the monkeys' activity as play, and not combat, are clearly crucial to their interaction. In the same way, when people encounter a service robot, which is designed to establish some kind of relationship with people, there must be some kind of metacommunication to establish the frame of interaction.

Visiting Robotworld

At Robotworld, an annual trade show held near Seoul in South Korea, visitors made their own readings of metacommunicative signals in interacting with the robots on display at each exhibit. They gauged by appearance, discrete features, behaviours, staging, and accompanying information how they might relate to the device. The Samsung security robots, with camera housings and guns, clearly communicated an identity quite different from Yujin's brightly coloured robots for teaching in primary schools. In approaching a robot, visitors might see practical indications, such as that the robot is sensitive to voice, touch or gesture. They might read accompanying text or talk with an attendant. Just as interacting with humans and animals, metacommunication helps establish and refine the 'frames' (Bateson, 1972: 177–193) for ongoing human robot interactions (HRI). A robot frame prepares visitors to encounter not only a gadget or a toy, but also a social actor.

I spent three days observing the visitors, exhibitors and robots at Robotworld in 2010, including several visits to FURO. Therefore, in this paper I concentrate on the Future Robot exhibit, which featured three proudly-appointed life-sized humanoid FURO robots patrolling its perimeter. I also interviewed Future Robot's CEO, Se-Kyeong Song about the robots' features, and the company's goals. After the show, I continued my research by watching many videos, reading brochures and other documentation.

FURO is a hybrid media-robot, combining an embodied robotic humanoid body with computer multimedia screens: one mounted in her back, another for a face, and a large flat screen held in her arms. But she is also a service robot that navigates, and performs robot gestures such as swinging the screen around to attract passersby, and adjusting the screen height to suit the user. At Robotworld, her interactions followed some conventional media frames. She became a mother reading Snow White. She became a hostess offering a game on touch screen. She became a waitress, holding the restaurant menu, which visitors could potentially use to order a meal, and pay with credit card. FURO's successful operation depended upon the visitor's willingness and energies to take up these playful offers. Even visitors with little experience with service robots seemed to have some satisfaction with FURO.

It is likely that over the next decade, service robots like FURO will become more common everyday actors in social and public situations: museums, retail, hospitals, and so on. With new designs, faster processors and more mutual familiarity, the frames and conventions for HRI will develop. Technologies will become more sophisticated, and cultural norms will mature. The multidisciplinary field of HRI has tended to be dominated by engineering and design (Goodrich and A. C. Schultz, 2007). Critical media studies might offer less instrumental approaches, for example, giving a reading of the importance to robotics of productive ambiguities such as irony, camp and humour.

Why Bateson? Towards a Robot Media studies

While Bateson is arguably on the margins of media studies, his critical role as a maverick thinker in early cybernetics, the 'science of communication and control' helped make his work a valuable resource for a critical Media Studies approach to robotics. In the Macy cybernetics conferences in the 1940s–60s, Bateson complicated many of the formalist and empiricist assumptions of mathematicians and hard science, such as advocated by Shannon and McCulloch (Hayles 1999). Bateson re-read the reductive assumptions of some cyberneticians, adding cultural complexity to information theory. For example, in a typical formalist cybernetic analysis, animals and machines are shown to use processes of feedback to correct their actions and maintain the stability of the system, such as in heat regulation. However, these examples do not scale well to account for cultural complexity. Bateson's metacommunication is another feedback system, but it doesn't seek any particular point of stability. Metacommunication disrupts the flow of 'normal' communication, and flags a change – such as an upcoming joke. However, even if a social actor hints that there is a joke coming up, this act doesn't guarantee there will actually be a joke, nor that the interactant will treat it as such. Metacommunication is a powerful force in communication, but quite legitimately, it is highly indeterminate.

Bateson's 'ecological' scholarship connects with many qualitative disciplines: psychology, philosophy, communication, epistemology, linguistics, cybernetics, and media studies. He worked in dialogue with Erving Goffman, sharing concepts such as 'frames' (Goffman, 1997: 153), which are 'guides to interpretation' (Sarangi 1998: 64) to create the conditions for communication. He has had broad influence since: in organisation studies (Morgan, 1997); systems theory media studies (Wark, 2004); philosophy (Deleuze and Guattari, 2004); and media ecology (Fuller, 2005).

Much media scholarship is geared towards the paradigms of traditional communications media, such as newspapers, radio, television, and now the internet. In most ways, robot communication is very different from these media. Researching and conceptualising robotics may be an even greater challenge than that face by internet scholars in the 1990s, or mobile media critics in the 2000s. Returning to Bateson's cybernetic media studies work helps address some of these conceptual challenges. The robot has an ambiguous status as an active agent in communication, rather than a (supposedly) transparent medium that carries the communications of other actors. With robot communications, the medium has a body.

If Media Studies can be translated into a Robot Media Studies, it will need to revisit related traditions that conceptualise mediated communication involving active agents, and not transparent media. These traditions may be represented by Haraway, Suchman, Nass, Latour and Bateson, as follows.

Haraway's (1990, 2007) work in feminist science and technology studies is a good starting point for exploring metacommunication and embodiment in 'companion species'. She demands that everyday relationships between humans, dogs and other species should be granted legitimacy (Haraway, 2007). Her analysis of 'significant other' relationships in animals could well extend to non-living actors. The dynamics of 'becoming with' other species could apply to some relationships between humans and technologies (Jordan, 2011).

One scholar who has focused specifically on robots is Lucy Suchman (2006b). Her anthropological studies found that technology is neither universally viable, nor autonomous. It is always situated in particular sites and relationships. In visiting labs at MIT, Suchman found that the robots Cog

and Kismet did not show the expected capacity to perform as autonomous actors, but required their human operators presence to take on the qualities of dynamic robotic interaction.

> None of our party was successful in eliciting coherent or intelligible behaviours from it… Framed as an autonomously affective entity, Kismet… failed… But… (we can) reframe Kismet… from an unreliable autonomous robot to a collaborative achievement made possible through very particular, reiteratively developed and refined performances' (Suchman, 2006b: 246).

The videos and other support materials for the Sociable Machines projects are more successful than the demonstrations in communicating Kismet's agency. MIT's ethnographic documents present the robots as though they 'have an ongoing existence — that they themselves are robust and repeatable and that like any other living creatures Cog and Kismet's agencies are not only ongoing, but continuing to develop and unfold' (Suchman, 2006a: 238). The videos are not simply external documentations of these robots, but are essential contributors to their successful operation. They are strategic imaginary pedagogical metacommunication, preparing for some future interaction with the robots.

Another different way of reading robots as social actors is in Clifford Nass's studies that show how people already tend to treat machines like humans (Nass et al, 1994). It is quite conventional for people to assume that robots are social actors. Nass's media and social psychology experiments at Stanford measured how people treat media artefacts, images and robots as actual social actors. This work extended upon Reeves and Nass's (1996) 'Media equation' theory, which found that, in many situations, people equated media objects with human actors. If this work is valid, it is almost inevitable that someone confronted with a robot will start by treating it as a social actor. They will look for social cues, and follow cultural conventions about politeness, personal space and so on.

Actor Network Theory (ANT) goes beyond Nass's media equation to consider all actors, human and non-human, as legitimate interactants connected through complex relationships. For ANT, the claim that all actors are equivalent is a strategic ontological flattening. ANT is not an experimental social psychological theory of how people relate to technologies, but a critical ethnographic tradition in science and technology studies. Analysing how FURO becomes a storyteller means analysing how the robot translates the traditional parental performances by offering an integrated collection of new actors – a maternal body, a soothing (synthesised) voice, a book (on screen), and an implied audience of children. It must become a cohesive, but flexible, compound actor that will become mother, hostess, and nurse...

To become this flexible, FURO must become a black box — a stabilised assemblage with discrete inputs and outputs. Unlike Kismet, it must be a robot, not a diverse collection of components constituted only with its operators. The term 'black box' originated in cybernetics. It suggests both a stable technical configuration, and a form of dissimulation that hides the box's contents. Bateson calls a black box 'a conventional agreement between scientists to stop trying to explain things at a certain point' (Bateson 1987: 48). For ANT, a black box consists in composites of actors that become stabilised so they reliably perform as a single actor: 'The assembly of disorderly and unreliable allies is thus slowly turned into something that closely resembles an organised whole. When such a cohesion is obtained we at last have a black box.' (Latour, 1988: 130–131).

FURO's apparent capacity to perform as a black box can be ascribed partly to the choice to return to technically and culturally stabilised technology of three LCD screens, which are mounted in the face, the back, and one held in the robot's hands. The blackboxed robot becomes a social actor, capable of participating in communicative acts. Just as human communication works with signals that shift the registers of meaning, is metacommunication possible for robots, or for animals?

FURO at Robotworld

How can visitors to the Robotworld trade show make sense of this group of black-boxed figures? What should they do when confronted by a FURO? Face to face with a being as unfamiliar as a service robot, visitors tended to improvise throughout the interaction. Most seemed to take into account the surroundings of the exhibit and the exhibition, and drew on past knowledge and previous experiences with artefacts, robots, and other people to inform their tactics for this engagement. Among the most common reactions was hesitant laughter.

FURO's physical design communicates even before she is switched on. She is a full scale humanoid capable of complex movements in the head and neck. Her arms move the screen up and down, and she can bow at the waist. Her profile is a stylised maternal body, with a wide rigid plastic skirt descending from broad hips, and minimal hint of breasts. She communicates with visitors through a combination of modes that attract and communicate: movement, flashing lights and speech. When she senses a visitor's presence, she will adjust the height of the large display screen to suit their stature. The screen presents multimedia content, controlled by a touch screen. In Robotworld, it was unusual for a robot to have a touch screen, but it seemed helpful in securing the meanings of the HRI transactions. Although clumsy, it seemed an appropriate design for the intended public settings such as restaurants, museums and schools.

FURO's appearance draws an implicit metacommunicative framing to promise a social HRI experience, without creating an expectation of a full human-human interaction. Most visitors understand that the robot has relatively limited capacities to sense and interpret what is happening, so the human actor plays the most active role in constructing a nuanced understanding of the particular event. Like Bateson's monkeys, the robot signals that this meeting is a form of play: flashing lights for ears; an animated line-drawn face; and jerky movements of arms, screen and body. The neck is the most articulated part of the robot. Its movement seems to suggest attentiveness and submissiveness. The user plays with the robot, some of the time, as if it were human, while understanding that it is not. This human capacity to deal with ambiguity draws upon a wider set of skills in managing the metacommunicative meanings, which extend beyond play.

Bateson intended 'metacommunication' to be useful in understanding not just play but what might more generally be called 'simulative' activities: deception, threat, and imitation, which occur in many species, as well as satire, sarcasm, and hysteria, which are more distinctly human (Mitchell, 1991: 73) Dealing with FURO is necessarily a 'simulative' activity. Visitors accept that she is an emotional service robot, with a willingness to please fulfilled in hardware and software design. A motor in the hips gives her a respectful bowing motion. She holds out the large screen as an offering to guests, with no capacity to do anything else with her hands. Unlike some robots, such as Hiroshi Ishiguro's Geminoids, FURO's robotic appearance makes no pretence at being a realistic human. This tells users that they should not expect that their interaction would resemble a normal human conversation.

FURO gets emotional

In humans, it is commonly assumed that emotions are outward projections of interior states: if I feel sad, I look sad. Even if I try to hide my feelings, my emotions will betray me. However, performances of human emotion are never simply read-outs of an inside. Expression is conditioned by many factors: the emoting subject's awareness of the context; who is in the room; judgements about which behaviours may influence others; the situated culture and personality of participants. Emotional expression is often feigned, deliberately or unconsciously, to manipulate others (Shouse, 2005). Further, if different people witness the same emotional expression, each may to read performances of sadness, anger or helplessness differently. What some see as sincere, others see as humorous, or overwrought.

It would be possible to design FURO so that her emotions indicated her actual internal states: temperature, electrical interference, memory status, disk fragmentation and so on. Events in software or data could appear as 'emotional' expressions. However, robot emotions are increasingly calculated. They mainly serve as the developer's strategies for managing users. For example, the design of 'emotion interaction systems' (Kwon et al 2007) is an emerging sub-field in robotics that, in the nature of engineering thinking, treats 'emotion' as a problem that can be measured and reproduced.

> The emotion interaction system is composed of the emotion recognition, generation, and expression systems. A user's emotion is recognised by multi-modality, such as voice, dialogue, and touch. The robot's emotion is generated according to a psychological theory about emotion proposed by Ortony, Clore, and Collins. The OCC model focuses on the user's emotional state and the information about environment and the robot itself. The generated emotion is expressed by facial expression, gesture, and the musical sound of the robot (Kwon et al, 351).

Such robot emotion research aims to create robots that sense, model and mimic human affect. Some researchers are prototyping robots that not only recognise user emotional behaviours, but also learn from them (Breazeal, 2009). However, as with all metacommunicative processes, user 'emotion' is too over-determined for any emotion system to control in software. Also, 'emotion' is too narrow as a category to encompass all forms of metacommunication. Robots will be read by diverse users as making explicit and implicit offers and demands of many types: 'come here'; 'watch my screen'; 'press my surface', or 'tip me over'.

The meanings of a robot exceed those of the designer. Future Robot attempted to give FURO welcoming body language. Others attempt to make the robot interpersonally dominant by deliberately positioning it in a favourable location in a room (Kennedy et al, 2009). Others aim to have their robots recognise user behaviours, and learn from their interactions with humans (Breazeal, 2009). However, all these strategies are only viable because communication can work despite multiple contradictory beliefs. Most visitors to Robotworld know that behind these expressions, the robot's interior states are not the same as human subjective experiences. However, knowing this is not a barrier to interacting as though the robot could experience affect. Visitors are willing to suspend disbelief: another metacommunicative move. As Nass et al (1994) discovered, even if visitors know a robot cannot feel emotion, they may still treat them as though they do. Expressions and gestures without substance can still operate as meaningful signals for parasocial interaction, but not necessarily because users are deceived.

The possible meanings for FURO extend beyond her appearance, which is calculated to present visitors with a black-boxed metacommunicative picture of machine servitude. She is laden with meanings associated with class, gender and ethnicity. Her friendly appearance and passive gestures suggest a willingness to serve and a desire to please. This performed submissiveness is more ethically acceptable in a robot than it would be in a person. FURO's face is a stylised graphical animation on a LCD screen, enclosed inside a boxy robot helmet. The head resembles an animated televisual close-up, or even more distantly, a mask or a puppet. Her face is ambiguously cartoon pan-asian, with calm, wide eyes and coloured hair. This non-realistic image uses a visual code that distances the robot from a human face, while carrying the dominant meanings of woman and servant.

While there are many expressive possibilities for FURO, flirting is understated in her design. Her sexuality is minimised, or left out of the ways in which she can communicate. However, in her excessive submissiveness, FURO makes an interesting alternate case in Dixon's (2004) analysis of 'camp', or exaggerated feminine behaviour, in robotic art and performance. He argues that camp is a common theme and style through the history of robots. Since robots inevitably vary from what is conventionally considered 'natural', they tend towards exaggeration, ambiguous sexuality, and behaviour that may even be seen as paradoxical. Camp preens, overacts and shows off, using narcissism to define and express its ontology of difference and to draw attention to itself. It exaggerates physical and vocal expression to be conspicuous or to stand out, the meaning of one of its various etymological origins, the Italian verb *campeggiare.* Its French root, *se camper,* translates as self conscious posturing, while its Indo-European origin, *kamp,* reflects the physical shapes and movements (Dixon, 2004: 23). Camp practices are rich in metacommunicative layering, challenging conventions of normality, and passing as something else. FURO's understated presentation may be read as camp in an inverted way, with her impossible innocence, over-expressive head movements and bowing servility.

When a robot such as FURO presents itself to visitors, the ambiguity in its presentation may be an asset. The capacity for holding multiple, often contradictory metacommunicational signs – it's a machine; it's human-like; it's science fiction; it's a computer; it's a servant; it's a woman supports a diversity of possible interactions. By contrast, the apparent metacommunicative clarity of a perfect simulation may be the fast track to the notorious uncanny valley, where the robot becomes so realistic as to be disturbing or creepy.

Recognition of user's information and intention: Metacommunication from

The company Future Robot makes strong claims about FURO's capacity to act appropriately to a situation. Their brochure implies that FURO is competent in reading metacommunicative shifts. It mentions features such as:

> Recognition of user's information and intention… Circumstantial judgment and creating emotion… Inducing engine for service… Service scenario editing tool according to the customer / situation… Automatic control for display's viewing angle. (Future Robot, 2011).

The company's descriptions of the functions of the robot suggest that FURO has a capacity not only to identify and recognise the users' communication (pressing on the touch screen, voice control), but also to interpret metacommunications such as recognising users' intentions and judging circumstances. Even after allowing for the translation from Korean, these seem to be a strong claims about the robot's capacities for sensing and interpreting.

And yet, much of the metacommunicative work for the proposed FURO installations is performed on behalf of the robot by the ways in which developers stage her social situation in software and choice of physical situation. Some rudimentary emotion sensing, along with touch screen selections, will complement these loaded set-ups. Among the roles that Future Robot identifies in their promotion for FURO is that she can be a 'waitress' at a restaurant. This scenario establishes clear metacommunicative boundaries, and a regular sequence of events. Dining is an over-determined ritual, where the unusual charms of the robot could allow it to substitute for a *maître d'hôtel.* Customers order drinks and food, eat, pay and leave. It seems likely that robots will find their best applications in such situations where they have tightly proscribed metacommunicative roles, following procedures within constrained situations: vacuum cleaning; entertaining; spotting intruders and so on.

Even without sensing the world in complex ways, the metacommunicative cybernetic features of robots could guide the flow of everyday interpersonal interactions, just as traditional media always have. A form on a website structures the user interaction with the site. A well-designed robot behaviour can constrain the interaction through direct communications (instructions) and metacommunications (expressions of disappointment, pleasure etc). In this way, robot metacommunication may be seen as a variation upon conventional techniques in other media to channel user interactions. The white space between columns in newspapers is a metacommunication that constrains the act of reading. In cinema, shot-countershot editing defines movement and relationships of characters over time. The GUI in computer interface design communicates an experiential and cognitive stability before any active communications.

Conclusions

This paper has explored the importance of metacommunication in the asymmetrical interactions between human and robot actors as an example of robot media studies. The black-boxed robot FURO robot performed an ongoing modulation of meanings with Robotworld visitors, adjusting how interactions proceeded from moment to moment. The robot's context, embodied features and programming helped constitute a parasocial event before and as it happened. Visitors often encountered contradictions, ambiguities and uncertainties in this interaction, and in the robot's identity.

The concept of metacommunication is an example of how a Robot Media Studies might address robots as an emerging medium. Metacommunication helps stabilise the interactions between FURO and her visitors without build systems to capture the meanings technically. In the face of a world with always shifting meanings, such as irony, satire and so on, metacommunication supports a tolerance for differences that extended well beyond any robot's capacities to compensate. As with Bateson's disruptive interventions at the Macy conferences, the concept of metacommunication, applied to situated performances of robotics is often open-ended, and capable of handling apparent contradictions. Within the asymmetrical intersubjective dynamics of HRI, there are possibilities for actors to thrive in spite of imperfect and ambiguous communication.

References

Bateson, G., 1972, *Steps to an ecology of mind: Collected essays in Anthropology, Psychiatry, Evolution, and Epistemology,* Ballantine Books, New York

Breazeal, C., 2009, 'Role of expressive behaviour for robots that learn from people', *Philosophical Transactions of the Royal Society B: Biological Sciences,* 364 (1535), pp. 3527–3538

Cottom, D., 1999, 'The Work of Art in the Age of Mechanical Digestion', *Representations,* pp, 52–74

Deleuze, G., Guattari, F., and Massumi, B., 2004, *A thousand plateaus,* Continuum International Publishing Group

Dixon, S., 2004, 'Metal Performance Humanising Robots, Returning to Nature, and Camping About', *TDR/The Drama Review,* 48 (4), pp. 15–46

Fuller, M., 2005, *Media ecologies: Materialist energies in art and technoculture,* The MIT Press, Boston

Goffman, E., Lemert, C. C., and Branaman, A., 1997, *The Goffman Reader*, Wiley-Blackwell, Oxford

Goodrich, M. A. and A. C. Schultz, 2007, 'Human-Robot Interaction: A Survey', *Foundations and Trends in Human-Computer Interaction,* 1 (3), pp. 203–275

Haraway, D. J., 1990, *Simians, Cyborgs, and Women: The Reinvention of Nature,* (1st ed.), Routledge, London

Haraway, D.J., 2007, *When species meet,* University of Minnesota Press, Minneapolis

Hayles, N. K., 1999, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (1st ed.) University Of Chicago Press

Jordan, T., 2011, 'Troubling Companions: Companion Species and the Politics of Inter-relations', *NORA – Nordic Journal of Feminist and Gender Research.* Vol 19, No 4, pp. 264–279

Kwon, D.-S., Kwak, Y. K., Park, J. C., Chung, M. J., Jee, E.-S., Park, K.-S., Kim, H.-R., et al., 2007, 'Emotion Interaction System for a Service Robot', Robot and Human interactive Communication, RO-MAN 2007, The 16th IEEE International Symposium, pp. 351–356

Latour, B., 1988, *Science in Action: How to Follow Scientists and Engineers through Society,* Harvard University Press, Cambridge

Morgan, G., 1997, *Images of organisation,* Sage, London:

Mitchell, R. W., 1991, 'Bateson's concept of "metacommunication" in play', *New ideas in Psychology,* 9, pp. 73–87

Nass, C, Steuer, J., and Tauber, E. R., 1994, 'Computers are Social Actors', presented at CHI 94: Human Factors in Computing Systems, Boston MA, pp. 72–78

Reeves, B. and Nass, C., 1996, *The media equation: How people treat computers, television, and new media like real people and places,* Cambridge University Press/CSLI New York

Sarangi, S., 1998, 'Beyond language, beyond awareness: Metacommunication in instructional settings', *Language Awareness,* Vol 7, Issue 2–3, pp. 63–68

Shouse, E., Dec. 2005) 'Feeling, Emotion, Affect', M*/C Journal,* 8 (6), retrieved 7 March 2012 from http://journal.media-culture.org.au/0512/03-shouse.php

Suchman, L., 2006a, 'Reconfiguring Human-Robot Relations', The 15th IEEE International Symposium on Robot and Human Interactive Communication, ROMAN 2006, pp. 652–654

Suchman, Lucy., 2006b, *Human-Machine Reconfigurations: Plans and Situated Actions,* (2nd ed.), Cambridge University Press

Wark, M., 2004, *A Hacker Manifesto,* Harvard University Press