14 Trying to Be Calm: Ubiquity, Cognitivism, and Embodiment

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In 1995, Mark Weiser and John Seely Brown proposed a "calm," backgrounded technology as a reaction to the laborious and foregrounded nature of 1990s computer systems and the technofetishism exemplified by mid-1990s virtual reality. This chapter traces discursive and technological transitions between the decade of "virtuality" (1990s) and the decade of ubiquity (2000s). It proposes that the notion of virtuality was in part a product of an incomplete technology. It also outlines the role of the cognitivist paradigm in shaping notions of computation and virtuality through the 1990s and draws attention to the increasing importance of discourses of embodiment in both human–computer interaction (HCI) and media arts since the early 1990s. I observe the key role of media artists in proposing and developing new modalities of embodied interaction and distinguish two quite different classes of technology that are often grouped under the rubric *ubiquitous computing*. I argue that the ongoing paradigm shift toward embodied and performative cognitive perspectives is critical to resolving theoretical and (interaction) design challenges inherent in the development of ubiquitous technology.

After Virtuality

I propose that discourses of technological "virtuality" during the 1990s are attributable in large part to the vestigial condition of interface technologies during that decade, a condition that was theoretically supported by the prevailing cogntivism. Computers, in their new roles as interactive multimedia systems, were inadequately supplied with interfaces to the physical world; the previously "normal" roles for computers did not call for such interfaces. This disjunction between comparative sophistication of computational capabilities and the relative paucity of interface capabilities led to the notion of the (computational) virtual and the confused rhetorics of virtuality. In hindsight, we might say that the 1990s furor around the "virtual" was symptomatic of this technological imbalance, that much of the research work and grassroots development of the 1990s was directed at correcting that imbalance, and that the current era of ubiquitous computing evidences the effectiveness of that correction.

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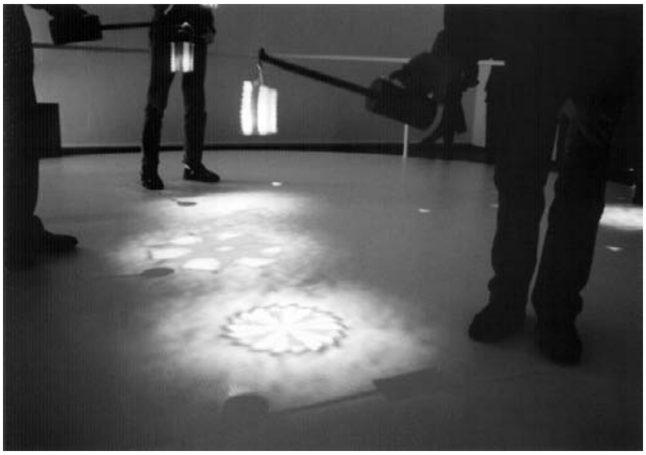

Figure 14.1
Naric Pares, Roc Pares, and Perry Hoberman, *El bal de Fanalet/Lightpools* (1998). This work combined sonar-based tracking and interactive artificial life–based graphics with artifacts derived from Catalan popular culture. Permission kindly granted by Perry Hoberman.

The 1990s saw an explosion of creative research in interactive and immersive art, catalyzed by the increasing availability of domestic and "prosumer" (professional–consumer) computer-based media technologies and fueled by burgeoning rhetorics of cyberculture (see figure 14.1). The realm of the arts was a highly charged vortex for this work as the traditional commitment to material immediacy and finely crafted sensorial effect abruptly confronted a technology framed as abstract immaterial manipulation of information. Over that decade, media-arts practitioners played a key and vigorous role in diagnosing, imagining, and developing interface technologies and new modalities of engagement. Capabilities of real-time interaction and databasing made central the questions of the aesthetics of (hyper)narrative and the embodied experience of the digital. A desire to reconcile the sensibilities of arts practices and the capabilities and constraints of emerging computational media technologies was as important as an exploration of the potential of the new technologies themselves. It was a radically interdisciplinary moment, bringing together artists, computer scientists, critical and media theorists, and others and driven by the traditions of open intellectual inquiry and interdisciplinarity in the arts and by the previous thirty years of "art and technology" practice.

The transition from the period of virtuality to the period of ubiquity was a result of the maturation of interface technologies absent from the technological palette of the 1990s. Since then, various technologies linking the data world with the lived physical world—sensing and tracking technologies (such as Micro Electro-Mechanical Sys-

Figure 14.2
Simon Penny, *Petit Mal—Autonomous Robotic Artwork* (1993–1995). Shown here in the Smile Machines Exhibition (curator Anne-Marie Duguet), Transmediale 2006, Berlin.

tems accelerometers, machine vision, laser scanners, Global Positioning System devices, radio-frequency identification (RFID) tags) and mobile communications technologies —have been developed and deployed (see figure 14.2). This development had the effect of nesting the "virtual" back into the lived physical world, revealing the panic to be focused around an explosive and messy technological transition period.[1] This belated integration of data with the world caused "the virtual" to evaporate. The transition from virtual reality to more nuanced augmented- and mixed-reality modes deploying virtual reality's stock-in-trade tracking and simulation techniques indicates that ubiquitous computing is less the kind of antithesis of virtual reality that Weiser envisaged and more of a continuity.

At the same time that HCI moved out beyond the research lab, human interaction with the world and with technology was addressed more intensively—as is evidenced by the rapid expansion of HCI, computer-supported cooperative work (CSCW), and related areas of research. The study of HCI became increasingly interdisciplinary as psychologists, anthropologists, and sociologists became involved. As recognition of the shortcomings of the cognitivist paradigm became more widespread, new modes of cognitive science grappled with the embodied, enactive, situated, and social dimensions of cognition (Varela, Thompson and Rosch, Suchman, Hutchins). Neuroscience research revealed new dimensions of the mind–body relation (Edelman, Ramachanran, Sacks, and so on). Conventional philosophy of mind has been challenged on these bases by Lakoff and Johnson, Clark, Thompson, and others. This movement met media artists coming the other way, as it were—exploring the application of computational technologies to embodied, material, and situated cultural practices. The crafting of embodied, sensorial experience is a fundamental expertise of the arts, an expertise that is as old as human culture itself.[2] Various topics of critical discourse that had been lumped in with discussion of the virtual have persisted, and it has become clear in particular that many of the aesthetic projects of "media artists" are inherently concerned with the central issues of ubiquity.[3]

Ubiquity: Figure and Ground

Mark Weiser, John Seely Brown, and others made clear their motivations for a "calm technology" that recedes from attention, but the term *ubiquitous computing* is applied to two quite different types of technology. One is industrial and embedded, effectively invisible and accessed by experts. The other is a consumer commodity, very visible and demanding of attention, but nonetheless affording sophisticated data-gathering capabilities to paying customers. Although the two categories have much in common technologically, they are very different in their relation to the social.

Intelligent buildings, augmented spaces, and complex machines as well as communications networks themselves involve distributed and networked "embedded" technologies composed of small, low-power units, in practice invisible, with no (immediate) human interface—no screen, no keyboards (perhaps a light-emitting diode (LED)). These systems have been integrated into existing technologies, edging them a little farther along the mechanically causal–homeostatic–adaptive trajectory, quasi-organisms with digital nervous systems. Cars, planes, refineries, hospitals, bridges, utility infrastructures, seismic fault lines, and national borders are now increasingly digitally instrumented. Engines run a little smoother and cleaner; industrial workplaces have fewer workers and fewer accidents due to human error; illegal immigrants are intercepted more efficiently.

In consumer goods, the obsession with the interface does not seem to have abated; the ecstasy of computation—if not the ecstasy of communication—seems to have become a fixture of popular culture. Although miniaturization and wireless networking have indeed moved "out into the physical world," they have not resulted in "repositioning [computing] in the environmental background" (Ulrik Ekman, introduction to this volume). Rather, the miniaturized but intensified interface, attention demanding and insistent, is foregrounded. Although the technological infrastructure

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(mobile phone reception, etc.) has indeed become ubiquitous, on the level of human experience many technologies reinforce a discontinuity between the data world and the physical world.

Mobile wireless technology has certainly become ubiquitous, but perhaps not in the way Weiser hoped. The words *ubiquitous*, *pervasive*, *embedded* have an ominous ring; they carry negative connotations of an oppressive informational monoculture or monopolistic order, perhaps because of their deployment in military jargon. Although the technical modalities of the technology are novel, the purposes to which they are put retain functions of surveillance and control. It is not just a question of to what ends the technology is deployed and for whom or against whom it is working, but of to whom the systems are visible and to whom they are invisible.

Skeuemorphs Rule, OK?

David Mindell reminds us: "Our computers retain traces of earlier technologies, from telephones and mechanical analogs to directorscopes and tracking to radars" (2002, 321). The physical conformation and functionality of the machine we use is determined by the history of technologies from which it arose. Interactive multimedia, we must recall, is the child of Cold War computing research. The Semi Automatic Ground Environment system put soldiers with keyboards and lightpens in front of monitors to accomplish the complex pattern-recognition functions that the system could not achieve autonomously. This constellation of technologies was the model for the keyboard–mouse–monitor paradigm. The fact that this harnessing of flesh to machine was later clad in the rhetoric of liberation in the heyday of interactive multimedia remains deeply ironic.

Why did the computer, which once was a basement-size machine staffed by attendants, morph into a desktop machine? The historical answer is that it was applied to the kinds of tasks that people who sit at desks do when sitting at desks. The desktop computer was functionally an enhanced typewriter and calculator with added filing-cabinet functionality. It follows then that it is particularly useful and relevant for activities that resemble office desk activities, such as record management, accountancy, and letter writing but is decreasingly appropriate for activities whose social and architectural placement diverges from that scenario. Many human activities, including cultural and art-making activities, do not resemble office work in their physical contexts, methodologies, or goals.

For the past generation, we have managed with computer technology that, for all its touted user-friendliness, has continued to demand that we preprocess our thoughts and experiences into a kind of keystroke mush that is easily amenable to these machines' limited *a–d* capability. If we are to pursue the fundamental goals of Weiser's ubiquity, it means developing computational technology past the stage that we and it appear to have got codependently stuck in—tolerating a technology that must be spoon fed with little alphanumeric streams. After thirty years of personal computing, I mercifully no longer have to put myself in work position at my workstation, from which I could not move even a few feet without breaking my connection with the machine by losing contact with screen and keyboard. But why, having finally freed ourselves from the bondage of the desktop, do we tolerate having to poke unidigitally at a miniature QWERTY on our mobile devices? What a profound failure of imagination!

Trying to Be Calm

There is a significant difference between enhancing the control systems of existing machine complexes and the enmeshing of computational processes with human cultural and biological processes. I have distinguished between, on the one hand, clandestine, faceless technologies that involve distributed units in a larger control array that itself is embedded in a larger machine complex and, on the other hand, garrulous, clingy technologies close to the body. Neither of these technologies seems particularly *calm*. Beyond embedded miniaturization (microcontrollers), location (tracking), and transmission (Internet and wireless communication), how far have we come along the trajectory to *calmness*? Is automated processing of logical operations necessarily applicable and an asset in every aspect of life? Are there aspects of our lives where digital intrusion might be utterly undesirable? (Do I need "blueteeth" that notify my dentist directly when they sense decay? Probably not. I certainly don't feel the need for pop-up ads on the periphery of my vision when I'm wearing my sunglasses.) To ask this question is to challenge the marketing rhetoric of the computer industry, to challenge the assumption of the desirability of the intrusion of computation everywhere: that automated processing of logical operations is necessarily applicable and an asset in every aspect of life. Computation is not value-free cognitive bedrock. There is nothing "neutral" about the culture of computation, even if we are naturalized to it.

Although such issues are not necessarily foregrounded in everyday use of consumer devices, we should review the aspirations of ubiquitous computing and its current implementations and consider the desirability of the current trajectory. In what more or less subtle or insidious ways does the bending of human activities to the needs of a not entirely calm technology stain or perturb the richness of those practices? I am thinking here of skilled embodied practices in particular—practices that have developed organically over generations, subtly adapted to the complex richness of human formation, where artifacts have coevolved in ways that adapt and optimize subtleties of human sensorimotoric capabilities, which may never have been nor have had to be made explicit. Consider two examples, one high, one low: the culture of the violin and the culture of the household kitchen. What makes a Stradivarius so much more of a violin than a cigar box with a rubber band stretched over it? The special quality of such an instrument is that it has been formed through an extended period of interplay between artisans and players. A history of coevolution between the material specificities of the artifact and the repertoire, an increasingly refined attunement between the embodied intelligences of the artisan and the musician. A kitchen likewise evolves as a workplace through use—chains of intuitive design tweaks—a subtle interplay between the ingredients, artifacts, and procedures of specific cuisines, spatial layouts, and its users physical capabilities.

In such contexts, the application of digital technologies almost always has the effect of "thinning out" the experience in question, and this effect is due in part to a preoccupation with problem solving on the symbolic plane and the ensuing elision of the situated, embodied action. This syndrome maps onto imperatives of computer engineering—modularity/reductivism, standardization/generality, optimality/efficiency—and instrumentality in general. These criteria are valid in their "home territory"—I want my laptop battery to have maximum life, I want my file to be compatible, I do not want anyone taking aesthetic liberties with the shape of an airplane wing. But the validity of these criteria wanes as they are applied in territories farther from home. Optimization of *King Lear* or Beethoven's Fifth by elimination of redundancy is an inherently ludicrous proposition.

The Profundity of Material Being

The term *human factors* speaks volumes about the engineering mindset—as if the qualities of human embodiment were peripheral "implementation details." This view is veiled cognitivism in the sense that thinking is conceived of as abstract symbol manipulation and is taken to be an end in itself rather than part of the process of ongoing lived being. Combined with a rather Victorian characterization of human perception and action and inflected with dualism, serial processing (input–output) and cognitivism inform much computational thinking. The crisis of the cognitivist model (heralded ironically by the faltering of artificial intelligence) led to renewed attention to embodied, situated, and material aspects of cognition. This new cognitive science is immediately relevant to the still-vexed "human factors" aspect of ubiquitous computing precisely because it addresses aspects of human experience pertinent to the development of richer and more subtle, if not calmer, technologies of interaction.

Escape from the cognitivist cul-de-sac demands a wholesale paradigm shift and a new set of axiomatic assumptions: mind and body are not separate or separable; "self and world" is likewise an invidious distinction; intelligence is making sense of the world; thinking occurs at the fingertips and in the soles of the feet, in the process of interaction with the world. Calm, embedded, context-aware technology implies a phenomenological understanding of being-in-the-world or, rather, of a performative "doing-in-the- world," of situated sensorimotor action. To come to understand the emergence of meaning through a temporal process of bodily interaction with things and people in the world is to engage what Andy Pickering (1995) has called "the mangle of practice." In his book so titled, Pickering captures a key aspect of the paradigm shift I am arguing for in his distinction between what he calls the "representational idiom" and the "performative idiom." In these terms, the cognitivist paradigm is firmly rooted in the representational idiom. I propose that the pursuit of ubiquity demands a postcognitivist approach attending to embodiment, to the performative relation to artifacts and the world, and to the relation of cognition to social and cultural formations. In the next section, I give an introduction to such perspectives via a discussion of the work of Edwin Hutchins.

Cognition Distributed and Embodied

In 1995, Edwin Hutchins published a remarkable work of interdisciplinary scholarship that combined anthropological fieldwork with cognitive science and computational theory. He analyzed the group activity of navigation on a ship's bridge as a case of "distributed cognition," in which a group of people performing specific roles, communicating with each other in specific ways, and using a highly developed set of tools perform computational tasks. In a more recent paper, "Imagining the Cognitive Life of Things," Hutchins makes some remarkable observations on cognition in the wild, which warrant quotation at length:

> In the last chapter of *Cognition in the Wild* . . . I argue that cognitive science made a fundamental category error when it mistook the properties of a person in interaction with a social and material world for the cognitive properties of whatever is inside the person. One enduring problem with this claim is that it demands a description of how cognitive properties arise from the interaction of person with social and material world. *Cognition in the Wild* provides a profoundly incomplete answer to this question. . . . For the most part, the cognitive processes described in *Cognition in the Wild*, and in other treatments of distributed cognition, are presented without reference to the role of the body in thinking. That is, in spite of the fact that distributed cognition claims that the interaction of people with things is a central phenomenon of cognition, the approach has remained oddly disembodied. (2010)

I want to dwell on Hutchins's laudable self-criticism because it is a useful example of the slow process of denaturalizing axiomatic assumptions (in general and in cognitive science) and is exemplary of the paradigm shift occurring in cognitive studies. *Cognition in the Wild* (Hutchins 1995) can be read as an attempt to recuperate a functioning and historically coherent system to computationalism. As Philip Agre puts it, "A computer . . . does not simply have an instrumental use in a given site of practice; the computer is frequently about that site in its very design. In this sense computing has been constituted as a kind of imperialism; it aims to reinvent virtually every other site of practice in its own image" (1997, 131). When Hutchins translates one activity into the terms of another, explaining navigation in terms of computation, the authority of this translation is given by the (presumed) authority of the discourse of computation. The ship crew's ability, their training and process, their tools and artifacts were demonstrably effective long before computational explanation—recall that the expressed purpose of Babbage's difference engine was to calculate tide tables for the British navy—aids to precisely the kind of navigation Hutchins observed.[4]

In what way and for whom did *Cognition in the Wild* "explain" the procedures of coastal navigation, or, to put it another way, what is the power of the computational explanation? An unreconstructed computational explanation would necessarily explain observed phenomena in functionalist terms (Putnam 1967, since recanted). Functionalism asserts that a mental state is constituted by the causal relations that it bears to sensory inputs, behavioral outputs, and other mental states. Cognitivism is just one (computational) version of functionalism. Functionalism has a rather industrial if not von Neumannesque cast in its reliance on the idea of serial processing, inputs, and outputs.[5] The cognitivism of *Cognition in the Wild* is more nuanced. Cognition, for Hutchins, is embedded in artifacts and practices and is shared among actors, but it is still understood as computation. As cognitive science reaches out farther and farther into cultural realms where computation is an increasingly alien concept, distinctions between technical and popular usages become increasingly hazy, and the imperializing project of computer culture insidiously persists.[6]

Hutchins recognizes that "interactions between the body and cultural artifacts constitute an important form of thinking. These interactions are not taken as 'indications' of invisible mental processes, rather they are taken as the thinking processes themselves" (2010) are reminiscent of remarks made by Hubert Dreyfus many years earlier in his phenomenological critique of artificial intelligence: "My personal plans and my memories are inscribed in the things around me just as are the public goals of men in general" (1992, 266). John Sutton has similarly noted more recently that "thought is not an inner realm behind practical skill, but itself an intrinsic and worldly aspect of real-time engagement with the tricky material and social world" (2008, 50). To permit that bodily motion may constitute the medium of thinking is a radical assertion for a rehabilitated cognitivist but will come as no surprise to the dancer or practitioner of martial arts or to any thoughtful person who does rock climbing or hangs out the laundry. But we must not underestimate the profundity of this sea change in cognitive science; it indicates a hard-won emancipation from naturalization to the tenets of artificial intelligence. Philip Agre lucidly documents his own such emancipation. He credits his reading of Michel Foucault's *The Archeology of Knowledge* specifically and poststructural writing generally as an epiphany: "They were utterly practical instruments by which I first became able to think clearly and to comprehend ideas that had not been hollowed out through the false precision of formalism" (1997, 148–149).

It is precisely this "false precision of formalism" that hollows out embodied knowledge. As Aldous Huxley observed long ago, "In a world where education is predominantly verbal, highly educated people find it all but impossible to pay serious attention to anything but words and notions" (1954, quoted in Pickering 2008). Numerous students of embodied cognition, from Michael Polyani to Evan Thompson, have stated what practitioners and teachers of embodied cultures have always known: the skills of bodily know-how are notoriously hard to document; such thinking is inherently nontextual and nonintersecting with textual representation and text-based reasoning. Dreyfus, after Polyani, refers to such knowledge as "muscular gestalts" (1992, 249). John Sutton notes in regard to the potter's skill: "Because this kind of expertise relies on an immense reservoir of practical skill memory, embodied somehow in the fibres and in the sedimented ability to sequence technical gestures appropriately, verbal descriptions of it (by either actors or observers) will be inadequate. . . . [W]hat the expert remembers is in large part consciously inaccessible as well as linguistically inarticulable" (2008, 49). Agre expresses the complementary point when he observes that computational fields "concentrate on the aspects of representation that writing normally captures. As a result, theories will naturally tend to lean on distinctions that writing captures and not on the many distinctions that it doesn't" (2003, 290). It is precisely this discontinuity that creates a deep tension in the modern academy between the pedagogy of the textuosymbolic regime, on the one hand, and the pedagogy of the arts and other embodied practices, on the other—accounting for the failure of interdisciplinarity noted earlier.

Such (embodied) thinking is not computational in the usual sense, so any attempt to recuperate it to the world of computation has to force it through several transmogrifications to fit a linear, atemporal, Boolean mode of representation. The framing of group performance on a ship's navigation bridge as distributed computation in a computational–cognitivist worldview was a tour de force by Hutchins. Yet, as he himself notes, the bodily dimensions of thinking rendered such analysis irrelevant or invisible:

> The processes that underlie the "Aha!" insight remain invisible to a computational perspective in part because that perspective represents everything in a single mono-modal (or even a-modal) system. A careful examination of the way the body engages the tools in the setting, however, helps solve the mystery of how the discovery was made, and why it happened when it did. The insight was achieved in and emerged out of the navigators bodily engagement with the tool. (2010)[7]

Hutchins comes close to Mark Johnson's (19890 work and also to Johnson's work with George Lakoff (Johnson and Lakoff 1999) regarding the origins of abstract concepts in embodied experience when he notes: "Motion in space acquires conceptual meaning and reasoning can be performed by moving the body" (2010). Here is revealed a fundamental cognitive cauterization among all but the most sensitively designed interfaces and interactive systems—a situation that has beleaguered digital-arts practices: they ignore and erase bodily engagement of the sort that complements material artifacts and tools developed over years or generations and, taken together, facilitate bodily reasoning. The navigator's hoey, the engineer's slide rule, the machinist's caliper, the carpenter's square are amenable to computational explanation because (loosely) what is involved is a relatively simple translation of geometry to algebra. The painter's brush, the violinist's bow, the harvester's scythe, and so many other artifacts are complex and sophisticated devices for thinking with because they have evolved in a deep structural coupling with the basic rhythms and modalities of neural circuits and sensorimotor loops. They are prosthetics that integrate with the user at a deep and more organic level precisely because they do not involve a translation into and out of mathematicological computation. On the subject of artifacts, Hutchins notes: "By interacting with particular kinds of cultural things, we can produce complex cognitive accomplishments while employing simple cognitive processes" (2010).[8] Aspects of the environment are deployed as off-board memory, and, consistent with Hutchins's notion of distributed cognition, computation is offloaded, too.

But in framing the situation in this way, are we not reinstating precisely the computationalist bifurcations we sought to avoid? Not simply of storage and processing, but of the world and representation? Lambros Malafouris asserts that it makes little sense to speak of one system's representing the other: "Although we may be well able to construct a mental representation of anything in the world, the efficacy of material culture in the cognitive system lies primarily in the fact that it makes it possible for the mind to operate without having to do so, ie, to think through things, in action, without the need of mental representation" (2004, 58). Micronesian canoeists gather knowledge about undersea geography colloquially "through the seat of their pants" (if they're wearing any), but more accurately through a subtle integration of proprioceptive and vestibular cues related to the movement of their craft (canoe, catamaran) as a prosthetic extension of their embodiment. Hutchins goes on rightly to observe: "From the perspective of formal representation of the task, the means by which the tools are manipulated by the body appear as mere implementation details" (2010).[9]

The phrase "implementation details" tells the score before the game begins. It belies a commitment to dualism that will automatically render invisible or irrelevant aspects of embodiment. Explanation of a group human activity in terms of computation will inevitably render invisible the significance of embodied practice because the irrelevance of embodiment is axiomatic to the rationale of the discipline. *Implementation details* is a phrase that stands in for an entire corpus of disciplinary rationalizations to justify the disembodiment of artificial intelligence, as first articulated by Herbert

Simon: "Instead of trying to consider the 'whole man,' fully equipped with glands and viscera, I should like to limit my discussion to Homo Sapiens, 'thinking man'" ([1968] 1969, 65). This arbitrary and convenient "limit" in the "root document" of cognitivism is a veritable Pandora's box that permitted the excision of embodied situated materiality from artificial intelligence and cognitive science for a generation. The devil is not so much in the (implementation) details as in the desire to ignore them. *Implementation details* cannot be swept under the rug. Like *human factors*, this term has allowed technical community to sidestep the overarching importance of human culture—engagement of which would of course demand a challenging interdisciplinarity that always has the awkward potential of destabilizing axiomatic assumptions.[10]

Conclusion

Two decades ago, at the emergence of the "reactive robotics" movement, Rodney Brooks critiqued the reigning representationalism in his pithy assertion that "the world is its own best model" (1991, 15), a sentiment that was sympathetic to emerging paradigms of embodied, situated, and distributed cognition and to Dreyfus's phenomenological critique of artificial intelligence. By virtue of evolutionary selection, there is direct cognitive correlation between the world and the bodily experience of it. This correlation results in a kind of (performative) knowledge and (non)cogitation irreconcilable with the cogntivist "physical symbol system hypothesis."[11] But it is this embodied, situated knowledge that provides the basis for precisely such cogitation as well as for introspection.[12] It is the lived solution to the symbol grounding problem (Harnad 1990). This double—that the world is its own best model and that there is direct (non) cognitive correlation between the world and the bodily experience of it—is the core of the postcognitivist position. It is a true paradigm shift that must be thoroughly internalized if real progress is to be made in the development of "calm" technology.

The period in which (ubiquitous/consumer/computer/digital) technology could be (and needed to be) developed in vacuo, in the lab, is resoundingly over. This technology must now be considered for what it demonstrably is: an integrated component of social and cultural fabric, just like automobiles and telephones. In my opinion, a rigorous engagement of postcognitive perspectives offers the prospect of new approaches to "calmness," context awareness, and other murky "human factors that have to date stymied the project of ubiquity.

Notes

1. Many theorists have deployed the term *virtuality* in rather abstract ways—for instance, Brian Massumi (2002). In my discussion here, I stay close to practices of interaction with sensor and data-driven technological systems.

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2. It is a telling and persistent failure of interdisciplinarity—directly pertinent to the development of ubiquitous computing—that although media artists were at forefront of such research, the two communities had limited connection.

3. As Merlin Donald argues, this "mimetic" intelligence is fundamental to human culture, and much cutting-edge research was done by artists in this period. Certain initiatives stand out as beacons through the 1990s—such as the artist-in-residence program at the Xerox Palo Alto Research Center, the Ars Electronica Futurelab, V2 in Rotterdam, ZKM, the Banff New Media Institute, the Australian Network for Art and Technology, and, more recently, Intel Labs.

4. To claim navigation on the deck of a ship at sea in the name of cognitivism is in this way analogous to Columbus's claiming Hispaniola in the name of the queen of Spain while rather obstinately ignoring the obvious fact that the land was already claimed, named, and occupied.

5. There are, of course, theories of cognition that dispute not simply such seriality, but the very existence of "inputs" and "outputs" as phenomena in the organism (as opposed to representations imposed by the observer)—for instance, the autopoietic theory of Humberto Maturana and Francisco Varela (1980) or the second-order cybernetics of Heinz von Foerster (2002).

6. A phenomenon I have referred to elsewhere as a Trojan Horse effect; see Penny 2008b.

7. Navigators talk of "thinking like a compass." Hutchins notes, "The bodily anticipation of clockwise rotation becomes a somatic anchor for the concept of increasing bearing number value" (2010, 445)—that is, a clockwise bodily twist corresponds to increasing numerical value.

8. This statement is akin to any of a number of approaches in philosophy of mind and cognitive archaeology that talk of offloading memory or computation or both onto a structured environment, such as Andy Clark and David Chambers's (1998) extended-mind hypothesis, Merlin Donald's (1991) exograms, and David Kirsh and Paul Maglio's (1995) epistemic actions.

9. Philip Agre makes a similar argument: "A theory of cognition based on formal reason works best with objects of cognition whose attributes and relationships can be completely characterized in formal terms" (1997, 143). In the study of material culture, little can be "completely characterized in formal terms."

10. This reticence is understandable in terms of the construction of the technical disciplines and academia in general. Interdisciplinarity in such contexts is generally meek and unadventurous precisely because of the fear of moving beyond one's own valorized and specialized expertise (see Penny 2008a). That is not to say that innovative efforts have not been made in some quarters—the humanistic informatics movement arising in Scandinavia in the 1990s and some aspects of what is referred to as "digital humanities" in the United States and elsewhere. The Informatics Department at the University of California, Irvine, is notable within schools of computer science in the United States for its openness to perspectives from anthropology and sociology.

11. "A physical symbol system has the necessary and sufficient means for general intelligent action" (Newell and Simon 1976, 116).

12. This idea is related to the notion of the "cognitive unconscious" as developed by Johnson and Lakoff in *Philosophy in the Flesh* (1999).

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