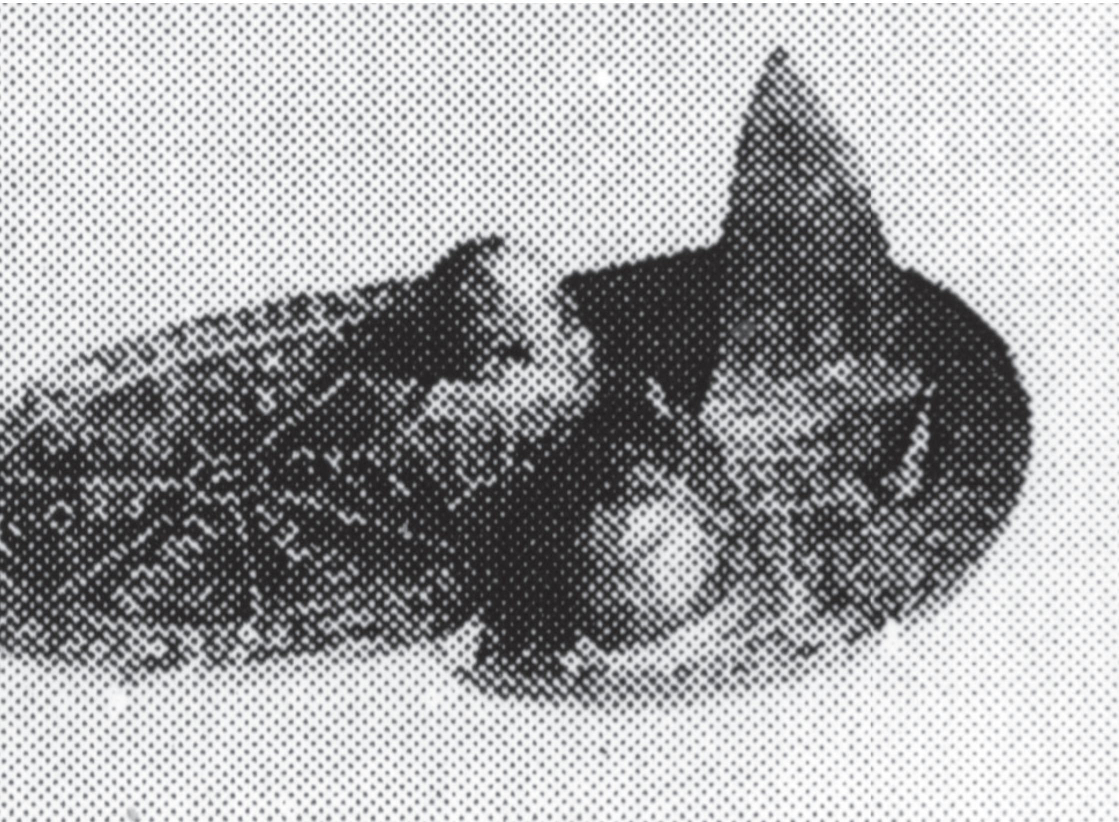
Cognitive, Embodied or Enacted? Contemporary Perspectives for HCI and Interaction

Marcio Rocha



Transtechnology Research • Reader 2011
Plymouth University
Portland Square, Drake Circus
Plymouth PL4 8AA
United Kingdom

ISBN 978-0-9538332-2-1

Cognitive, Embodied or Enacted?
Contemporary Perspectives for HCI and Interaction

Marcio Rocha
marcio.alvesdarocha@plymouth.ac.uk

Abstract

The argument discussed in this paper presents the following movements: first, it presents a brief history of cognitive science and human-computer interaction, raising some considerations arising from the interaction between these two disciplines. Basically the argument here suggests that HCI is still based on the vision known as first-generation cognitive science, where it is still possible to observe how human beings are seen as information processing, treating the act of thinking as an act which is purely computational, neglecting the complexity involved as well as the complexity of human experience. Then it will present the concepts of *embodiment* and *enaction* as a more externalist vision of cognitive science and philosophy of mind, introducing concepts such as new prospects for the paradigm of interaction. The effort of this paper will be to look for ways to understand how we can translate and apply Embodiment and Enaction in order to improve human-computer-interaction and consequently the interaction design practices.

Historical Paradigms of Cognitive Sciences and HCI

The cognitive sciences, as the study of mind and intelligence, provided by its interdisciplinary condition subsidise various fields of research, understanding how the mind works is important for several human activities, including Human-Computer Interaction (HCI) which traditionally is concerned with the design, evaluation and implementation of interactive computing systems for human use, and with the study of the major phenomena surrounding them.

The field of Human-Computer Interaction has traditionally been responsible for making our interactions with technology more friendly and natural, smoothing this relationship using methods and approximation techniques, however with frequently emphasis on technology and in consequence, a timid humanistic focus. Much of what is known about Human-Computer-Interaction is based on the archaic notion of computation within cognitive science, which maintained that people behave as information processors and that the process of thinking is very similar to the process of computing, know as the first-generation of cognitive sciences. Much of this thinking was based upon the ideas of Alan Turing, his Turing machine and later, the Turing test [1] and Claude Shannon in 1937 from his master's thesis *A Symbolic Analysis of Relay and Switching Circuits*, which later contributed to the origin of information theory.

Gradually, however, there have been some advances in the thinking that people and computers are not similar and that the thought process would be much more complex than just processing of raw data. An example of this argument known as John Searle's Chinese Room [2] (John Searle, 1980) refuted the idea that the mental process was similar to computing. Even if a computer simulated behaviour or an intelligent dialogue, which did not necessarily mean it is able to 'think'. As such, Searle maintained that Humans, in turn, more than manipulating symbols, think about the symbols that are being manipulated, operating them syntaxically and semantically a much more dynamic and complex process than the computional models can sustain.

Much later, still in the same spirit that boosted this time, some methods were developed to equalise the user interactions with the computer in an attempt to reduce the perceived friction between them (Card, Moran and Newell, 1983). These actions, classified as physical, cognitive or perceptual actions, served to develop techniques that provide valuable information for the study of interfaces. However these still had some drawbacks for they did not consider how human beings can be affected by different factors such as fatigue, their individual degree of disability, physical limitations, habits, personalities, or the level of experience of users and the social environment in which they belong.

This focus on usability, inherent within these approaches, also downplayed the functionality of the system, based on a system of rules, which are invariably, complex and difficult to adapt. The inclusion of the use of *personas* and different techniques that consider the individuality of the users became more specifically focused on humans and their human conditions, but were still far from a definitive resolution. The field then began to integrate different disciplines and while proposing more inclusive methods, the central tendency of HCI has been essentially simplified. The way of simplification suggests a lucid way, with many prepositions that come from Information Theory. It is not only to reduce errors, but also to convey information more effectively. In contrast, the word 'simplify' suggests that despite advances in understanding the methods, paradoxically, a human is still being seen as an information processor, who needs to have their actions shaped; steps and mouse clicks calculated, in order to avoid human memory to be overloaded with dates to remember and which needs to be constantly warned about its own actions and errors. Many of these techniques were applied with the use of constraints and direct manipulation provided by the Graphical User Interfaces (GUI).

The advent of graphical interfaces has helped popularise the personal computer driving the integration between man and computer, expanding the access previously restricted to scientists, programmers and technical expertise, generating a field full of researchers interested in computer interfaces (reference). In fact much has been said about interfaces, but little has been done to penetrate the human side of interface. The democratisation afforded by the advent of personal computers and computer interfaces transformed the computer into something more popular, but our interaction with technology has not become less complicated and less obscure. The same interface that supposedly translates the computer and makes it intelligible to most of us, often divides man and machine instead of bringing them together. By separating the surface structure, much of the meaning between the physical and the 'virtual' world is lost and sometimes the interface does not reflect all real potential and possibilities of the software.

The cognitive sciences have travelled this path to make our relationship with technology more natural, but still seems to be insufficient to deal with the problem of interaction in a broader aspect. The human being endowed with biological bodies, emotions, consciousness, free will and subject to all complexity of environmental conditions has many times been demonstrated unable to understand this new digital repertoire that has become increasingly complex over the years. Supposedly, the way we reflect on and produce knowledge about ourselves, is not to follow the speed and dynamics involved in this relationship. Technology itself is responsible for making some aspects more faster and for extending some human capabilities as well. Therefore, this process of reflection about ourselves, determined by the dissonance between the nature of our self-reflection and by the ecology of new products in a faster technological expansion seems to be slower in some way.

Some evidence indicates that the human ability to deal with information supported with technology has progressed. When using automation, video surveillance and control, computers demonstrate to be more effective in many tasks than humans. A game of chess for example, became a classic for some scientists to test the capability of their computers, in order to compare with human capabilities or just to understand the dynamics envolved and can be traced in some research with (Shannon, 1950), (Levy and Newborn, 1991), (Hsu, 2002) and (Lasar, 2011) among others. For a computer it is very simple to "play" chess, even though for a human being it is considered to be a somewhat difficult task to play at a high level. Using the computer will calculate the gross and massive processing power operating mathematical simulations of likely movements, but it still is far from 'playing' chess in a more human use of the term. The computer will calculate and predict the movements of the pieces on the board, but it is still far from understanding all the dynamics that are involved in a game of chess in an amplified sense, as well as from predicting the actions of its human opponent. Computer software will merely manipulate symbols, operate mathematical functions, calculate probabilities, whereas the human mind constructs meaning from the game. The computer competency in a mathematical matrix ends by the limits imposed by the board, the possibilities of game pieces, as well as the movement of parts available. This expertise seems more related to computing capacity and processing power, but humans have particular competencies to do things considered more complex, such as learning, understanding poetry, interpreting a text and appreciate the arts.

As the literature has shown, to predict human actions has often proved to be a complex activity, and recent history makes us believe that there are areas of problems in which humans can attain knowledge, but are not formally computable. The conclusion is that knowing the biological roots behind human actions seems to be one way to understand people's interactions with digital technologies. Many researchers, such as Paul Dourish (2001) and Malcolm McCullough (2004), have worked on topics they consider this closest approach considering our embodied mind, emphasising how the concepts are socially constructed and how cognition is distributed contextually (Hutchins, 1995). Although not essentially new fields, research in this area indicates a shift towards the recognition of a plurality of new perspectives.

Embodiment and Enaction Perpectives

There are, however, other notions of human cognition, which figure in the histories of both computer science and cognitive science. Contemporary accounts of human cognition within the cognitive sciences depart from the computational views of old to address an 'externalist' view held amongst cognitive scientists and philosophers, primarily concerning the theory of Embodiment and Enaction. Such works depart from the computational models through the phenomenological enquiries of Husserl and Merleau-Ponty, updated by philosophers and scientists such as Clark (1997), Varela *et al.* (1991), Sheets-Johnstone (1990, 1999), Thompson and Varela (2001), Wheeler (2005), and Thompson (2007) amongst others.

The concept of Embodiment is based on the premise that the body is linked directly to thought and subsequently to understanding, and that cognitive processes are intrinsically connected to the body:

> According to the embodied perspective, cognition is situated in the interaction of body and world, dynamic bodily process such a motor activity can be part of reasoning process, and offline cognition is body-based too. Finally embodiment assumes that cognition evolved for action, and because of this, perception and action are not separate systems, but are inextricably linked to each other and to cognition. This last idea is a near relative to the core idea of enaction (Hutchins, 2010, p. 428).

In addition, Enaction is the notion that our worldly experience is created through the body shaped by our actions:

> Embodiment and enaction are names for two approaches that strive for a new understanding of the nature of human cognition by taking seriously the fact that humans are biological creatures. Neither approach is yet well defined, but both provide some useful analytic tools for understanding real-world cognition. […] Enaction is the idea that organisms create their own experience through their actions. Organisms are not passive receivers of input from the environment, but are actors in the environment such that what they experience is shaped by how they act (Hutchins, 2010, p. 428).

Both concepts remain provocative within the literature of cognitive science to the extent that, although promising, they are not completely elucidated. However, these two assumptions provide a platform in which the body can be understood not as a passive receiver of environmental input but as having an active role in the environment in which experiences are shaped by bodily actions. Such an account implies that human learning process of cognition is not only connected with bodily doing but also especially connected with a real world experienced.

Despite their provocative nature, it is curious to note, as in the following examples, how we are easily inclined to agree with these two assumptions drawn from embodiment. Consider the following thought experiment. When someone is shown a new object, they are often inclined to want to touch and feel the object. Almost instantly and sometimes preemptively, the person showing the object tells the person looking at it, rather humourously: please, look at it with your eyes and not with your hands! Where only looking seems insufficient, it seems necessary to pick up and to feel the object. This everyday story, though simplistic, illustrates a condition rooted within human nature which suggests how interacting with objects is mediated not only by the biological body, but also by interactions themselves rest upon embodied perception. The perception of incompleteness is emphasised when the object is not touched. This seems like an indication of human bodies not only being just passive receiver of information, but avid reactors to their experience, which includes a sensory-motor that has a predilection for acting with the environment. That might be the way in which biological bodies have found to connect more naturally to the world around them, adapt to it, be transformed and shaped by it, supporting a cognitive perspective *embodied* in large part to the human process of thinking and learning resulted by human experience and rejecting the traditional view of computation over representations, emphasizing *embodied action* as a more appropriate term.

> By using the term *embodied* we mean to highlight two points: first that cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context. By using the term *action* we mean to emphasize once again that sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition. (Varela *et al*., 1991, p. 173).

Another example that illustrates the embodied nature of experience is the interaction with an application on a computer. At one point of the interaction (assuming this is an application that allows this relative immersion), the user forget that a mouse or keyboard is present and being manipulated, as they are absorb into the content or task accomplished, as Andy Clark (2003):

> The accomplished writer, armed with pen and paper, usually pays no heed to the pen and paper tools while attempting to create an essay or a poem. They have become transparent equipment, tools whose use and functioning have become so deeply dovetailed to the biological system that there is a very real sense in which—while they are up and running—the problem-solving system just is the composite of the biological system and these non-biological tools. The artist's sketch pad and the blind person's cane can come to function as transparent equipment, as may certain well-used and well-integrated items of higher technology, a teenager's cell phone perhaps. Sports equipment and musical instruments often fall into the same broad category (Clark, 2003, p. 38).

Another often used example is that of a blind man with a walking stick, which assists him in the process of cognition and integrates him in his environment, (as initially described by Head (1920)). As Merleau-Ponty describes:

> The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight (1962, p. 143).

Clark also emphasises the process by which we become able to integrate these tools in arguing that we are not born with the necessary skills, but biological organisms are shaped to interact with these tools, with different difficulty layers of apprehension in order to integrate with our bodies:

> Often, such integration and ease of use require training and practice. We are not born in command of the skills required. Nonetheless, some technologies may demand only skills that already suit our biological profiles, while others may demand skills that require extended training programs designed to bend the biological organism into shape (Clark, 2003, p. 38).

Embodied and enacted models of cognition open a scope for interaction being understood not only in terms of what is being done (as in the computational approaches), but more fundamentally how relationships between people and technologies develop. These approaches recognize that body, mind and environment work in harmony and attempt to understand them as connected and co-dependent. These conditions make embodiment and enaction interesting perspectives for thinking about how human cognition works in relation to the natural world and what kind of knowledge can emerge for understanding how humans can interact with digital technologies. Particularly when applied to the field of Human Computer Interaction (HCI), which has recognised cognition not as linked to bodily action, but passive receivers of information.

Connecting Interactions, Embodiment and Enaction

The movement described above sought to integrate Embodiment, Enaction and Interaction in order to understand these phenomena inter-relatedly, which is a challenge to Human Computer interaction and interaction as a whole. To change this view suggests that the problem is intrinsically connected to the mutability of the cognitive sciences and Human-Computer-Interaction as a field of knowledge. In fact interaction design has emerged as an alternative approach to Human-Computer-Interaction considering a more plural point-of-view, which is not limited only to our relationship with computers, but connects to a much wider range of objects, products, artifacts and complexity, which results from this new technology ecology, with a multidisciplinary and holistic approach. Recent trends in interaction design for instance include, emotion in design; Technology as Experience (McCarthy and Wright, 2004); usability and pleasure in interactive products (Norman, 2004); persuasive technologies (Fogg, 2000); affective computing (Picard, 1997); affective design (Aboulafia and Bannon, 2004); autonomous agents (Tomlinson, 2005); performative design (Kuutti, Iacucci and Iacucci, 2002) and context sensitive computing (Dourish, 2001b), among others.

It is thus possible to discern, for example, a certain approximation of this interactive dimension in some products. You can see some movement in the game-industry focused on developing products that consider the use of the body, using resources in research and development of its deep sensors, and with skeletal tracking algorithms, which work by assigning each pixel in an image to a particular part of the body, creating a fuzzy picture of the human body where the depth of each point is recognised, using infrared sensors. The system is primarily fed a vast catalogue of data of captured movements that include dancing, kicking and running. Through these captured frames, body parts are identified and the system calculates the probable location of the joints and maps this information to build a human skeleton. The algorithm is implemented to recognise the human body and track the movements quickly enough to be incorporated into the system. It is a highly innovative combination of cameras, microphones and software, which turns your body into a control system, with voice-activation, video capture and facial recognition, with great potential for application.

Still far from being a definitive solution, the quality of this specific product takes into account that the mind and body seem to be equipped with different ways in which they conceptualise reality, enhancing the experience for learning, cognition and intuitive discovery, given the complex human biological conformation. The rationale behind this type of product is that it considers the interaction of an individual's compelling body as part of the process of interaction and cognition; encourages autonomy and creates the user experience without ignoring the individual's context.

Maturana and Varela describe the term Enactivism, which suggests that cognition depends on a dynamic set of relationships and context-dependent associations:

> Thus we confront the problem of understanding how our experience – the praxis of our living – is coupled to a surrounding world, which appears filled with regularities that are at every instant the result of our biological and social histories. [...] Indeed, the whole mechanism of generating ourselves as describers and observers tells us that our world, as the world which we bring forth in our coexistence with others, will always have precisely that mixture of regularity and mutability, that combination of solidity and shifting sand, so typical of human experience when we look at it up close. (Maturana and Varela, 1992, p. 241)

Embodiment means that the cognitive process is embedded in our bodies and Enaction suggests a future potential action and both concepts are related. Also according to several researchers (Varela, Thompson and Rosch 1991; Thompson, 2005) we can identify five linked ideas that constitute the notion of Enaction. These are Autonomy, sense-making, emergence, embodiment and experience, but for now does not fit well here. What seems interesting in this perspective is to consider what kind of dialogue can be formalized with the new technologies. First the computer must be recognise within a broader perspective. The computer is no longer a device cloistered only to our desks. With the advancement of technology, computer engineering and the growth of processing power of these devices, coupled with miniaturisation, the advancement of semiconductors and processors, any object can potentially be a computer, since it would carry with it the potential to manipulate and execute instructions. Much of the ecology of new digital artifacts has undergone radical changes in recent years. With the advent of wireless networks, mobile technologies and implementation of touch screens, a new range of products were created, such as laptops, netbooks, notebooks, tablets and phones. In addition to these changes, the pervasive and ubiquitous computing promises to increase the complexity of this new scenario, including new ways to interacting with digital artefacts, including gestures, touches, movements, voices and sounds, becoming new forms of interaction. Within this new perspective - cognitive science based on Embodiment and Enaction - HCI could move beyond the problems inherent within a computational model.

Conclusion

Part of the effort here seeks to counter this position focused on prospecting new possibilities from a more contemporary understanding of human cognition and how it can substantially reduce the friction between man and technology, especially toward for HCI and Interaction design. In the history of cognitive sciences, some kinds of representations and computations were developed to understanding human thought, including computational-representational account now available does justice to the full range of human thinking. As some evidence points, the idea of embodiment and enaction contradicting the idea that the cognitive process occurs only through the representation and more than that, externalist theories suggest that the mind and cognitive processes are extended beyond the border of the individual's body. In addition, Embodied and Enacted cognition opens a scope for understanding that interaction is not only in terms of what is being done, but more fundamentally how this relationship is established. The effort this argument, are presented elements for a theoretical reflection suggesting that from these externalist theories of Philosophy of Mind new knowledge can contribute to HCI and Interaction Design founded upon computational theories of mind, expanding theoretical development on the subject.

Particularly when applied to the field of Human Computer interaction (HCI), which has recognized cognition not as linked to bodily action, but passive receivers of information. The traditional functionalism, which dominated the beginning of the theories that sought to understand the relationship between man and computer, has not completely dissipated.

The embodied and enactive trend proposed by Varela cannot be considered a full consensus in this theoretical paradigm. However, it has the merit to highlight some internal fragilities in the cognitive sciences, in particular its tendency to neglect dynamic phenomena, autonomy, action and context, characteristics that must not be neglected on the autonomy of human beings and should be considered for the HCI to develop more inclusive interactions. Current and future research will show whether it can accommodate some of these aspects of cognition in a more comprehensive theory from which the designers and interested parties can benefit in some way. Above all, this theory suggests that our interaction alone is not reduced to a representational model only, but is moving to a new set of relationships that should be considered and this in itself represents a complete paradigm shift in understanding how we interact with the natural and artificial world and with the technology around us. Thus, this essay is nothing more than part of the effort to questioning, understand and contribute for this phenomenon can be better understood. Embodied cognition and Enactive perspectives can be translated and applied to the development of best practices for HCI and interaction design? The future will tell us.

Notes

[1] Turing Machine/Test - The test consisted of submitting an operator in a closed room, to discover whether those who answered their questions, introduced by the keyboard was another man or a machine. The intention was to find out if we could assign to the notion of machine intelligence.

[2] Chinese Room - or the Chinese Room experiment is considered a response to the theory proposed by Alan Turing, who largely demystified the notion of intelligence to suggest that by manipulating symbols it is not necessarily to understand them. The argument is intended to show that while suitably programmed computers may appear to converse in natural language, they are not capable of understanding language, even in principle. Searle argues that the thought experiment underscores the fact that computers merely use syntactic rules to manipulate symbol strings, but have no understanding of meaning or semantics (Stanford Encyclopedia of Philosophy).

References

Aboulafia, A. and L. Bannon (2004) 'Understanding affect in design: An outline conceptual framework', *Journal of Theoretical Issues in Ergonomics Science*, 5, pp. 4–15.

Brooks, R.A. (1990) 'Elephants don't play chess', R*obotics and Autonomous Systems*, 6, pp. 3–15.

Card, S., Moran, T. P. and Newell, A. (1983) *The Psychology of Human Computer Interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

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

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

Clark, A. (2008) *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*. New York: Oxford University Press.

Cooper, A., Reimann, R. and Dubberly. H (2007) *About Face 2.0: The Essentials of Interaction Design*. Bognor Regis: Wiley Publishing, Inc.

Dix, A., Finlay, J., Abowd, G. and Beale, R. (2003) *Human–Computer Interaction*. 3rd Edition. Prentice Hall

Dourish, P. (2001) *Where the Action Is: The Foundations of Embodied Interaction*. Cambridge, MA: The MIT Press.

Dourish, P. (2001) 'Seeking a foundation for context-aware computing', *Human–Computer-Interaction*, 16, pp. (2–3).

Dourish, P., Edwards, W., LaMarca, A. and Salisbury, M. (1999) 'Presto: An experimental architecture for fluid interactive document spaces', *ACM Transactions on Computer–Human Interaction*, 6, pp. 133–161.

Fogg, B. J. (2000) 'Persuasive technologies and Netsmart devices', in Bergman, E. (ed.) *Information Appliances and Beyond: Interaction Design for Consumer Products*. San Francisco: Morgan Kaufmann, pp. 335–360.

Gallagher, S. (2001) 'The practice of mind: theory, simulation, or interaction?', *Journal of Consciousness Studies*, 8(5–7), pp. 83–107.

Gallagher, S. (2005) *How the Body Shapes the Mind*. Oxford: Oxford University Press.

Gallagher, S. (2008) *The Phenomenological Mind*. Oxford: Oxford University Press.

Gibson, J. J. (1986) *The Ecological Approach to Visual Perception*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gibson, J. J. (1979) *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

Head, H. (1920) *Studies in Neurology* [Volume 2]. London: Oxford University Press.

Hsu, F. (2002) *Behind Deep Blue: Building the Computer that Defeated the World Chess Champion*. Princeton, NJ: Princeton University Press.

Hutchins, E. (1995) *Cognition in the Wild*. Cambridge, MA: The MIT Press.

Imaz, M. and Benyon, D. (2007) *Designing with Blends - Conceptual Foundations of Human-Computer Interaction and Software Engineering*. Cambridge, MA: The MIT Press.

Kuutti, K., Iacucci, G. and Iacucci, C. (2002) 'Acting to know: Improving creativity in the design of mobile services by using performances', *Proceedings of the Fourth Conference on Creativity and Cognition*. Loughborough, UK, October 13–16, pp. 95–102.

Lasar, M. (2011) 'Brute force or intelligence? The slow rise of computer chess', *Ars Technica* [Online] Available at: http://arstechnica.com/gaming/news/2011/08/force-versus-heuristics-the-contentious-rise-of-computer-chess.ars (Accessed on 30 September 2011).

Levy, D., Newborn, M. (1991) *How Computers Play Chess*. New York, NY: Computer Science Press.

Licoppe, C. (2004) '"Connected" Presence: The Emergence of a New Repertoire for Managing Social Relationships in a Changing Communication Technoscape', *Environment and Planning: Society and Space*, 22, pp. 135–156.

McCarthy, J. and Wright, P. (2004) *Technology as Experience*. Cambridge, MA: The MIT Press.

Merleau-Ponty, M. (1962) *Phenomenology of Perception*. Translated by Colin Smith. London: Routledge and Kegan Paul.

Nielsen, J. (1993) *Usability Engineering*. Boston, MA: Academic Press.

Norman, D. (1988) *The Psychology of Everyday Things*. New York: Basic Books.

Norman, D. (1991) 'Cognitive artifacts', in Carroll, J. (ed.) *Designing Interaction: Psychology at the Human–Computer Interface*. Cambridge: Cambridge University Press, pp. 17–38.

Norman, D. (1993) *Things That Make Us Smart: Defending Human Attributes in the Age of the Machine*. Reading, MA: Addison-Wesley.

Norman, D. (1998) *The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution*. Cambridge, MA: The MIT Press.

Norman, D. (1999) 'Affordance, conventions, and design', *Interactions*, 6, pp. 38–42.

Norman, D. (2004) *Emotional Design: Why We Love (Or Hate) Everyday Things*. New York: Basic Books.

Norman, D. and Draper, S. (eds.) (1986) *User-Centered System Design: New Perspectives on Human–Computer Interaction*. Hillsdale, NJ: Lawrence Erlbaum.

Núñez, R. (2011) 'Enacting Infinity: Bringing Transfinite Cardinals into Being', in Stewart, J., Gappene, O. and Di Paolo, E. (eds.) *Enaction: Towards a New Paradigm in Cognitive Science*. Cambridge, MA: The MIT Press, pp. 307-333.

Picard, R. (1997) *Affective Computing*. Cambridge, MA: The MIT Press.

Shannon, C. (1950) 'Programming a Computer for Playing Chess', *Philosophical Magazine*, 41(314) [Online] (Accessed: 21 June 2009).

Sharp. H., Rogers, Y. and Preece, J. (2007) *Interaction Design: Beyond Human–Computer Interaction* [2nd ed.]. Hoboken, NJ: John Wiley & Sons Ltd.

Sheets-Johnstone, M. (1990) *The Roots of Thinking*. Philadelphia, PA: Temple University Press.

Sheets-Johnstone, M. (1999) *The Primacy of Movement*. Amsterdam: John Benjamins.

Stewart, J., Gapenne, O. and Di Paolo, E. (eds.) (2011) *Enaction - Toward a New Paradigm for Cognitive Science*. Cambridge, MA: The MIT Press.

Stolterman, E. (2011) 'Transform Grounds', *Interaction Design, Technology and Society, Philosophical Reflections*. [Online] Available at: http://transground.blogspot.com/ (Accessed: 18 July 2011).

Thompson, E. (2007) *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*. Cambridge, MA: Harvard University Press.

Tomlinson, B. (2005) 'Social characters for computer games', *International Journal of Interactive Technology and Smart Education*, 2, pp. 101–115.

Varela, F.J., Thompson, E. and Rosch, E. (1991) *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: The MIT Press.

Varela, F.J. and Maturana, H. (1998) *The Tree of Knowledge: The Biological Roots of Human Understanding*. Boston & London: Shambhala.

Wheeler, M. (2005) *Reconstructing the Cognitive World*. Cambridge, MA: The MIT Press.

Websites

Mastery the game - The history of Computer Chess http://www.computerhistory.org/chess/ (Accessed: 30 September 2011).

Colin Frayn's Computer Chess Theory Page http://www.frayn.net/beowulf/theory.html (Accessed: 30 September 2011).

Computer Chess History by Bill Wall

http://web.archive.org/web/20091028083247/http://www.geocities.com/SiliconValley/Lab/7378/comphis.htm - (Accessed: 30 September 2011).

http://plato.stanford.edu/entries/chinese-room/ - (Accessed: 30 September 2011).

Chinese Room, entry in the Dictionary of Philosophy of Mind, Chris Eliasmith. - http://philosophy.uwaterloo.ca/MindDict/chineseroom.html - (Accessed: 20 September 2011).