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An introduction to embodiment and digital technology research: interdisciplinary themes and perspectives

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Abstract

Renewed interest in theories and perspectives of embodiment has emerged in conjunction with advances in ubiquitous computing and the development of technologies that inherently change the character of human computer interaction. The very nature of technologies such as tangible, multi-touch, sensor and mobile technologies offers opportunities for exploiting a wider range of perceptual-based experiences than traditional desktop computing. Primarily they offer opportunities to exploit more bodily-based physical experiences in new ways, for example, through manipulation of physical objects linked to a variety of digitally augmentations; enhancing contextually based experience in real world environments through mobile devices, fostering new forms interaction and new ways of thinking. These developments are important in explaining the contemporary interest in concepts of embodiment, in the context of digital technologies that foster more embodied forms of interaction and experiences. However, notions of embodiment have a long and complex history, with continued debate from various disciplinary perspectives. This working paper provides a brief history of theoretical approaches to embodiment, an introduction to ways in which embodiment is described within different disciplines, and outlines key ways in which these perspectives are of interest in the current context of digital technology research.

Introduction

Over the past 20 years there has been a surge of interdisciplinary interest in the body and embodiment, and it is now a key topic of study and theorisation across the social sciences. In part this marks a shift in attention from the spoken and written communication to an interest in the range of ways in which people communicate, particularly within the context of complex digital environments. That said, debates around embodiment are not new, it has been discussed from the times of Plato, with previous peaks of interest notably in the early 1900's. This review aims to provide an introduction to how embodiment is described within philosophy, psychology, neuroscience, sociology, and computer science. In particular, we are concerned with approaches to embodiment within the context the contemporary digital landscape, and seek to sketch the key ideas and questions that ideas of embodiment raise with respect to digital environments and technologies.

Theories of embodiment have a long and complex history. The initial ideas emerge from a philosophical tradition of inquiry into the nature of being and knowledge. Plato in *The Republic* (c.380 BC) discusses the immateriality of the soul – what we might today call the mind - and argues that this immateriality means that the soul (or mind) exists as an entity separate from the body, and therefore separate from reality (the here and now of your life). In other words the mind was perceived as having its own reality, because its existence was seen to continue after the death of the body. This idea that the mind was separate from the body was later dominant in the Christian metaphysical tradition in the form of a 'soul' (Anderson, 2003; Blattner, 2006). This idea of a mind-body split persisted into the 18th century through the works of Locke, Hume and Kant, notably in the latter's *The Critique of Pure Reason* (1781). Here Kant argues that there can be no doubt that all knowledge begins with experience, and notes that thinking is 'awakened' by people's interaction with objects, which then affect the senses. Thus, a dichotomy existed in that while earlier thinkers sought to only address the separation of mind and body, they also saw this separation as a necessity for understanding *how the mind acquires ideas*. Descartes (1641), for example, showed that trusting to perception alone to explain experience is limiting, as the senses can be deceived. For example, visual illusions clearly illustrate how vision can be deceiving. The mind, once freed from the restrictions that are placed upon the body[1], such as physical laws like time or gravity, is then a place where study can be truly focused (Anderson, 2003). From this

[1] Modern writers in this area argue that the body in fact is not limiting but freeing. For example activity via the body can free the mind, e.g. see the works of Sylvie Fortin and Helena Wulff on dance, expression and self-knowledge. Whilst this appears to be a return to the mind as a metaphysical object, and therefore a precursor to the mind/body problem again, this is more in the tradition of Heideggerian 'throwness'.

perspective, then, for people to learn and acquire knowledge, somehow this knowledge must be ‘translated’ from the physical experience to the mind.

Yet the precise process and nature of this translation introduces an enduring conundrum across the social sciences. Mapping (or translation) is generally considered to be achieved through metaphor, and the form that this takes, or whether it occurs at all, is the subject of much debate. Indeed Artificial Intelligence (AI) works with this notion of translation and mapping, drawing on the work of philosophers to establish theories of mental abstraction and representation, which form an overarching theme of cognitivism. On the other hand, Lakoff and Johnson (philosopher and linguist) see the notion of metaphor through language as playing a significant role in how we express and conceptualise our world. For them the language we use is bounded and shaped by our physical experience, and subsequently influences the abstract ways in which we conceptualise the world.

Thus, the separation of the body from mental abstraction is a problem, and many theorists argue that the two (body and mental abstraction) are not separate but part of a unified experience. This reunification of body, action, and mind is a key consideration in contemporary debates around embodiment. At a high level we can trace the pathway of ‘embodiment’ discussions from philosophical notions, which influenced the cognitivist traditions and views on embodiment. While cognitivism influenced AI, the subsequent pathways of development have differed with one pathway focusing more on evidence-based investigation, while the other generated theory driven explanations (see fig 1). Today’s terminology emerges from these developments, with most of the recent evidence for ‘the body influencing and mapping to the mind’ arising from the cognitive sciences, such as psychology and neuroscience. The meaning of terms used, though, is widely contested, causing variation in terminology, which often talks about similar concepts but in vastly different ways.

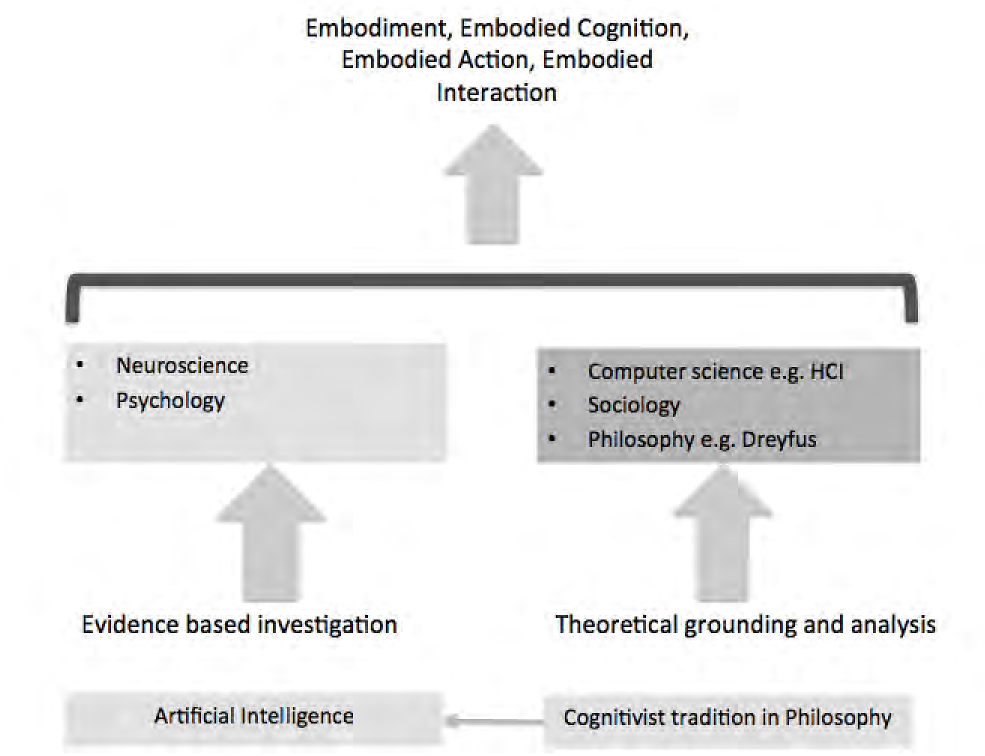

Figure 1. The emergence of embodiment as a research area

Thus, each discipline approaches ideas of embodiment from different initial starting points. While philosophers draw upon notions of embodiment found within Platonic and Aristotelian work, for computer scientists, embodiment derives primarily from Heidegger’s (1927) seminal exploration of the relationship between mind, body and knowledge in the early twentieth century. Inevitably, the question, audience, scope of the discussion and potential outcomes of each discipline influences what is meant by the term 'embodiment'. These perspectives drive the disciplinary research agenda.

This review seeks to sketch out a basic understanding of the embodiment debate with an eye toward its impact on research approaches to interaction with digital technology. In particular, we seek to understand the role of concepts of embodiment in the context of digital technology. The review begins by outlining three key lines of debate around embodiment from the perspectives of philosophy, psychology and neuroscience, and sociology. These sections provide parallel notions of embodiment, each emphasising particular aspects within their own disciplines. The review then turns to Human Computer Interaction and Computer Science to try to get a handle on how concepts of embodiment have emerged within these disciplines, the key traditions they have drawn on, to derive a more contemporary idea of the role of embodiment within the context of digital technology interaction. Finally, the paper presents a discussion of the interrelationship between technology, embodiment and multiple disciplines.

1. Embodiment from the philosophy tradition

Philosophical approaches were the first to describe embodiment as purporting to the idea that humans are living, thinking, feeling beings that inhabit and interact with the physical world. The notion of embodiment within the philosophical discipline emerges primarily in the twentieth century as a reaction to logical positivism (or scientific reductionism) in the scientific community. The reductionist approach emphasised the Cartesian idea that mind and body were considered as separate elements. A reaction to positivism begins in earnest with Heidegger's *Being and Time* (1927), which builds on the work of Husserl (the principle founder of phenomenology) who set out to create a science of experience. Husserl was interested in explaining reality through a subjective interpretation of experience. Heidegger's approach to understanding 'being' is therefore based on the subjective notion of experience and consciousness, rather than on a subjective view of the world as a set of objects and their relations with one another (Cartesian). Heidegger argues that as we inhabit the physical world, our experience within it is grounded in our actions. Our actions with tools and objects can change the nature of our relationship with the tool. For example, we can become so entrenched in activity with a particular tool (e.g. a pen when writing) that we often forget its existence. In this way it is seen to become 'embodied', to become part of you as a 'master' of that the tool. This has particular relevance today for thinking about embodiment in the context of ubiquitous digital technologies, such as sensor based and haptic technologies, because of their proposed 'seamless use' (Weiser, 1991). The properties of these technologies are considered to enable interaction with them to occur through everyday action and activity with the world, thus offering a 'seamless' connection between the digital and the physical.

One effect of the apparent disappearance of materiality is that it can question the nature of our reality, as objects in the environment therefore begin to conjointly govern action within social, historical, psychological, and biological contexts. In other words, objects (or tools) combined with human interaction can generate much more beyond the objects mere physical form. A pen, for example, is a small object, but with human use can generate other objects or texts far beyond its physical form. Most importantly for Heidegger though is the disruption that is caused when tools and objects that we employ fail in their use, and we are then faced with the bare reality of grounded existence in the flesh – the here and now. For Heidegger, the experience we have as individuals with specific objects, such as tools, creates mastery. As objects become tools, and we grow in our experience of them and attain mastery, our interaction with those objects changes. In this light, digital technology, in particular situations, such as in learning with science, would require keenly thought-out objects and tools that serve specific purposes, and make use of the capabilities of the body such as the hand allows grabbing, as Heidegger explicates in his discussion of a hammer.

Merleau-Ponty (1945) takes up Heidegger's ideas of mastery, disruption and use by foregrounding the body in all situations, rather than in certain situations such as mastery. Merleau-Ponty uses the notion of inter-coporeality to discuss 'skilful coping'. In other words, the body inhabits the here and now, and experience a *gestalt* or experiential flow of a situation. For embodiment, Merleau-Ponty views the body as standing squarely in the middle of all interactions, reactions, and creation of understanding. Merleau-Ponty claims that for perception the body must achieve flow - without thinking and rules - to get an optimal grip on the situation that the individual is placed within.

Consciousness is a lived experience, where “to be a body is to be tied to a certain world…our body is not primarily in space: it is of it” (Merleau-Ponty, 1945, p. 148). These ideas are continued in the work of Hilary Putnam (1994) and John McDowell (1998) who agree that the body and mind are nothing more than a “structured system of object involving abilities” (Putnam, 1994, p. 356). In other words: we learn and understand because we inhabit our bodies. For digital technology, this has meant a continued re-negotiation of the physical/digital divide. In human-computer interaction design the rise of mobile, tangible and haptic computing continues to blur the boundaries of the bodily interaction with digital information. For example, Tangible User Interfaces embed objects with digital information so that digital information can be *directly* manipulated and investigated, so-called embodied or tangible interaction (e.g. Dourish, 2001; Shaer & Hornecker, 2010).

More recently, a radical move away from cognitivist approaches in philosophy and computer science is apparent in Lakoff and Johnson’s work (1999). Lakoff and Johnson suggest that communication and language show the extension of our experiences within our own body through the use of metaphor, which shapes our communication as well as the way that we think, act and perceive abstract concepts. They distinguish between bodily metaphor and conceptual metaphor. Bodily metaphor refers to basic ideas that we learn as children. For example, the idea of containment is based on our own experience of using containers. We begin as children by placing objects in and out of containers, we learn that containers can hold items, and can be full or empty, and containers can be placed on surfaces. Lakoff and Johnson suggest that these ideas and concepts become more complicated over our lifespan, and move from being used in concrete contexts to enable expression of more abstract ideas. For example, “Social Interaction is Containment … He doesn’t fit in. She’s a square peg” (Lakoff, Espenson, Goldberg, & Schwartz, 1991, p. 21), or “OBLIGATIONS/AGREEMENTS ARE CONTAINERS….What obligations have you gotten yourself into? Can you get out of doing the dishes? There’s no way out; I have to do it.” (Lakoff, et al., 1991, p. 36). Conceptual metaphor then occurs at a more common level than we would believe, with speech showing the extension of our experiences within our own body and with the physical world. For thinking about embodiment with digital technology this means that that there are potentially certain verbal indicators that can highlight the physical experience of individuals. These can be used to either evaluate digital technology as they show deep level understanding of concepts, or can be used within design planning and assessment (e.g. Hurtienne et al., 2010). Indeed, such metaphorical ideas form the basis of the design of many systems where mapping action to digital effects is central to interaction with the system (e.g. Price and Pontual Falcão, 2009; Antle, Corness, & Droumeva, 2009).

In opposition to the Lakoff and Johnson approach, philosopher Andy Clark remains doubtful about this theory of embodiment, and argues - similarly to many of the criticisms aimed at Gibson's theory of ecological perception (see section 2) - that dynamic embodiment really only works in an extremely small number of cases. For Clark words, for example, are nothing more than a form of environmental structuring rather than an information stream, as they are "cheap stand-ins for gross behavioural outcomes" (Clark, 2005, p. 234). In other words, language is something that sits at the tip of the iceberg, without revealing everything that has gone on underneath, in this case, the physical action that has taken place first. This is due to the fact that all attempts, according to Clark, to find action in all that we do, lie in the "key move in scaling up simple embodied cognitive science… to take very seriously the potent role of human-built structures in transforming the spaces of human learning and reason” (Clark, 2005, p. 233). Here Clark is criticizing an approach where using theories and models to scale up to bigger contexts tends to reduce ideas to the level of neuroscience, removing all cultural and social influences. For example, a robot that can sweep one room does not necessarily scale up effectively to a bigger room. In contrast, in HCI investigations in the wild are considered important as lab-based interaction cannot show everything. However, to disengage interaction from reason ignores localised high-level reasoning, and so Clark argues that we need to be careful of complete adoption of embodiment without representational forms when they still exist in activities that may require planning. This suggests the need to argue for ‘mind’ going on at some level, which equates with Wilson’s (2002) idea of off-line cognition (see section 2).

Clark argues that examples of embodiment used in science are better thought of as "surrogate situations" of the perception-action-reason cycle, and offer a way into understanding whether embodiment exists all the way up to cognition.

Examples of this surrogacy may be seen in notions of external cognition (Rogers & Scaife, 1997) or even in tangible user interfaces, as they reveal how little we yet understand about the place of our bodies in cognition, but focus on man-made situations, which is where digital technology becomes useful.

2. Psychology, Cognitive Science & Neuroscience

This section draws collectively on psychology, cognitive science and neuroscience, as their discipline boundaries are not always clear, yet similar concepts are expressed with different emphases.

Psychology

Within psychology embodiment usually refers to how the body and its interactive processes, such as in perception or cultural acquisition through the senses, aid, enhance or interfere with the development of the human condition. From a developmental perspective, one tradition emerges from the works of Piaget (e.g. 1953; 1954) and argues that mental representations exist and so individuals experience *embodied cognition*. Theorists like Piaget understood the importance of bodily movement and experience for cognitive development, which are then amalgamated after the acquisition of an experience into a higher order form of representation that Piaget called ‘schema’ (Seitz, 2000). For example a child may experience the use of containers in all forms and gradually understand their use over time by interacting with and playing with different types of containers, and so build a mental picture of or ‘scheme’ about containers. Schemas are, therefore, formed within the mind while being supported by interaction with the environment. This is particularly relevant for thinking about embodiment with digital technologies as it provides a way to understand how experiences with digital technology may ‘map’ onto the mind. For example, mapping may occur on a variety of levels, highlighting important aspects of the learning experience for children such as space for action, perceptual, behavioural, and semantic mappings (Antle, 2007; Antle, Droumeva, & Ha, 2009).

Bruner’s *The Course of Cognitive Growth* (1964) stands as an early example of understanding the move from action in the environment to cognitive representation. Active cognitive load becomes externalized and supported, “[p]ast experience is coded and processed so that it may indeed be relevant and useable in the present when needed.” (1964, p. 2). Development of cognitive representation for Bruner occurs through enactive, iconic and symbolic levels of representation, where: enactive is action-based, and primarily physical (e.g. for infants sitting, rolling, walking); iconic is image-based, as children begin to understand pictures and diagrams; and symbolic is language based (or a symbol system), as children begin to understand or work with abstract concepts.

The engagement and classification of experience within the world then is so important for children that their, “understanding of object permanence and the developmental stage of their loco-motor ability” ultimately enables "[b]odily experience and sensori-motor interaction… to form the basis for meaning making” (Price, Roussos, Pontual Falcao, & Sheridan, 2009, p. 5). So much so that when coupling objects, representations and actions with meaning in the form of digital technology, the impact becomes significant on understanding and learning such that children "produce knowledge by expressing themselves through the representations they create [and] the artifact embodies the children’s activity and thoughts" (Marshall, Price, & Rogers, 2003; Price, et al., 2009, p. 11).

In parallel with the Piagetian tradition, but adding an important layer to the theory of child development, Vygotsky’s (see 1962; 1978) socio-cultural approach argues that the community is vital for making meaning and for our understanding and interpretation of the world. Social learning for Vygotsky precedes formal development through *a)* culture, a tool which allows for adaptation *b)* social factors and *c)* the importance of language.

Whilst Vygotsky's theory is not directly linked to the tradition of embodiment, it forms a strong basis for later theories of embodied interaction, which explain that interaction (for example the discussion of digital technology in the work of Lucy Suchmann) is better understood when placed within the [situated] cultural context.

A rather different approach from Piaget and Vygotsky can be seen in Gibson's *Ecological Approach to Visual Perception* (1979), which follows from the Frankfurt school tradition of the Gestalt, arguing that objects which inhabit our environment offer themselves to us in the form in which they will be able to be used, here referred to as 'affordances'. This idea postulates that the potentialities that an object offers are static and do not change according to the user, yet have a relationship with the user's own physical form. For understanding the theory of embodiment Gibson's notion grounds individual action within the *here and now,* and explains how we understand the world in terms of object interaction and perception. In Gibson's words "Knowing is an extension of perceiving. The child becomes aware of the world by looking around and looking at, by listening, feeling, smelling, and tasting, but then she begins to be made aware of the world as well. She is shown things, and told things, and given models and pictures of things, and then instruments and tools and books, and finally rules and short cuts for finding out more things…They transmit to the next generation the tricks of the human trade. The labors of the first perceivers are spared their descendants" (1979, p. 258).

Cognitive Science

Theories of embodiment within cognitive science generally sit under the umbrella of 'embodied cognition'. Recent work on *embodied cognition* differs in its motivation for developing notions of embodiment. There is no longer a simple affordance/schema dichotomy, where the debate is over whether it is information from the environment or the storage mechanism that matters most, rather it is more about dynamic interaction, where cognition occurs in real time. However, there are a number of diverse foundations and descriptions that contribute to what is considered 'embodied cognition'. Here we provide an illustration of the breadth of these, all of which speak to similar ideas, but with slightly different nuances.

Lakoff and Johnson's work (e.g. Lakoff and Johnson, 1980; Lakoff and Johnson, 1999) suggests that our way of reasoning ("the very structure of reasoning") is derived from our bodily actions. Meaning and understanding are shaped by our experience of the particular physical form of our bodies (their constraints and potentials), and their everyday functioning or interaction with the world (see section 1 for more detail).

Hutchins (1995) developed the 'distributed cognition' approach, which is grounded in ethnographical studies. Here cognition, or cognitive phenomena, is viewed as being distributed across individuals, artefacts and internal and external representations. The motivation for this approach was to move away from traditional cognitive science approaches of information processing, and individual cognition, to place emphasis on human activity as a process that is equally dependent on other individuals and artefacts or tools, as their own cognitive activity. "Depending on their organization, groups must have cognitive properties that are not predictable from knowledge of the properties of the individuals in the group. The emphasis on finding and describing "knowledge structures" that are somewhere "inside" the individual encourages us to overlook the fact that human cognition is always situated in a complex sociocultural world and cannot be unaffected by it. …I have in mind the distinction between the laboratory, where cognition is studied in captivity, and the everyday world, where human cognition adapts to its natural surroundings. I hope to evoke with this metaphor a sense of an ecology of thinking in which human cognition interacts with an environment rich in organizing resources" (pp1-2).

In contrast, Anderson's (e.g. 2003) work originates in AI and robotics, yet makes somewhat similar claims, that "[R]eal-world thinking occurs in very particular (and often very complex) environments, is employed for very practical ends, and exploits the possibility of interaction with and manipulation of external props. It thereby foregrounds the fact that cognition is a highly embodied or situated activity —emphasis intentionally on all three—and suggests that thinking beings ought therefore be considered first and foremost as acting beings" (p.91). Drawing on both of these, we can see an emphasis on 'human activity' and the central role that this activity is thought to have in cognition.

Wilson (2002) draws on a variety of sources, including some of those above, to provide what she sees as "six [key] views" of embodied cognition:

(i) Cognition is situated: i.e. cognition takes place in context, (and as such is influenced or shaped by that context), and is "on-line", reacting to the moment, and is therefore *without* time for representation:

(ii) Cognition is therefore also time pressured: there is no time for reflection as "realtime" occurrences are simply too fast, [in which case]

(iii) Cognitive work is offloaded onto the environment: furthermore, due cognitive limitations such as memory, we use the environment to reduce cognitive work. For example, tying a knot in a handkerchief as a reminder, or using contemporary tools like mobile phones.

(iv) The environment is part of the cognitive system: i.e. the flow of information between an individual and his environment makes it impossible to distinguish between the two, and any unit of analysis must consider both.

(v) Cognition is for action: or in other words the mind's function is to guide action, where the perception is intimately linked to subsequent 'situation-appropriate' behaviour. Thus, behaviour and environment are interdependent.

(vi) Off-line cognition is body based: For Wilson this is the heart of embodied cognition, as all physical activity feeds into on-line cognition at some level. "Decoupled from the physical inputs and outputs that were their original purpose…assist in thinking and knowing…the function of these sensorimotor resources is to run a simulation of some aspect of the physical world, as a means of representing information or drawing inferences" (Wilson, 2002, p633).

We end this section with a quote from Rohrer (2006), who offers a comprehensive overview of 'embodied cognitive science' drawing on key cognitive science perspectives (Rohrer, 2006). This quote eloquently describes our common propensity to move in and out of our own bodily awareness, and which highlights a key dichotomy in discussions of embodiment. "Human beings have bodies. Academics of every variety, so often caught up in the life of the mind, find that simple truth altogether too easy to forget. Imagine working late into the night, hotly pursuing another bit of perfect prose. But now let there be a power outage and, in the absence of electric light or the pale glow of the computer screen, imagine how we grope and fumble to find our briefcase, locate the door, and exit the building. In such circumstances, the body returns. Whenever we are unexpectedly forced to move about in the dark, we are forcibly reacquainted with our bodily sense of space. Problems ordinarily solved beneath the level of our conscious awareness become dominant in our cognition; we find ourselves noticing subtle changes in the floor texture underfoot, carefully reaching out for the next step in the stairwell. It is a most peculiar experience, one that may well remind us of being young and just learning to walk down stairs" (pp1-2).

Neuroscience

In parallel, work within neuroscience suggests that motor activity is the basis of thought, in effect our physical actions directly link to our thought processes and so "we think kinesically too" (Seitz, 2000, p. 24). Neuroscience increasingly gives much of the workable data that backs up cognitive theories of embodiment. In neuroscience the discovery of canonical and mirror neurons strongly grounds the theory of embodiment strong in brain structure. Both types of neuron are equipped with motor and visual properties, and fire during tasks that involve action, or (and most importantly) the observation of action. The firing of the neuron occurs *as if* the observer were actually carrying out the act itself. Mirror neurons are implicated more in the transitive hand movements such as grasping, holding, releasing, manipulating and releasing. Accompanying sounds that go along with a particular action are enough to make mirror neurons fire in the same way. Conversely, canonical neurons are tied up with the visual perception of objects. Whilst an object's characteristics such as shape, size, and orientation are important, they only occur and impact upon the observer when an action is executed upon it (Garbarini, 2004). This highlights the close bodily relationship with perceptual functioning.

Current research has moved beyond a focus on neuronal links to try to understand their interactive relationship with the body. For example, by exploring the neuronal activity triggered by functional tasks or activities, suggests the level and distribution of neuronal activity in a more dynamic fashion. Research indicates that more than one area of neuronal activity is triggered highlighting the complexity of the interaction.

'Body Schema' or 'forward' flow models have thus been developed to seek to understand the sensory-motor representation of an agent's body by looking at possibilities for action (e.g. De Preester & Knockaert, 2005). Forward predictor models explain how agents are capable of predicting, acting on, and anticipating behaviour. This may be through feedback in the form of locomotion (which may be body movement or locomotion in a robot). Neuroscience here has some overlap with AI as the notion of forward planning, and prediction has plagued AI, with only very recent research projects being able to address these issues. Foremost of these is the iCub project (Metta et al., 2008) which addresses the issue of 'emergence', or how it is that intelligent action emerges from perception that is housed within a body, and how this knowledge can be transferred to artificially intelligent machines, so that they can predict and plan in unfamiliar environments (Anderson, 2003).

3. Sociology

Sociology critically reflects on how the body is drawn into (and made through) embodied interactions, regulation, control and identities. Primarily the body is seen as being actively shaped and "subjectively embodied in a fluid, emergent, and negotiated process of being" (Waskul and Vannini, 2006). For Waskul and Vannini (2006) there are five areas of bodily discussion:

The 'Looking Glass' Body

The idea of the 'looking glass' body is influenced by the works of the American Pragmatists, and in particular Charles Horton Cooley, where the self and the body can only be formed from the imaginary perspective of others. Charles Goodwin in 'Action and embodiment within situated human interaction' (2000) argues that the construction of action is an ever-unfolding semiotic field. Social processes are to be found within the 'historically shaped material world'. For digital technology this means that multiple sign systems exist, present with power structures, social structural arrangements, participation frameworks and orientation issues "made by actors' bodies" (Goodwin, 2000 p. 1492). This is particularly the case as experiences of people on social networking sites show with facebook, twitter, and second life, placing a wall of meaning between the actor and the reader. This increase of online identity with a parallel increase in presentation, means that for some observers there is an easy increase in contact, e.g. through facebook, but it also means that it is equally easy to avoid contact (Turkle, 2009, 2011). New forms of 'online' contact create new forms of cyberculture, and cybersubjectivity (Sundén, 2003). Online encounters are thus seen as new ways in which the individual is embodied, and may even be engendered, with feminist interpretations offering the only salient interpretation (i.e. the emphasis is on the subjective interpretation of meaning) (Sundén, 2003). Overall, technological "boundaries, in a physical and social sense, are examples of embodiment and presence, e.g. the sense of someone else (through the avatars) being in "your" space." (Price, et al., 2009, p. 13). Digital bodies can therefore be used to interact in multiple ways such as greeting, playing, or conveying opinions or feelings (Price, et al., 2009).

Dramaturgy

The concept of 'dramaturgy' is influenced by Erving Goffman, where the body is perceived as being embedded in social practices, and "people actively do a body". For Goffman (1959) identity is created anew by individuals, depending on their circumstance, image, or desired image portrayal. It can thus change from context to context. Furthermore, Goffman argues that we all seek to influence our social setting through the use of actions, props, and the places we choose to stage ourselves within. In this sense identity is replaced with character, and becomes a more loosely manifested social construct that rather ebbs and flows with time, but only within certain places such as institutions and buildings.

Judith Butler (1990) is concerned more closely with issues of identity creation with respect to gender. For Butler we are embodied with a sense of who we are through the impact and exposure to entrenched and engendered stereotypes. The creation of the feminine or the masculine occurs over time and hence we become 'male' or a 'female' over time, and in fact never fully reach the gendered destination that society imposes upon us. The embodied identity that society imposes Butler describes as inevitably a failure, which is a positive starting point from which the individual can embark upon the journey of gender creation.

Ultimately, as varying social restrictions are placed upon people who depart from the created set of gender norms, the individual's "experience of a gendered... cultural identity is considered an achievement" (Butler, 1990).

Phenomenology

This perspective influenced by Edmund Husserl, perceives the body as 'embodied', but only in clear and situational circumstances. In other words, the body is "embedded in our experiences within the world", and in terms of the environment(s) that it creates. The embodied habits, or habitus, that people use, or develop, are discussed by Merleau-Ponty (1945) and later by Pierre Bourdieu (1984). For Merleau-Ponty, the phenomenological body has a somatic presence, that is, that the self, society and symbolic order are all found "through the work of the body" (Waskul and Vannini, 2006). The body:

"[S]erves as a fundamental corporeal anchor in the world; we… experience ourselves through numerous "bodies of meaning". These "bodies of meaning" are both literal and metaphorical: meaning is comprised in embodied action and the body is interpreted by frameworks of meaning" (Waskul and Vannini, 2006, p9).

Examples of the impact of habitus are found in the works of Helena Wulff (1998), Wainwright's (2006), and Sylvie Fortin (2002), who seek to show that stylized and formulaic methods of dance found in ballet create types of people, institutions, and even working practices in the form of choreography. For Fortin the somatic (i.e. 'of the body' as opposed to 'of the mind') practice, which is dance is the search for the 'elusive obvious', where "truth is linked to…experience and as such…voices a construction of reality" (Fortin, 2002). Here the emphasis is on the act of doing something in constructing 'reality', your physical action is the only thing you can rely on in terms of experience, which must therefore be 'reality'. The embodiment of styles in schools of ballet encapsulates the essence of the ballerina or danseur noble but also inhibits movement between types. The trajectory of the somatic element to embodiment in fact begins to pursue the mind-body split again as "the body is perceived from within by first person perception…The soma, being internally perceived, is categorically distinct from a body…Dance teachers must be alert to see how dualism is conveyed in their practice" (Fortin, 2002). Ultimately the body is transformational; the self should be seen as a process, a 'selfing' rather than a clearly defined object (Fortin, 2002). For digital technology this means that embodied action through digital technology such as with the Playstation *dance dance revolution* or Kinect dance create not only a games but feedback in the form of onscreen mirroring of action, and so create habits and cultures around the technology. Game situations then provide new and different frameworks of meaning for self – expression, where the soma is no longer viewed – as would be the case in a dance studio - in a mirror, but *mirrored* back in imitation (e.g. Jenson & de Castell, 2009).

The Socio-Semiotic perspective

The socio-semiotic perspective on the body is influenced by the work of Michael Foucault (e.g. 1978), where bodies disappear under culture and discourse, and embodied interaction occurs through meaning-making, which is dictated by power relations. Individuals, for example, are subsumed or consumed within institutions, groups or media. As a result the body becomes an object and a sign-vehicle. The body becomes an area for physical capital. The body becomes a situated entity that is influenced and manipulated by surrounding society. In the medical sociological of Dawn Goodwin, the body is assessed through its place within the surgical theatre. Goodwin (2008) argues that the anaesthetised patient becomes heavily reliant on machines, and in a sense becomes a 'mix of organic and technological components, in other words, a cyborg" (Goodwin, 2008, p346). The person, for Goodwin, becomes silenced and rendered passive, or depersonalised by health care practices. The body becomes a "living cadaver". In this sense the body becomes a challenge to our understandings of society, our own body, and the mechanisms of health care. The patient becomes a "passive object of knowledge", where the transformational processes and relations between humans and artefacts become "folded" into one another. Thus challenges around ideas of embodiment are created with digital technologies where the digital technology becomes part of the body, and the boundaries between are merged.

However, if the idea of the body is removed from the discussion about the uses of technology and how it interacts with humans, the interaction element is now different and digital technology is left with 'context'.

Here Suchman (Suchman, 2007) argues within the Vygotskian tradition that “situation is crucial to [an] action’s interpretation” (p.176). The “contingency of action on a complex world of objects, artifacts, and other actors, located in space and time, is no longer treated as an extraneous problem with which the individual actor must contend, but rather is seen as the essential resource that makes knowledge possible and gives action its sense” (p.177). Embodiment then in this sense bypasses the body altogether and so frames embodied action within a system of meaning, proposing that situations create context-oriented action. However, Donna Haraway (1988) warns that the so-called objectivity in all scientific endeavor, such as concepts of embodiment in digital technology, is a “contestable text”, and a “power field”. Here “artifacts and facts are parts of the powerful art of rhetoric” (Haraway, 1988, p. 577). Technology as part of that rhetoric whilst semiotic and open to a variety of ways to make meaning is present in the “irreducible difference and radical multiplicity of local knowledges” (p579). However, Haraway (1988) warns that visualization, as occurs in *on-line interaction* y has led to “compounded…meanings of disembodiment” (p. 581). For example, with social networks disembodiment is compounded through the likelihood of not seeing another person. This theory of feminist embodiment “is not about fixed location in a reified body, female or otherwise, but about nodes in fields, inflections of orientations, and responsibility for difference in material semiotic fields of meaning (Haraway, 1988, p. 588)”. The body becomes an agent, “not a resource” where “boundaries materialize in social interaction (pp. 594-595).”

The Narrative Body

The narrative body viewpoint contends that the person is a narrative accomplishment. The individual is made sense of through the stories and narratives we create and tell others and ourselves. For example consultation in the doctor’s surgery reveals how individuals embody their lived and ill experience on a small-scale during consultation using gesture to indicate places of agreement and pain (Heath, 2002). This ‘intercorporeal knowing’ places the body back at the centre of action, where trajectories of action take centre stage alongside talk (Hindmarsh & Pilnick, 2007). In the context of technology and learning interaction, a sociological perspective could mean consideration or awareness, of how different people interact with and use technology to take on different roles within groups to ‘play out’ ideas. Technology can for example – even in small doses – offer a variant interpretation to the co-ordinated action of others, making action visible that would otherwise not be seen (e.g. Heath, Hindmarsh, & Luff, 1999). Individual differences in interaction may be explored through the notion of dramaturgy or ‘performance’ with digital technologies like tangibles or sensor based devices or mobile technologies – where ‘performance’ through action on objects or devices is central to the interaction. In medical situations interaction with technology is nothing new in itself, but it is with the interpretation of bodily interaction in and around technology, particularly in the medical workplace. Here the suggestion is that technology embedded or embodied in a human changes the nature of the ‘body’ and the interaction with it – it is no longer purely human but has features of a cyborg. In this context technology is invasive rather than siting external to the body like technologies such as tangibles where the relationship between technology and ‘body’, and the notion of embodiment differs.

4. Human-Computer Interaction (HCI) & Computer Science

The question of embodiment has re-emerged within the context of HCI, particularly with new forms of interaction reaching the marketplace through systems such as the Nintendo Wii, the Xbox Kinect, multi-touch tables, and touch interaction technology of the iPad/I Phone/iPod Touch. These digital technologies have created new controllers, and new forms of play (Jenson and Castell, 2009), as well as the potential for other, new, forms of interaction. With new types of interaction, “play is very much situated within a broader network of actions, actors and activities which are community-based and supported (Jenson and Castell, 2009, p1.)” The resulting relationship between actors highlights inter-dependencies, interactions and support networks that grow and occur as a result of new forms of interaction (Latour, 2005). Jenson and Castell (2009) argue that previous forms of technology produced an experience of simulation, whereas now the emphasis has moved toward imitation, which for the authors means that where action is “just like it” as opposed to weak simulated copy. This echoes ideas found within the embodiment debate as imitation models reality in physical interaction.

Computer scientists began by drawing on computational models of the mind, initially focusing on ideas around symbolic representations of real-life occurrences, called 'mental representations', a lineage going back as far as Hume, Locke and Berkeley as discussed earlier in this paper. Mental abstraction in representation, for cognitivists is disassociated from real things. Anderson for example argues that: "To some degree, of course, such formal abstraction is a necessary condition for representation – the token for 'green' in my mental lexicon is not itself green, nor does it necessarily share any of the other properties of green. Indeed the relation between sign and signifier seems in this sense necessarily arbitrary" (Anderson, 2003, p93). From the perspective of cognitivists, the context of an object becomes unimportant, as the primary focus on formal rules and logic that evolved from attempts to establish computer languages in artificial intelligence – to reflect mental abstraction- and evolved into a key goal in AI (Dreyfus, 1972, 1992). Early works in artificial intelligence also sought to make computer parallels with the human mind. These early symbolic representations in AI have on the whole been unsuccessful according to criticism of the cognitivist approach by Hubert Dreyfus (e.g. in *What Computers Still Can't Do*, 1992). Dreyfus argues that mental representations of the world formed the basis of languages of symbolic representation in computing, but AI and cognitivism fails as the dynamic interrelationship with the world that humans experience, especially in subtlety through, for example, eyes (gaze) and gesture, embodied interaction cannot currently be replicated in this way. Simply put Dreyfus believes that mental representation does not work without the body placed in context. Furthermore, AI has problems in the "twin scale-up of environmental richness and real-time dynamics [which] has so far proved insurmountable" (Anderson, 2003, p97). The issue here is that an AI system has not only to perceive or sense what it is in the environment, but has to interpret its meaning. A further problem has been in the area of planning for AI systems, "that of figuring out what to do next, given, say, a certain goal and a current situation" (Anderson, 2003, p97). Dreyfus believes that computer science and AI will never have the answer to mirroring the human mind, even though 'emergence' and the use of non-symbolic modeling is beginning to show that computers can learn context and environments that they are unfamiliar with (Anderson, 2003).

Approaches to embodiment in computer science then emerge from a critique of the cognitivist tradition with Winograd and Flores' (1986), who return to the work of Heidegger to develop the idea of 'ready to hand', and 'present at hand' as part of the human condition (dasein). Heidegger suggests that whilst objects may exist in our environment – present at hand – when they are used and fulfill their function well they become a part of the user and become ready-to-hand (Dourish, 2001; Marshall, et al., 2003). In other words, as an object, especially a tool becomes a part of the body through action it thus 'disappears' from consciousness or focus of attention. Tools with tangible qualities only become revealed again (or present-at-hand) when the tool or object breaks (Heidegger, 1923), and the focus of the tool itself is foregrounded, rather than the action with it.

Heidegger focuses on the importance of mastery in interaction and of practical wisdom, or when an individual is acting in the right place, at the right time with the right experience (Dreyfus, 1991). The resulting practical wisdom of being 'thrown' into and grounded in reality can result in an ability to change the perception of others. This idea of Heidgger's was elaborated upon in the works of Merleau-Ponty who moves the discussion to the body (see section one on philosophical notions of embodiment). Here Merleau-Ponty looks at 'skilful coping', and explains the body in terms of the gestalt of a situation that an individual finds themselves placed within. Examples of this are to be found in the sociological literature (e.g. Fortin, 2002).

These approaches are explicitly manifested within the practical application of computer science. The idea of 'disappearing tools' forms the backdrop to 'ubiquitous computing' (Weiser, 1991). *Weiser's ideas expanded here* i.e. *computing as a tool*. The 'skilful coping' and 'mastery' approaches echo the importance of context put forward by thinkers such as Vygotsky (see section two on Psychology). Context-oriented action is often additionally coupled with the manipulation of external props (Anderson, 2003), the importance of which are developed further in Dourish's theory of 'embodied interaction' (2001). Dourish argues that historically computing became divorced from real interaction in the environment with the evolution of traditional desktop computing. He proposed that we should exploit our interaction with the everyday world, and our familiarity with objects as the "world of social interaction and physical artifact is the place computer technology should be inhabiting" (Dourish, 2001, p.17).

Dourish explains that phenomenologically, the use of multi-sensory artifacts enhanced or embedded with digital technology makes more sense than mere desktop computers especially when placed in particular cultures, times, or environments.

Tangible User Interfaces offer one explicit way where embodiment might be exploited through digital technology. Marshall, et al. (2003, echoing Heidegger, 1927) argue that tangible user interfaces embed digital technology in artifacts allowing for two types of tangibles: expressive and exploratory. Expressive tangibles focus on the present-at-hand and on external representation of activity, whereas in exploratory interaction tangibles provide a ‘ready at hand’ kind of interaction where the tangible is used to ‘explore’ a model that someone else has created, either by practical manipulation or theoretical reflection. Other work in the context of tangible interfaces goes so far as to suggest that children ‘think with the hands’, especially to simplify problem solving tasks (Antle, Droumeva, et al., 2009) e.g. physically turning jig-saw pieces to see where their shape fits into the puzzle. This is an example of using ‘epistemic action’ (Kirsch and Maglio, 1994), that is, action that changes the environment to reduce cognitive work (also see Wilson, section 2). Action based learning in this way with digital technologies such as tangible user interfaces provide the opportunity for potentially powerful learning experiences in context and with particular users in mind (Antle, 2007).

Gesture is also considered an extensive and important aspect that supports observable discussion and explanation (e.g. Goldin-Meadow, 1999). Manipulation of objects is seen as a gestural precursor, where physical arrangement, participants, and artifacts provide the support necessary to achieve communicative competence (Roth, 2002). Tangible interfaces offer such manipulative /gestural activity with artefacts, potentially fostering effective communicative ability. In HCI, gesture has also been used to make experiences more seamless. Instrumental and empathic gestures (i.e. gestures that do something like pointing at an object as opposed to showing surprise by placing the hand over ones mouth) have found that technological experiences that are high in gesture, are equally high in social interaction (Lindley, Le Couteur, & Bianchi-Berthouze, 2008) More recently, gesture has been used as an indicator of quality of experience with multi-touch interaction (Hurtienne, et al., 2010). Gestures are now being explored not only in the 2D touch dimension but in the 3D 'free form' type which can occur with a MS Kinect system (Hurtienne, et al., 2010).

As active exploration, in contexts like tangible interfaces, extends sensitivity in haptic feedback, tangibles offer a hands-on way of extending our perception (Hoggan, forthcoming). Haptic interfaces offer an important and powerful tool for interaction, as they usually exist multi-modally, using visual, auditory and haptic feedback. Tactile feedback in particular has been found to be better when used passively or actively for "alerts and structured feedback" (Hoggan, forthcoming, p.15). The “skin is often less engaged in other tasks than the eyes or ears, and [so] it is always ready to receive information (Hoggan, forthcoming, p.3)." In contrast, kinesthetic perception refers to sensations that arise from muscles and tendons in real space and are at the mercy of force, position and velocity. Kinesthetic feedback is useful for active interaction with objects as our own awareness of our limbs placement in space ranges only from 20-30Hz, as opposed to tactile perception of frequencies that can be anything from 10-250Hz (Hoggan, forthcoming). This makes it understandable as to why the iPhone and touch screen technology has become more advanced than interactive gaming equipment, which, whilst popular, has not had as much immediate impact on the technological market. Haptic technology is still relatively new, and as result most haptic feedback only offers low resolution for quantitative information. However, haptic interfaces can create the physical sensation of pressing a button, holding a ball or even completely new touch sensations (Hoggan, forthcoming).

Kinesthetic interaction with digital technology has led to exciting ways in which whole-body interaction may be invaluable. For example, where concepts are otherwise hard to engage with, such as tonal harmony, whole body interaction can enable learning to occur particularly by applying the theory of conceptual metaphor, discussed in section one (Holland, Wilkie, Bouwer, M., & Mulholland, 2011). Holland et al. (2011) used Dalcroze Eurhythmics to show how simply hearing examples of tonal harmony was not sufficient for understanding. Rhythmic gymnastics and movement were integrated into a game 'Harmony Space so that different musical pieces through movement places harmony, pitch, scale, key, chord function, root and bass line onto a visual plotting device.

Whole body interaction also allows interactional mappings between "input actions and output responses” (Antle, Corness, & Droumeva, 2009). For example, in their SoundMaker environment, musical concepts such as tempo, volume and pitch were mapped to movement in terms of the speed, proximity and flow of movement. This relationship between conceptual metaphor and whole body interaction was also explored in Springboard (Antle, Corness, et al., 2009), where children physically engaged with a balance board to explore notions of social justice. Here ideas following three themes of agricultural production, health and nutrition and culinary aesthetics to explore balance are related to three images displayed on a screen. As participants moved on the balance board the image and sound were triggered to display representations that approximated the users' understanding of social justice.

Tactile interaction in mobile systems, coupled with context-aware systems are now found in the Android, iPhone, and other mobile platforms. The world in mobile form therefore takes a step closer to becoming the interface, and enables computer supported work with sensors embedded in the physical environment (e.g. Weiser, 1991; Price and Winters, 2005). Applications such as Layar, ARCGis, Google Earth, and learning prototypes such as the mobile application GeoSciTeach place the individual at the heart of geographical interaction (Haklay, 2010). Here embodiment extends the reach of the individual to being part of a larger environment, making individuals context aware through information presentation and overlay. Applications such as Layar, overlay information on top of what is already present in the immediate (or remote) environment. Space is then calculated according to co-ordinates, distance or the ability to extrapolate and interpolate information (Haklay, 2010). The extent to which the interface alters with mobile technology enables physical and social location to be impacted upon, and this can affect learning task as well as the extent of collaboration taking place (Price and Winters, 2005). In this respect context itself becomes content (Price and Winters, 2005).

Conclusion

What does this mean for research in digital environments, and of particular interest within the MODE project, the research methods for exploring digital learning environments? Some key themes that emerge, and which can form the basis for empirical work, include: action, gesture and physical engagement; context and situated-ness; environment-interaction-cognition relationship; and metaphor-based interaction, particularly with respect to digital-physical mappings for both physical and conceptual interaction. Each of these themes are important in shaping research directions to gain insight into the role of ‘embodiment’ in technology learning environments, and raise questions such as,

What does embodied learning look like and what kinds of embodied learning do people experience?

How do digital technologies enable or shape ‘experience’ and to what extent – if any - are these then ‘embodied’ experiences?

Do context-aware mobile applications support more ‘embodied’ interaction with the environment? What forms of embodiment do tangible technologies or sensor technologies foster, and what is their role in learning?

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