Physical Creatures in a Digital World

Alan Dix[1,2]

[1] Talis
43 Temple Row
Birmingham, B2 5LS, UK

[2] InfoLab21
Lancaster University
Lancaster, LA1 4AW, UK

alan@hcibook.com

http://www.hcibook.com/alan/papers/ecce2011-keynote/

ABSTRACT

We are creatures of flesh and blood, our whole cognitive nature well fitted to a physical world of solid things, and yet, within our lifetimes, learning to deal with digital devices our flint-knapping forbearers could never envisage. This paper explores some aspects of this. Inter alia, we see how Fitts' law is really a law of cybernetic extension and how this extension has been part of our being since the earliest humans and we discus the way imagination and externalisation, two complimentary aspects of our cognitive being, fit us for physical life and yet are also essential as digital denizens.

Keywords

embodiment, external representation, Fitts law, imagination

INTRODUCTION AND MOTIVATION

For many years I have been driven to understand our physical nature. This is partly to inform the design of the many devices that surround us, phones, washing machines, automatic doors, which have both physical form and digital behaviour. It is also partly to understand the design of purely virtual spaces; and at present especially the web as I work part of my time for Talis a semantic web company. In the digital world of web, desktop, VR and visualisation, some, but not all the rules of the physical world are relaxed, but which are the ones that really matter?

To make sense of these rich facets of our nature as humans I look partly to past theory in various areas (from cognitive science to mathematics, from textile technology to philosophy), partly to personal experience and common sense (sadly underrated in academia!), partly to empirical work (some I have been involved with personally and some reported in the literature), and partly to more esoteric sources: fairytale, science fiction and the cognitive psychology of dreams.

DIGITAL AND PHYSICAL WORLDS MEET

My own professional life and I'm sure that of all at ECCE is constantly sitting at the interface between the physical and digital. To some extent the ubiquitous GUI enables us to 'abstract away from' (*aka* ignore) the physical nature of screen, keyboard and mouse, but more recently the raw stuff of the physical world has been rubbed in our faces with mobile devices, consumer electronics and burgeoning fields of ubiquitous computing, tangible user interfaces and touch-based interfaces.

LEAVE BLANK THE LAST 2.5 cm (1") OF THE LEFT COLUMN ON THE FIRST PAGE FOR THE COPYRIGHT NOTICE.

From Philosophy to Action

Philosophical exploration of this area dates back many years. Heidegger's 'Being and Time' [22], is often seen as the start point of this, and several of Heidegger's concepts have found their way into human–computer interaction literature: the idea of *'thrownness'*, that unconsidered, artful interaction with devices, people and things, and, perhaps more well-known, *'breakdown'*, when some problem forces us to think more explicitly about what we are doing. Heidegger's hammer example has become *passé*, albeit often misconstrued in terms of 'pick up and use' interaction. Rather the hammer is artfully used by the skilled carpenter as part of an overall workplace of equipment, hardly noticed, *'ready to hand'*, with the focus on nail and wood joining, not the hammer (thrownnness) ... until, when the head becomes lose, suddenly the hammer becomes the centre of conscious attention (breakdown).

In perceptual psychology Gibson's notion of *affordance* [18] (albeit, again, often misconstrued) has become part of everyday user interface parlance [17, 26, 21]. However, more fundamentally Gibson challenged the input–output pipeline view of perception–thought–action, instead regarding perception and action as intimately intermixed. We immediately perceive the potential for action of (natural) objects around us (affordance), but also act to perceive: turning our eyes, or stretching our neck to see better, or even moving in the environment to see around a corner (*epistemic action*).

In addition to themes from both these strands finding their way into human–computer interaction (HCI), *distributed cognition* [24] and *situated action* [32] have had a strong influence on HCI thinking since the late 1980s. Both emphasise the way in which we do not simply think inside our heads, but instead our thinking / cognition / planning is part of a constant engagement with the environment, both physical and digital. *Information foraging theory* [27] can also be seen within this light as it is crucially about

epistemic action, the continuous decisions made about the *actions* required for acquiring knowledge

Sometimes the terms used: distributed *cognition* or extended *mind,* cause controversy even where the underlying phenomena are undisputed. However, Halpin, et al. [20] note that the web community finds little problem with the language of embodiment, indeed '*collective intelligence*' is widely accepted without it eliciting great debate about the nature of intelligence. But, it may be that the form of this non-localised 'intelligence' *should* generate more discussion; Carr and Harnard [2] have shown that while web search uses the agglomerated results of massive amounts of human text, it functions very differently from individual human memories in terms of the kinds of associations it forms. The collective human mind is no less alien to the individual human than ET.

Optimality and the Optimal Fallacy

The idea of optimality is central to *'rational analysis'* in traditional psychology [1] and Darwinian arguments for fitness to environment. It also arises in embodiment theory where the *'parsimony'* principle asserts that we do not bother to represent things in our head that are better represented in the world. Of course the counter is also true (but less often asserted): we do not bother to consult the world when we can more rapidly simply remember things. In fact, these ideas of optimality are overstated, there is an *optimal fallacy* [11], assuming things are optimal when in fact for many reasons they rarely are. The reasons fpr partial or non-optimality include *path effects* (we can only build on what is there already), *self-reinforcing structures* (like the sexual selection that leads to the peacock's tail), *resource limitations* (if we were really perfect optimisers our brain would be so big it would break our neck).

Simon's concepts of *'bounded rationality*' and *'satisficing'* [30] and more recent work on *bounded rational analysis* [23] do take the last of these into account, but there is still a widespread belief in at least some level of optimisation. In particular the fundamental infinite regress of true physical optimisation[1] is rarely considered.

Non-optimality is evident in various experiments. Gray and Fu [19] found that, when given the option of consulting instructions or recalling from memory, people rely *too much* on their own memories; in the sense that their total task times are longer due to errors. Similarly Salmoni and Payne [29] found that, when assessing the relevance of search results, even expert web users gave undue credence to Google-style snippets as compared to web page titles, even though the former gave less accurate results.

[1] The infinite regress arises because the process of selecting an optimal (or even good enough) action requires potentially costly epistemic action and may result in costly delays in action choice (tiger has eaten you before you decide to run). So there is then a meta-level choice as to when to stop considering and just do something. Of course this meta-level decision requires consideration and information ...

Fitts' Law and The Eternal Cyborg

Fitts' Law is undoubtedly the most well known psychological result in HCI. In Fitts' original paper [15], he used *information theory* in order to explain the empirical results, based on the success of Shannon and Weaver's analysis of communication [34]. Personally, I prefer more *cybernetic models* of Fitts' Law behaviour [5], because they reflect closely the actual processes going on and moreover allow successful predication of novel situations, including ones where Fitts' Law itself does not hold, but some cybernetic variation does. By cybernetic, I mean models that take into account the closed feedback loop between muscle movement and perception (visual, haptic, or procioceptive). This naturally leads to Fitts' Law under certain circumstances (e.g. error proportional to distance moved) based on a series of exponentially reducing iterative movements and corrections.

Sadly the field of psychomotor research largely avoids either information theoretic or cybernetic explanations and is virtually model/theory free. The rigorous and richly empirical papers in the area are often methodologically flawless, frequently winning best paper prizes, but ultimately point samples in an unbounded space, offering little opportunity for generalisation. There are exceptions, notably Eslambolchilar's work [14], but this is sadly rare.

However, it was Drewes work [13] on the failure of Fitts' Law for eye gaze that opened my own eyes to the deeper truth about Fitts' Law. Drewes quite rightly criticised the explicit or tacit assumption in so much work that Fitts' Law holds universally. This was based on his own experiments and examination of the literature of eye gaze 'pointing'. The majority of work in the area claimed "Fitts' Law" whereas what it actually demonstrated was, at most, some level of increasing difficulty with distance and size, not the strict logarithmic quotient of Fitts' Law.

Eye gaze is different from finger or mouse pointing as these are hand-eye coordination tasks, where the fixation of eye on target is the rapid initial component rather than the whole of the interaction. Furthermore, a single saccade of the eye is sufficient to take the eye to within one foveal distance of a target; that is 'good enough' target acquisition within a single ballistic movement, with no corrections.

However, there are a small number of eye gaze results with a pointer tracking the eye, which is then much smaller than the fovea (e.g. [33]). In this case there does seem to be additional corrective movements, even though this is never necessary with natural saccades. That is there does appear to be a cybernetic law (although not strictly Fitts' Law), when the eye is *artificially augmented*.

On reflection this is equally true of hand and arm movements. Choose a point on the desk, look at it for a moment, close your eyes, and move your arm to cover the point with your hand. You will find you can do this almost every time. Do the same with a dot that is close to you finger. Our arms and finger muscles are accurate enough to

move to the accuracy required, that of the manipulator at the end of them, with a single ballistic movement.

Fitts' Law only arises when our arms or fingers are artificially augmented with an effector of smaller size (e.g. mouse pointer or pencil tip), requiring finer accuracy than our natural hand or finger. That is, Fitts' Law is not just a cybernetic law, but a *law of cybernetic extension*.

Some years ago I wondered about the way we extend our sense of self and body, for example, when driving a car. The amazing thing is that we have the ability to do this despite the fact that cars (and equally knives and forks, violin bows, or computer mice) are recent in evolutionary terms. My conclusion was that the long heritage of tool use from termite sticks to stone axes had prepared us for the extensions we use today. The same seems to be true of that staple of HCI, Fitts' Law.

This physical cybernetic extension dates back to pre-human hominids. Looking at a more recent and core human attribute, Clark suggests that *language* acts as an information extension allowing higher-level thought, distributed cognition and cultural development; another form of cyborg extension [3]. In the past I have suggested several information ages since this first acquisition and cultural use of language: the second marked by the large empires and the use of distant communication (written or oral messages); the third by the informational role of money as information transfer agent in the emerging market economy of the 15/16th centuries, and now, in the fourth age, this role of money and all information becomes digital. At every stage, the locus of the information that shapes us is distributed; that is our informational cyborg qualities are also nascent from the earliest times.

A FOOT IN BOTH WORLDS

So, our human natures have always sat at the cusp between physical and virtual. Two complimentary aspects of our cognitive being, *imagination* and *externalisation*, fit us for physical life and yet are also essential as digital denizens:

Imagination

Various writers, coming from different psychological perspectives, suggest that our minds are not like 'Swiss Army knives'[2] equally adapted to any situation, but more a collection of special purpose tools, 'intelligences' for different contexts: social, physical, etc. [16, 28]. However, we clearly do manage to operate in an integrated fashion. Mithin [25] traces the way in which these different special purpose intelligences developed from the paleontological record, and concluded that it is precisely the linking, which emerged approximately 60,000 years ago, that gave us our special human abilities. The individual special purpose 'intelligences' are still operating [4], and indeed learning to harness these is important in many aspects of life including interface design, however, they are also able to operate together in what Mithin refers to as 'cognitive fluidity'. Mithin does not say what this linkage comprises, although language is clearly part of the picture.

Of course, even the simplest creatures do operate consistently in the world, not at the mercy of schizophrenic warring between differing cognitive systems. For them it is the world itself that acts as the point of linkage – a very embodied intelligence. I have previously argued that imagination effectively fulfils the same role as the external world, but internalised, offering an additional way for multiple intelligences to operate in concert, effectively internally embodied in a virtual world [6].

So both language and imagination, often seen as opposing aspects of personality: rational vs. intuitive, are both acting as points of integration. Moreover, I am constantly amazed at the way these are not alternatives, but richly interwoven features of even the most basic aspects of life. I have been particularly fascinated by the nature (and computational modelling) of regret and how it brings together imagination, rationality, emotion and primitive response [7], and also the way the orderliness of dreams gives insight into the cognition of waking life [8].

Externalisation

The counter to this is *externalisation*, the way in which we represent our internal concepts and thoughts in the world outside – both digital and physical: from cave art to mathematics, from maps to design sketches [10].

External representation is clearly central to communication and collaboration including 'boundary objects' [31] and a core element of 'offloading' in distributed cognition. I refer to these as the *informational* and *transformational* role of externalisation respectively.

However, most amazing is the way in which externalising on paper or in words seems to increase what we know or understand, even if it is our own words. We have all experienced this, when we read back words we have written and think "I never knew that before", and yet the words came from our own hand.

This learning from our own words arises from two further roles of externalisation. First is the *formational* role. We already know something, in the sense that we can use it or apply it, but it is the *processing* required to make it explicit, whether to communicate to others or simply to world on it ourselves, that gives it solidity.

Finally this making both explicit and observable what was tacit and hidden, exposing the 'unknown knowns', allows higher levels of cognition as we can talk about out very concepts and thoughts. This talking about our thoughts is allows a higher level of thinking, and so I usually refer to this role as *transcendental* (without its mystical overtones), literally raising us to a different level.

In fact this transcendental role, is the common experience of many HCI papers, with diagrams laying out design

[2] Note the term 'Swiss Army knife' is heavily used, but is really a poor metaphor for general purpose intelligence, as it is effectively a collection of special purpose blades in one package. Maybe the way a backwoodsman uses a machete for everything would be a better analogy.

spaces. Indeed, the research and creativity techniques I have worked on often involve making criteria, properties and relationships explicit and thereby making it possible to reason about their own interrelationships [9].

Of course once concepts are explicit and discussed, ideas about the concepts can in turn become explicit allowing yet further levels of meta-reasoning, as indeed this very paragraph is doing!

AND MORE

For more on these topics see my recent Web Science paper [11] and the new (well partly written!) book TouchIT [12].

REFERENCES

1. Anderson, J. 1990. *The adaptive character of thought*. Erlbaum
2. Carr, L. and Harnad, S. 2009. Offloading Cognition onto the Web. *Proc. of WebSci'09*
3. Clark, A. 1998. *Being There: Putting Brain, Body and the World Together Again*. MIT Press.
4. Cosmides, L. 1989. The Logic of Social Exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. *Cognition*, 31:187–276.
5. Dix, A. 2003. *A Cybernetic Understanding of Fitts' Law*. Human–Computer Interaction: Online!. http://www.hcibook.com/e3/online/fitts-cybernetic/
6. Dix, A. 2003. *Imagination and rationality*. http://www.hcibook.com/alan/essays/
7. Dix, A. 2005. *The adaptive significance of regret*. http://www.hcibook.com/alan/essays/
8. Dix, A. 2006. *The stuff of dreams*. http://www.hcibook.com/alan/essays/
9. Dix, A., Ormerod, T., Twidale, M., Sas, C., Gomes da Silva, P. and McKnight, L. 2006. Why bad ideas are a good idea. in *Proc. of HCIEd.2006-1 inventivity*, Ballina/Killaloe, Ireland. 23-24 March 2006
10. Dix, A. 2008. Externalisation – how writing changes thinking. *Interfaces*, 76, 18-19. http://www.hcibook.com/alan/papers/externalisation-2008/
11. Dix, A. 2011. A Shifting Boundary: the dynamics of internal cognition and the web as external representation. In *Proceedings of WebSci'11.*
12. Dix, A., Gill, S., Ramduny–Ellis, D. and Hare, J. 2011. *Touch IT exploring the physicality of the world and the design of digital products*. http://physicality.org/TouchIT/
13. Drewes, H. 2009. *Eye Gaze Tracking for Human Computer Interaction*. Ludwig-Maximilians-Universität, Munich.
14. Eslambolchilar, P. 2006. *Making Sense of Interaction Using a Model-Based Approach*, PhD thesis, Hamilton Institute, National University of Ireland, NUIM, Maynooth, Ireland.
15. Fitts, P. 1954. The information capacity of the human motor system in controlling the amplitude of movement. *Jnl Exp. Psychology*, 47, 6, 381–391.
16. Gardner, H. 1983. *Frames of Mind: The Theory of Multiple Intelligences*. Basic Books.
17. Gaver, W. 1991. Technology affordances. In *Proc. of CHI'91*. ACM Press. 79–84.
18. Gibson, J. 1979. *The Ecological Approach to Visual Perception*. Lawrence Erlbaum.
19. Gray, W. and Fu, W. 2001. Ignoring perfect knowledge in-the-world for imperfect knowledge in-thehead. In Proc. of CHI '01. ACM Press, 112–119.
20. Halpin, H., Clark, A. and Wheeler, M. 2010. Towards a Philosophy of the Web: Representation, Enaction, Collective Intelligence. In *Proc. WebSci10*
21. Hartson, H. 2003. Cognitive, physical, sensory, and functional affordances in interaction design. *Behav Inform Technol*. 22, 5, 315–338
22. Heidegger, M. 1927. *Sein und Zeit*. (English translation: *Being and Time*. Harper, 2008)
23. Howes, A., Vera, A., and Lewis, R. 2006. Bounding rational analysis: Constraints on asymptotic performance. In Gray, W. (ed.), *Integrated Models of Cognitive Systems*, Oxford University Press.
24. Hutchins, E. 1995. *Cognition in the Wild*. MIT Press.
25. Mithin, S. 1996. *The Prehistory of the Mind*. Thames and Hudson.
26. Norman, D. 1998. *The Design of Everyday Things*. MIT Press.
27. Pirolli, P. 2007. *Information foraging theory: adaptive interaction with information*. Oxford University Press
28. Tooby, J. and Cosmides, L. 1997. *Evolutionary Psychology: a primer*. http://www.psych.ucsb.edu/research/cep/primer.html
29. Salmoni, A. and Payne, S. 2002. Inferences of Content from Search Engine Summaries and Headings. *Proc. HCI2002*, vol 2.
30. Simon, H. (1992). What is an "explanation" of behavior? *Psychological Science*, 3, 150–161.
31. Star, S. The structure of ill-structured solutions: boundary objects and heterogeneous distributed problem solving, in: Gasser, L. Huhns, M. (eds.), *Distributed Artificial Intelligence*, Volume II, Morgan Kaufmann, SF Mateo, 1989, pp. 37–54.
32. Suchman, L. *Plans and Situated Actions: The Problem of Human-Machine Communication*. Cambridge University Press. 1987
33. Ware, C., and Mikaelian, H. 1987. An Evaluation of an Eye Tracker as a Device for Com-puter Input. In *Proc. CHI '87*, 183 – 188
34. Weaver, W. and Shannon, C. 1963. *The Mathematical Theory of Communication*. Univ. of Illinois Press.