Interaction Design for Active Bodies: Two Themes

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ABSTRACT

Our physical bodies play a central role in shaping human *experience* in the world, *understanding* of the world, and *interactions* in the world. Reality-based interfaces promise to better leverage the capabilities of our bodies in human-computer interaction. In two themes, *thinking through doing* and *thick practice*, we introduce aspects of human bodily engagement with the world that designers of interactive systems should attend to.

INTRODUCTION

One of the most sweeping (and unintended) transformations that the desktop computing paradigm has brought about is the extent to which the physical performance of work has homogenized. With a keyboard and mouse interface, the use of our bodies for writing a paper is the same as for editing photographs. And playing music. And communicating with friends and family. Reality-based interfaces such as tangible UIs and augmented reality applications promise to reintroduce our bodies' capabilities for rich and subtle expression into human-computer interaction. For a combination of computation with real-world actions and artifacts to be successful though, a thorough understanding of what each can offer is needed first.

In our current work, we are shifting focus from the technologies of embodied interaction to the participating human bodies themselves. New design considerations emerge when our bodies are understood as more than just "Baby Bubbleheads" (*i.e.,* the Model Human Processor [3]). By drawing on psychology, sociology, and philosophy, we seek to elucidate how human bodies shape *experience* in the world, *understanding* of the world, and *interactions* in the world. We hope to contribute to the discussion about the future of HCI a set of interaction design considerations for active bodies and a language that can both stimulate ideation and give guidelines for evaluation of reality-based interfaces.

We have identified *five themes* that we believe are particularly salient for designing and evaluating interactive systems. The first, *thinking through doing*, describes how thought (mind) and action (body) are deeply integrated and how they co-produce learning and reasoning. The second, *performance*, describes the rich actions our bodies are capable of, and how physical action can be both faster and more nuanced than symbolic cognition. *Visibility* describes the role that observable actions on physical artifacts play in collaboration and cooperation. *Risk* explores how the uncertainty and risk of physical co-presence shapes interpersonal and human-computer interactions. The final theme, *thickness of practice*, argues that because the pursuit of digital verisimilitude is more difficult than it might seem, embodied interaction that gives primacy to the physical world may be a more prudent path. In this paper, we provide an overview of two of the five themes and show how both are concerned with the tradeoffs between physical *presence* and virtual *representation.*

THINKING THROUGH DOING

Direct physical interaction with the world is a key constituting factor of cognitive development during childhood. The importance of physical action as an active component of cognition extends throughout life. In this section, we review the connection between thinking and doing as uncovered by educational theorists, gesture researchers, and cognitive scientists. Cumulatively, their empirical work point towards a common nexus of perception, cognition, and action.

Learning through doing

Being able to move around in the world and interact with pieces of the world enables learning in ways that reading books and listening to words do not. Jean Piaget [18] posited that cognitive structuring requires both physical and mental activity. Particularly for infants in the sensorimotor stage of development, *physical interaction in the world facilitates cognitive development* [11]. In this very basic sense, humans learn about the world and its properties by interacting within it.

Pedagogies such as the Montessori method [17] employ bodily engagement with physical objects to facilitate active learning. The use of tangible manipulatives has been shown to improve elementary school student understanding of mathematical concepts. Such educational methods nicely leverage the bodily basis of mathematical concepts for learning [14]. Physical reasoning can also play an important role in professional and higher education. An example is the Illuminating Light interface [23], which enables students to create light reflection simulations by placing tangible reflectors on a tabletop surface with virtual projection (see Figure 1).

The Role of Gesture

Just as moving about in the world helps learning, gesture plays a role in pre-linguistic communication for babies [9] and aids cognition and fully linguistic communication for adults. From studies of gesturing in face-to-face interactions, we know that people use gesture to conceptually plan speech production [2] and to communicate thoughts that are not easily verbalized [4].

While gesturing is normally thought of as having a purely communicative function, many studies suggest that gesture may also play a helpful role for the speaker; for example, even congenitally blind children gesture [10]. For both adults and children, gesturing has been shown to lighten their cognitive workload [6].

Beyond continuing work in gesture recognition and synthesis, a less obvious but no less important point is that systems that constrain gesturing (*e.g.,* by having your hands stuck on a keyboard) are likely to hinder the user's thinking and communication abilities. Consider telephones: we have seen shifts from corded phones to cordless phones to mobile phones and mobile phone headsets. Experimental studies demonstrated that more physical mobility increased user creativity and disclosure of personal information in microphone use [24]. The increasingly freeing form factors of telephone technologies help users think and communicate by getting out of the their way.

Epistemic Action

Bodily engagement with physical and virtual *environments* constitutes another important aspect of cognitive work. We are familiar with people leaving keys or notes for themselves in strategic locations so that they serve as reminders in the future.

Distinguishing *pragmatic* action—manipulating artifacts to directly accomplish a task — from *epistemic* action — manipulating artifacts to better understand the task's context [12], provides an interpretation for such behavior. A laboratory studies of Tetris gameplay [15] illustrates the importance of epistemic action. One might expect that the predominant task in Tetris is piece movement with the *pragmatic* effect of aligning the piece with the optimal available space. However, contrary to intuitions, the proportion of shape rotation that are later undone by backtracking increases (not decreases) with increasing Tetris-playing skill levels: players manipulate pieces to understand what they are and how different options would work.

An analogous example of how a user's environment may be appropriated to facilitate cognitive work that would otherwise have to be done entirely in the head is how people move lettered tiles around in the game of Scrabble to help explore possible word formations [16].

Thinking through prototyping

Iterative design practices provide yet another perspective on the importance of concrete, artifact-centered action in the world to aid thought. *Reflective practice,* the framing and evaluation of a design challenge by *working it through*, rather than just *thinking it through*, points out that physical action and cognition are interconnected [19]. The production of concrete prototypes provides the crucial element of surprise, unexpected realizations that the designer could not have arrived at without producing a concrete manifestation of her ideas.

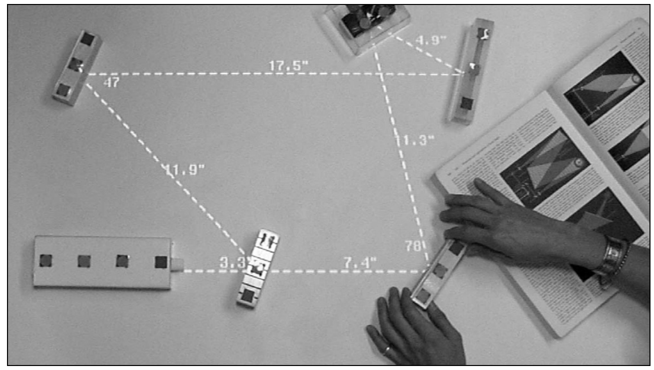

Figure 1 The tangible Illuminating Light workbench lets students learn about optical systems by designing them.

The *backtalk* that artifacts provide helps uncover problems or generate suggestions for new designs. Prototypes thus become the "essential medium for information, interaction, integration, and collaboration" [20]. Beyond backtalk, creating intermediate tangible artifacts allows for expression of tacit knowledge. It also facilitates communication within a design team, with clients, or users, by providing a concrete anchor around which discussion can occur. Prototypes then present us with a different kind of embodiment: they themselves embody design ideas or specifications, render them concrete and, in doing so, inform the designer's thinking.

THICK PRACTICE

It may seem a platitude, but it is worth repeating that, "if technology is to provide an advantage, the correspondence to the real world must break down at some point" [7]. Interaction design is simultaneously drawn in two directions. First, the promise of new technology is that it provides previously unavailable functionality. Second, in designing almost any new technology, one is drawing on existing human understanding of the world. In the creation of the new, much technology formalizes some aspects of a work practice. However, a complete formalization of practice is an elusive goal — important aspects of real-world work often remain invisible to system designers and are subsequently denied by the introduction of new technology (*cf.* [21]).

This section argues that interfaces that *are the real world* can obviate many of the difficulties of attempting to *model all of the salient characteristics of a work process as practiced*. This argument builds on Weiser's exhortation to design for "embodied virtuality" rather than virtual reality [25]. Designing interactions that *are the real world* instead of ones that simulate or replicate it hedges against simulacra that have neglected an important practice.

A system that respects the primacy of physical practice is Final Scratch [1], which provides access to digital music for DJs through specially encoded vinyl records (see Figure 2). These vinyl records contain a time code instead of an audio signal. The system interposes a soundcard into the signal path between turntable and mixer to pick up the time code, link it to playback of digital music files on a laptop computer, and return that audio signal to the inputs of the mixing console. FinalScratch affords continuity of practice —skills acquired over years of practice still apply since the physical interface has not changed. DJs regard it as superior to competing digital control products (such as CD players with jog dials) because digital controls do not provide the sensory richness or the nuance of manipulation offered by the "real thing."

Books with Voices [13] augments paper transcripts of oral histories with barcodes printed alongside the text. These can be scanned by a PDA to access original audio recordings. In retaining the printed paper page as the primary artifact around which interaction is structured, the system embraces existing reading practices, grafting digital media onto them.

The project of technology is the creation of increasingly malleable materials, and computation is perhaps the most malleable created so far. Given the techno-utopian ideology of computer science, it can seem heretical to suggest that one should undertake a project other than replacing the physical world. Clearly, the digital world can provide advantages. To temper that, we argue that *because there is so much benefit in the physical world*, we should take great care before unreflectively replacing it. More precisely, from a design perspective, solutions that carefully integrate the physical and digital worlds — leaving the physical world alone to the extent possible — are likely to be more successful by admitting the improvisations of practice that the physical world offers.

REPRESENTATION AND PRESENCE

A shared problematic underlies the discussion of both preceding themes: which parts of a reality-based interface should be assigned to the virtual realm and which to the physical realm in order to best combine the affordances of both? Is it more advantageous to start with a symbolic model and reify it by providing physical handles that *represent* objects in the virtual world, as in the Illuminating Light workbench? Or should one instead focus on preserving the *presence* of existing artifacts and enhance them with virtual functionality, as in the FinalScratch system?

The promise and challenge of reality-based interfaces lies in the fact that they simulatenously represent an underlying digital model (they stand for something else), while they are also present (in immediate existence) in the actor's world.

Figure 2 Final Scratch: encoded vinyl for digital music.

The crux for interaction design then is deciding how to tie properties arising out of the presence of the interface to properties of the digital information being represented and vice versa.

Tangibility offers both direct familiarity and a set of common metaphors to leverage in interaction. But some mappings between the physical and the virtual work, while others clearly don't. An example of an interactive system that successfully leverages our familiarity with everyday physics is the automotive drive-by-wire system that uses force feedback to alter driver perceptions of the road [22]. It discourages lane drifting by exerting forces on the wheel such that the driver has the impression that the driving lane is shaped like a shallow bathtub. On the other hand, a professor of computational logic demonstrates to his class how propositional inference can be performed in physical space using stackable boxes – however, in this case a purely symbolic representation of the problem on paper will yield a solution much more quickly.

So what guidelines can we give to designers? Djajadiningrat *et al.* [5] cite that many tangible user interface researchers have gravitated towards "natural" mapping, which are intuitively understandable because of their straightforward identification of virtual attributes with physical ones. *I.e.*, objects are positioned in virtual space by moving physical handles in physical space. We share their concern that these identifications are only possible for a restricted domain of systems – how do we interact with symbolic information that does not have an obvious physical equivalent? While we cannot provide ready operationalizable guidelines, we believe the problem of developing successful representation strategies is a fruitful area for further research.

CONCLUSION

Hollan and Stornetta argue that the impact of electronic media should not be measured by how well they can approximate the affordances of face-to-face interaction, but rather how they can surpass the constraints of co-presence and co-location to offer value that motivate their use even if face-to-face communication is available [8]. Similarly, we should not just strive to approach the affordances of tangibility in our interfaces and interactions, but to go beyond what mere form offers. A better understanding of the affordances of physicality and concreteness for the design of interactive systems is a first step in this direction. We believe this work will be of value both *generatively*—helping designers come up with new solutions — and for *evaluation*—providing a rich set of axes for analyzing the benefits of systems.

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