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Immediate Interactive Behavior — How Embodied and Embedded Cognition Uses and Changes the World to Achieve its Goals

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Motivation

We rarely solve problems in our head alone. Instead, most real-world problem solving and routine behavior recruits external resources and achieves its goals through an intricate process of interaction with the physical environment.

Immediate interactive behavior (IIB) entails all adaptive activities of agents that routinely and dynamically use their embodied and environmentally embedded nature to support and augment cognitive processes. IIB also characterizes an emerging domain of cognitive science research that studies how cognitive agents exploit and alter task-environments in real-time. Examples of IIB include arranging coins when adding their values, solving a problem with paper and pencil, arranging tools and ingredients while preparing a meal, programming a VCR, and flying an airplane.

Whenever a cognitive agent actively interacts with the world, the resulting process is likely to transform both the cognitive system and the environment. Thus, IIB is *adaptive* in two complementary but distinct ways: On one hand, the cognitive system adapts itself to the structure of its task environment to transcend its inherent limitations (e.g., of attention and memory). On the other hand, cognitive systems exhibit a pervasive tendency to adapt and structure their environments in service of their goals.

The bi-directional plasticity of the mind-matter coupling is both a boon and burden to researchers. *Conceptual* and *theoretical* challenges of an environmentally embedded cognitive science include the following:

A new role for cognition? When cognitive processes are seen as reaching out into the world the traditional boundaries between cognition, perception and action are blurred. Whereas the scope of ‘cognition’ is traditionally limited to mental processes, it can be extended to include an all-encompassing superset of internal and environmental activities. Alternatively, the role of cognition could be re-interpreted as a highly specialized mediator between various internal and external subsystems. This more narrow view of cognition shifts the emphasis from the scope of cognition to the control of integrated cognitive systems.

What constitutes ‘the environment’? Identifying the relevant context of an environmentally embedded agent is non-trivial. An adequate representation of the environment will have to adopt a functional perspective. The functional task environment differs from the physical environment and includes aspects of the agent’s history, knowledge, goals, and capacities for action. Rather than a source of problems, the environment becomes a resource of constraints with opportunities for perception and action.

What kind of theories? Despite a long and distinguished history in philosophy, psychology, and anthropology, notions about the fundamentally embodied and embedded nature of cognition have been expressed primarily in verbal form and do not easily lend themselves to scientific abstraction. Current research employs the formal tools of mathematical modeling, computational cognitive modeling, and robotics. Although these methodological shifts promise to bridge the gap between context-free formal theories and context-rich informal descriptions it is currently unclear to what extent cognition and environment can be modeled in a unified framework. Building realistic models of complex environments imposes high costs on researchers while taxing the capacity of tools (like cognitive architectures) that have evolved in the context of simpler laboratory tasks.

Specific issues regarding the nature of the agent-environment relationship in IIB are frequently implicit assumptions about the optimality of the adaptive process, the types and shapes of trade-offs that an interactive agent engages in, and the metric on which system costs need to be evaluated.

These theoretical challenges are counterbalanced by an ecologically enlightened perspective’s enormous potential for *practical applications*:

Designing artifacts and environments. The ubiquitous human tendency to exploit the environment can be used to design tools and environments that enable augmented cognition. As our actions are increasingly mediated through technology, cognitive engineering applies insights into the nature of IIB to create better user interfaces, complex data visualizations and decision aids.

Education and instruction. Designing environments that allow for an opportunistic exploitation of their resources creates new learning experiences. Flexible training methods that can be adapted to the specific needs of individuals can transform traditional classroom settings and inform the design of new learning materials.

In summary, the study of IIB is situated at the intersection of cognitive science, engineering, and design. As part of a true 'science of the artificial' a deeper understanding of the interactive nature of cognition promises to change the world through cognitive technologies.

Contributors

Richard A. Carlson: Intentional control depends on active representations that specify the self acting with respect to mental or physical objects to achieve goals. Active representation is costly, and skill is achieved in part by streamlining and schematizing these representations. This streamlining relies on support from environmental regularities, such that some elements are minimally specified in advance and bound only briefly to information immediately available in the environment. I will sketch an account of intentions as states of working memory, emphasizing how those states may differ as a function of skill acquisition and the conditions for streamlining and schematization. This account implies particular roles for spatial and temporal regularities in the environment, and constraints on the potential for metacognitive monitoring of one's performance. These constraints are present in real-world high-performance environments, and may be responsible for undetected lapses and slips that can have serious consequences. I will present examples of empirical data that support this account and discuss the challenges these data pose for computational models.

Wayne D. Gray: Immediate interactive behavior occupies a special place in Allen Newell's timescale of human action. It is squeezed between the neural level where behavior is determined by the structure and functioning of neurons and neural circuits, and the knowledge level where behavior is determined by the structure of tasks. At the ~~1 sec level, cognitive behavior is *assembled* out of pre-existing, cognitive, perceptual, and motor operations to form interactive routines. These interactive routines represent the basic building blocks of embodied cognition. At the next level, the unit task level (~~10 sec), interactive routines are selected and composed to deal with the given task in a given task environment. The Soft Constraints Hypothesis maintains that these properties of unit tasks and interactive routines make resource allocation in immediate interactive behavior exquisitely sensitive to the temporal cost-structure of the task environment.

Alex Kirlik: An important commentary on our science is implied by both the title of this symposium ("Immediate Interactive Behavior") and the theme of this year's conference ("Cognitive Science in the Real World"), as if they had much in the way of significant alternatives. Almost certainly, the vast majority of human cognition involves monitoring and controlling our behavior in real-time interaction with our physical, technological and social environments, and most certainly, all of the cognition we know about exists in the real world. So, what exactly is meant by these terms, and why does immediate interaction with the "real world" occupy such an esoteric rather than central place in our science? I will examine these questions and, more importantly, present insights gained from our research program on modeling cognition accompanying dynamic, interaction with the world, focusing on implications for theory and methodology.

David Kirsh: It is by now well accepted that people are closely coupled to their environments at different temporal levels, ranging from a few hundred ms to minutes. The class of immediate interactive behaviors I will discuss may be called *externalizations*: talk or action that makes manifest inner state. When people talk out loud, for example, to help understand a problem or to remember a telephone number they are externalizing. By externalizing they recruit different pathways for processing information than those which are active when information is processed from the inside alone. Externalization is pervasive: people are taught to read aloud rather than silently when they proof read, they learn to manipulate playing cards to externalize plans or plan fragments, they shift scrabble tiles around to complement their internal search, they annotate to externalize ideas that they want to keep in front of them, to illustrate in order to extend structure to levels that are hard to maintain internally, to write down to permit reworking, and so on. I will discuss the computational and psychological reasons why externalization is a good strategy. It is a technique that is rational, powerful, and with quantifiable benefits for reasoning and coordination.

Stephen J. Payne: Even expert users of computer systems cannot plan some simple sequences of actions, because they do not know the exact effects of operations, instead needing to read these effects from the display. In other situations, planning is possible, but costly, so that problem solvers may choose not to plan — a critical influence on behaviour becomes the ongoing plan-or-act decision cycle. How people choose to schedule the interleaving of their cognitions with their actions exerts a crucial role on learning-by-doing and learning from instructions, and is central to the understanding of multiple-task activity.

Objectives and Online Forum

The symposium provides a platform to prominent researchers to highlight recent work, discuss current issues and help to define the identity of IIB as a field. Rather than presenting results and solutions, we aim to identify gaps in our current understanding and propose directions for future research.

An *online discussion forum* complements the event at **http://iib-wiki.cogsci.rpi.edu**. All are welcome to contribute to this forum, and recapitulate or continue the discussion beyond the actual event.