The Cognitive Revolution: The Next Wave

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Scientific progress sometimes comes not from new methods, but from new concepts, new ways of framing old problems. The cognitive revolution is a wonderful example of this. The language of information processing and computation provided a new way of thinking about what the brain does. Recently, though, I was forcefully reminded that this revolution is not yet complete. It's not just a matter of explaining its implications to the scientific community at large. We psychologists have barely begun to tap the potential of the cognitive revolution for transforming our own field.

What occasioned these thoughts? Recently, I had to explain to a panel of eminent biomedical scientists — most were pharmacologists, biophysicists, chemists, molecular biologists, and physiologists — what I spend my time doing and why they should care. You all know the problem this poses. No one thinks that having a heart gives them special insight into how it operates. But it is seductive to think that having a brain gives us each special insight into its internal workings — a problem made worse by the theory of mind mechanism, which generates the intuition that the causes of behavior are simple: our beliefs and desires.

So I started by connecting what I do to what they do: We all study organ systems. Each organ in the body evolved to serve a function: The heart was designed by natural selection to pump blood, the intestines to digest, the liver to detoxify poisons. The brain is also an organ, but its evolved function is not primarily metabolic. Its evolved function is to extract *information* from the (internal and external) environment and use that information to generate behavior and regulate physiology. From this perspective, the brain is a computational device — a physical system that was designed to process information. So to describe the brain's operation in a way that captures its evolved function, you need to think of it as composed of programs that process information. This requires theories expressed in information-processing (computational) terms. I explained that these are not the poor relations of neural or molecular theories: Neural circuits were retained or discarded by selection *because of* the computations they created. This means the information processing level of description is essential for knowing what the neural circuits are *doing*, and will never be made obsolete by progress in molecular biology and neuroscience. This powerful insight turned the study of perception, attention, memory, reasoning, and learning into a real science. But, there are so many topics to which it has barely been applied!

So far, the cognitive sciences have told us a reasonable amount about the computations that go on in our brains when we are learning mathematics, reading, or reflecting on our day — so-called "higher-level" or "cold" cognition. But they have told us very little about the automatic, spontaneous, and largely nonconscious computations that go on in our brains when we are angry, grieving, falling in love, jealous, feeling guilty, helping friends, or soothing a child, let alone the computations that give rise to family love and conflict, the desire to be part of an "us" or to compete with "them," the impulse to contribute to the common good or to punish those who don't. Clinical psychologists deal with phenomena like these on a daily basis. But how many cognitive scientists study these topics? Would a program in cognitive science be likely to hire someone who did?

The psychological sciences are poised to make remarkable progress in understanding these emotional/motivational states as evolved adaptations to the social lives of the huntergatherers from whom we evolved. Evolutionary biology and behavioral ecology are providing detailed formal models of the adaptive problems that arise when family members interact, friends cooperate, groups compete, and lovers bond. These models tell us that what counts as a functional outcome in each of these domains is different, suggesting that natural selection will have engineered distinct computational specializations for each. The cognitive sciences, in turn, provide methods and a language in which the information processing architecture of each computational system in the brain — socio-emotional or otherwise — can be precisely stated and empirically investigated. Given content-specific theories of the adaptive problems our brains evolved to solve, we can now search for previously unknown computational systems, ones that are well engineered by selection for producing evolutionarily functional outcomes. This will lead to a field populated by topics far different from those to which we are accustomed.

Let me illustrate the promise — and institutional problems — of this upcoming approach with a simple example. Kin selection theory leads one to expect a computational system regulating when you should feel the impulse to help siblings. This system requires a special kind of learning mechanism, one that detects which individuals in your social environment are likely to be biological siblings. A domain-general learning mechanism that picks up local, transient cues to genetic relatedness cannot solve the problem (to deduce which cues locally predict relatedness, the mechanism would need to already know who it was related to!). This line of reasoning leads one to expect that the brain will be equipped with a human kin-detection system: a neurocomputational system that is well engineered — given the structure of ancestral environments — to detect genetic relatedness in familiar others. It should use cues that were reliably correlated with relatedness among hunter-gatherers, such as duration of childhood co-residence, as the great Finnish sociologist Edward Westermarck suggested long ago. Debra Lieberman, John Tooby, and I have been exploring the computational design of this learning mechanism.

Now here is the question: at this point in history, how many cognitive scientists would recognize this as falling within the purview of their field? Yet it is the study of a learning mechanism, an investigation of its computational operations and products: what cues it takes as input; how they are combined; what kind of representation it produces as output; and what motivational systems that representation entrains. At the same time, this approach seems excessively computational to many social psychologists. Where does the study of such systems fit in? Everywhere and, therefore, nowhere.

The design of most psychology departments enforces boundaries that have outlived their usefulness. Distinctions among cognitive, social, and developmental psychology are dissolving as more and more psychologists work on formulating computationally explicit (and neurally grounded) theories of how the brain processes information in more and more domains. It's all computation, and as that realization becomes more deeply integrated into the psychological sciences, the organization of departments may revolve around adaptive problems: perception, spatial cognition, and language acquisition surely, but also parental love, romantic relationships, social exchange, coalitional cooperation, kin relations, foraging, and habitat selection. Programs in cognitive science will eventually disappear — not because the cognitive revolution has outlived its usefulness, but because it will have finally realized its full potential.