JOBS IN SOCIAL SCIENCE III

Cognitive Neuroscience: A World With a Future

At a time when many young scientists find themselves working in areas that are overcrowded and underfunded, the fast-emerging field of cognitive neuroscience offers a bracing contrast. The field these days is about as hot as they get, not least because it offers a very real chance to solve one of the fundamental mysteries of science: how the mind arises from the brain.

"The critical pieces have fallen into place in the early 1990s," declares Walter Schneider, the University of Pittsburgh psychologist who directs a joint Pitt-Carnegie Mellon University program called Neural Processes in Cognition. Neuroscientists, no longer forced to study the brain slice by slice, are now armed with new scanning techniques that enable them to watch how various regions of the brain are activated by distinct thoughts or perceptions. Psychologists, for their part, are no longer confined to studying mental events from the outside but can use "neural network" models of distributed information processing to probe how high-level functions such as perceiving, attending, learning, planning, and remembering emerge from the massively parallel neural architecture of the brain. The result is an exhilarating sense that "things are about to be understood," says Israel Lederhendler, chief of behavioral neuroscience at the National Institute of Mental Health (NIMH). "We're going to look back on this as a watershed period," says psychologist Stephen Kosslyn of Harvard University.

Flowing through that watershed is a current of new job opportunities. At the moment, notes Marta Kutas, acting chair of the Department of Cognitive Science at the University of California, San Diego, "there are probably no more than 100 people in the country who could be called cognitive neuroscientists." And they don't come close to meeting the demand. "Psychology departments across the country have realized that they've got to get into brain science—in humans and not just rats," says neuroscientist Michael Gazzaniga of the University of California, Davis, a pioneer in the study of split-brain patients. "Some little experiment looking at an effect that's isolated from the total functional story of the mind just won't cut it anymore. Departments want people who can liaison with clinicians working with brain-damaged patients, with the people doing brain imaging, with the computer jocks."

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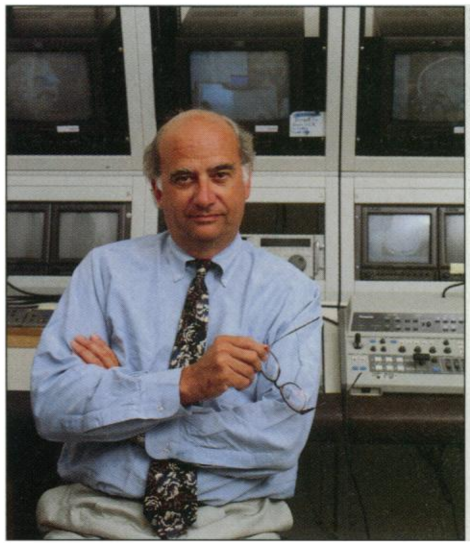
At the same time, he says, hospital neurology departments realize that they've got to get people with those same skills if they want to do state-of-the-art clinical work. University-based neuroscientists likewise see that to understand cognitive processes, their departments are going to have to start hiring people who can go beyond the field's long obsession with synaptic processes and neurotransmitters. All this means that jobs are relatively plentiful in cognitive neuroscience right now—because not many graduates have the range of experience required. Indeed, when Pittsburgh's psychology department decided this year to create a new position in cognitive neuroscience, Schneider warned that the search would probably last at least 2 years. "The demand is far outstripping the supply, and I expect that to last for quite some time," he says. "Cognitive psychology, neurophysiology, computational modeling, brain imaging—it's a tall order to bring all that together, and very few programs have the resources to carry it off."

How it began. And it's only recently that anyone has tried. The field didn't even have a name until about a decade ago, when Gazzaniga and Princeton University psychologist George Miller first coined the term "cognitive neuroscience" for a series of small meetings designed to get cognitive scientists and neuroscientists talking to each other. The field didn't really begin to take off until later in the 1980s, when some cognitive psychologists began to team up with neuroscientists to systematicially scan the brain with positron emission tomography (PET). PET scans, which identify regions of heightened neural activity by using a radioactive tracer to pinpoint areas of increased blood flow, are notoriously slow, coarse-grained, and expensive. Even so, the images they produced were galvanizing.

The experience of Harvard's Stephen Kosslyn was a case in point. By the late 1980s, Kosslyn explains, he had reached an impasse in his work on mental imagery. After years of working with psychological tests, he and others had shown that mental images seem to have much the same spatial structure as real objects. (Imagine the couch in your living room, for example. Now shift your focus to the living room window: the time it takes to do that is roughly proportional to how far apart the couch and window really are). From this, Kosslyn hypothesized that both internal and external images activate the same parts of the visual system. However, there was no way this could be verified by standard psychological tests. "The whole research program had ground to a halt," says Kosslyn.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Founding father. Michael Gazzaniga says tools now exist to explore the mind-brain gap.

But PET gave him the empirical data he needed. And the recent advent of functional magnetic resonance imaging (MRI), which allows researchers to produce finely detailed maps of brain activity with clinical MRI scanners, has provided even more. "Now we can literally see the mental image spatially laid out on the visual cortex," says Kosslyn. "When subjects alter the size of an object in a mental image, distinct regions of spatially organized visual cortex are activated in the same way as when the subjects view real objects at those sizes." These results have already been replicated in other labs. "This gives us enormous leverage. Before, all we had was cognitive data and theorizing. Now we have the brain, too."

Computational tools. Even as researchers such as Kosslyn were probing the brain with new imaging tools, other scientists were beginning to discover a similar sense of power and excitement by using new computational methods.

Psychiatrist Jonathan Cohen, for example, is using computer models to clarify how deviant brain chemistry can give rise to disorders such as schizophrenia. Cohen, who holds a joint appointment in psychiatry at the University of Pittsburgh and psychology at Carnegie-Mellon, says he has been motivated by the gap in psychiatry between clinical practice and biological research. In the case of schizophrenia, he says, you have on the one hand a purely descriptive approach—a diagnosis that includes such symptoms as auditory hallucinations and weird mental associations. But then you have the biological approach in which schizophrenia is treated with antipsychotic drugs that affect how neurons respond to the neurotransmitter dopamine. And no one knows how the two realms connect. "People have been working on both ends, with nothing in the middle," he says.

Cohen's frustration led him to team up 5 years ago with his University of Pittsburgh colleague David Servan-Schreiber, a psychiatrist with a Ph.D. in computer science; their goal was to close the gap with a neural network computer model of schizophrenic thought. Just as the brain consists of a dense web of neurons, the neural network software simulates a (much smaller) web of "nodes," in this case, on-off switches. Just as real neurons communicate by synapses, moreover, the software simulates a series of simple "connections" between the nodes. And just as the brain modifies its own behavior by changing the strength of the signals going through its synapses, a neural network can be trained for tasks such as recognizing handwriting, or guiding a vehicle down a highway, simply by adjusting the strength of its connections.

Cohen and Servan-Schreiber trained their neural network simulation on a simple word test that is known to be very difficult for schizophrenics. Once they had the network performing like a normal human, they changed the way certain nodes responded to inputs—the idea being to mimic the way a dopamine deficit is thought to affect the response of real neurons. Finally, they tested the network again—and found that it was now making much the same kind of mistakes on the word test that schizophrenics do.

To Cohen, this kind of result is just as exciting and promising as brain imaging work (which he is also involved in). "A neural network is the perfect language for bridging the gap between biological and cognitive processes," he says. "It allows you to make a much clearer mapping between the levels—using a structure similar to that used by the brain."

New skills for new jobs. For those who have been going through graduate school in the midst of all this ferment, there's been a sea change in a matter of a few years. "When I started graduate school 7 years ago it was perfectly acceptable for a cognitive psychologist to know nothing about the brain," says Thad Polk, who recently earned his Ph.D. at Carnegie-Mellon doing computer models of human reasoning and problem-solving under the late artificial intelligence pioneer Allen Newell. "But now everybody at least feels like they should know something about the brain."

"Look at the job advertisements from the major universities," agrees Oberlin College psychologist James Tanaka, who recently completed a postdoc at the University of Pennsylvania under cognitive neuroscientist Martha Farah. "They're looking for good experimental skills [in psychology], at the same time they want good computational skills and/or a strong neuroscience background. The people who are just one or the other may be outstanding scientists. But they aren't the hot candidates they would have been 5 years ago."

Tanaka adds that he had to do some scrambling to get the preparation he needed. "My area of research was object recognition," he says, "and it became clear early in my graduate training that it was inconceivable for a psychologist to develop a theory of object recognition without knowing what the visual system actually does. So I started going to neuroanatomy courses." At the same time, says Tanaka, he needed a precise way to express the theory he was developing. The obvious solution was to take courses in computational modeling of neural networks.

Recently, there have been a number of efforts to replace this kind of ad hoc self-education with a more formal and rigorous cirriculum in cognitive neuroscience. A prime example is the joint Neural Processes in Cognition program that Schneider directs at Pittsburgh and Carnegie-Mellon. Funded by a 5-year, $1.4 million, interdisciplinary training grant from the National Science Foundation, the program is entering its third year. And prospects for its graduates are looking good: Many of the program's 15 students are already being courted by potential employers, even though none has yet finished a dissertation. A similar effort is under way at the University of California, San Diego, where the Department of Cognitive Science is now entering its fourth year. "Nobody can get through here without a heavy dose of brain science," says San Diego's Marta Kutas. The first half-dozen Ph.D.s should be finishing up this year.

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New money. There is growing interest in cognitive neuroscience research among federal funding agencies as well—that is, the National Science Foundation and the Office of Naval Research as well as the NIMH, which this year is putting $24.9 million into grants for cognitive science and neuroscience, a portion of which is cognitive neuroscience. By all accounts, however, the most influential support is from the McDonnell Foundation in Saint Louis and the Pew Charitable Trust in Philadelphia. Together they have contributed some $4 million per year to cognitive neuroscience research and training over the past 5 years, and plan to continue at that rate for at least another 5 years. In addition, they sponsor annual summer "training camps," where one or two dozen young researchers gather for intensive tutorials. Most have been organized by Gazzaniga, who says the the proceedings of the latest one will be published as a new *Handbook of Cognitive Neuroscience*.

Next March, adds Gazzaniga, San Francisco will be the site of the first meeting of the new Cognitive Neuroscience Society. Gazzaniga guesses the turnout will be respectable judging from the number of postdocs and graduate students from around the world—more than 1200—who have applied to the summer program. The 5-year old *Journal of Cognitive Neuroscience*, which Gazzaniga edits, has acquired a similar number of subscribers. It's all coming together, he says. And this is a field with a future. "Figuring out how the mind arises from the brain—there's a couple of hundred years of work yet."

–M. Mitchell Waldrop