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Bridging the Brain Gap

A scientist explores the biology of isolated minds and mutual trust

By BRUCE BOWER

When a rabbit whiffs an onion, glimpses another rabbit, hears a loud sound, feels itself enveloped by a pair of hands, or otherwise encounters the world through its senses, electrical activity crackles through the creature's brain in a curious way. Within a fraction of a second, groups of neurons that greet incoming sensations generate a distinctive electrical burst that materializes again in the brain's outer layer, or cortex. There, the activity vanishes, poof, "just like the rabbit down the rabbit hole in *Alice in Wonderland*," remarks neurophysiologist Walter J. Freeman of the University of California, Berkeley.

Freeman, who has described this electrical disappearing act in rabbit brains since 1982, now suspects that the analogy to Lewis Carroll's classic children's tale runs even deeper. Much as the white rabbit's hasty departure turned Alice's world upside down, transient electrical responses to sensation may preface life-altering changes in the brain, he proposes.

More precisely, new patterns of brief cortical activity scurry forth one after another following a short-lived sensory outburst. They produce no less than a perception of what a particular sensation means, constructed in accordance with past experiences and other relevant knowledge. Mammals—including the two-legged, talkative ones—learn about the world through constant sensory and perceptual updates, Freeman theorizes.

But learning does not always proceed in an orderly, cumulative fashion, he argues. Mammalian brains contain a mechanism that can loosen the grip of previously acquired perspectives on the world and lay the neural groundwork for securing crucial new knowledge.

Having such a delete mechanism in the brain pays reproductive dividends, in Freeman's view. At appropriate ages, male and female mammals must jettison many habitual behaviors of their youth and forge the mutual trust necessary for mating and developing expertise at raising offspring. Humans have exploited the biology of pair bonding to form larger groups, from bands of foragers to modern civilizations, the Berkeley scientist maintains.

Freeman's theory, which he elaborates in *Societies of Brains* (1995, Hillsdale, N.J.: Lawrence Erlbaum), contains plenty of speculation. For that matter, it's not even clear yet how best to measure and interpret the brain's electrical landscape. Nonetheless, Freeman hopes to nudge neuroscientists toward a consideration of what brains do in groups, not just inside individual skulls.

"Despite notable successes in recent years, brain science is in crisis because our models neglect the most important function of human brains, which is to interact with each other to form families and societies," Freeman contends. "The importance of this function is shown by the need for education and cultural learning in bringing young people to maturity."

Freeman's perspective clashes with materialist theories, which conceive of the mind as a by-product of biological happenings in the brain—the interplay of billions of neurons for most neurobiologists, a cerebral stew of chemical and hormonal interactions for geneticists and pharmacologists, and the commingling of quantum forces for physicists.

The Berkeley researcher also rejects the view, widespread in cognitive psychology, that the mind contains representations of the world in the form of thoughts, ideas, images, and symbols that are processed according to sets of rules. This assumption has spurred attempts to simulate various facets of language, vision, and other mental functions in computers.

Both materialist and cognitive approaches assume that the brain, in an as-yet-unspecified way, binds together parallel strands of neural activity or related representations to compose the perception of, say, a fragrant bouquet of flowers in a vase.

In contrast, Freeman regards the mind as the product of an unfolding sequence of goal-directed behaviors that provides the individual with constant feedback, thus shaping perceptions and future actions. He endorses the view of existentialist philosophers such as Jean-Paul Sartre, who argued that each of us constructs a self through his or her own actions and that we know that self as it is revealed in our actions.

This perspective harks back at least to the 13th century Italian philosopher Thomas Aquinas, who wrote that achieving one's objectives requires a "stretching forth" and shaping of the self to the world.

Psychologist James J. Gibson, who died in 1980, pursued the perceptual implications of that theme. He asserted that through their actions, humans and other animals perceive meanings in sights, sounds, and other stimuli that contain essential information about particular environments. His ideas now influence psychologists who study how people gauge their physical movements through space (SN: 8/12/95, p. 104) and discern the personality traits of themselves and others (SN: 10/29/94, p. 280).

If the mind indeed emerges at the crossroads of action, perception, and learning, researchers who want to locate its biological roots face a stiff challenge. Electroencephalograms (EEGs) of brain waves in rabbits, whose nervous system can be treated as a rudimentary model of the human variety, offer some intriguing clues, Freeman maintains.

Foremost among the implications of the EEG data is that each brain constructs a sense of self and frames of knowledge about the world in isolation from all other brains. "Brains are self-organizing systems that are closed with respect to meaning," says Freeman.

At the heart of this process pulses the brain's background noise, a chaotic activity in the mathematical sense of the word (SN: 1/23/88, p. 58), Freeman posits. Cooperative clusters of brain cells generate what amounts to a flexible "I don't know" energy state, from which massive numbers of neurons can instantly generate coordinated responses to sensations.

Freeman and his coworkers have developed computer models of such activity from the resting brain waves of rabbits.

Chaotic activity in the brain's olfactory bulb—the entry point for sensations of smell—switches on and off in the course of each breath taken by a rabbit, according to Freeman. With each inhalation, the animal has immediate access to every electrical waveform pattern linked to specific smells that it has previously encountered; thus, its brain does not need to retrieve smell memories from a specific storage area or through some sort of file system.

As a rabbit undergoes training to recognize different odors, each sniff causes electrical activity in its olfactory bulb to shift abruptly from a state of manageable commotion to a systematic waveform pattern.

Bulb-generated electrical bursts trigger comparable waveforms in the cortex; these quickly disappear "down the rabbit hole," Freeman holds. The cortex then reformulates these sensory responses into fields of electrical activity that, he says, reflect a complex perception of the smell and its meanings (which may include, for a laboratory rabbit, whether or not licking in response to the odor has resulted in the availability of water).

In recent EEG studies, Freeman's group found that mathematically coherent, apparently cooperative activity by groups of neurons during the perception of a sensory stimulus lasts for only about one-tenth of a second and occupies cortical regions no more than three-quarters of an inch in diameter.

Cooperative processes must involve many more neurons and larger patches of tissue, Freeman notes, but scientists lack a widely accepted method of exploring this possibility.

Still, he considers the EEG data supportive of the notion that each brain creates its own mean-

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ings and perspectives for understanding the world. We are literally alone with our thoughts.

If each person operates in his or her own private cerebral universe, it seems unlikely that individuals could muster enough trust to form lasting friendships or abiding romantic partnerships, much less cohesive tribes and societies. Fortunately, evolution equipped mammals with a biological mechanism for bridging the gap between isolated brains so that pairs of animals in a species can reproduce and raise their offspring, Freeman argues.

Studies of prairie voles, for instance, indicate that when these mammals mate and give birth, certain chemicals are released into their brains that stimulate maternal or paternal behavior (SN: 11/27/93, p. 360; 10/19/96, p. 246).

Substances such as these may wipe away connections formed among neurons by experiences early in life and usher in a temporary period of cerebral malleability, Freeman proposes. Sexually intimate voles can then nurture mutual bonds and acquire the radically different types of knowledge required for maintaining a family and ensuring that their youngsters reach adulthood.

Men and women who manage to set off this brain mechanism fall in love, first with each other, then with their kids, he suggests. But the meltdown of long-standing neuronal connections and their attendant attitudes and beliefs is frequently experienced as a frightening loss of identity and self-control, especially for those smitten by a first love, Freeman adds.

Russian physiologist Ivan Pavlov tapped into this mechanism in his classic studies of brainwashing more than 70 years ago, the Berkeley scientist suggests. Pavlov found that dogs put through the stress of sensory overload, sleep deprivation, and physical exhaustion became demoralized and completely forgot what they had learned in previous experimental trials. When sources of stress were removed, the grateful dogs quickly learned new behaviors in training sessions.

Soviet officials seized on Pavlov's findings and used them as the basis of their "reeducation" efforts with political dissidents. A shrewd mix of isolation, deprivation, and small, calculated acts of kindness instilled startling changes of heart in formerly outspoken critics of the Soviet regime.

Stressful manipulations such as these fall at the extreme end of widespread efforts to induce brain states that are conducive to incorporating collective values, says Freeman. In fact, he speculates, human ancestors may have tapped into this biological conversion process to form group identities, using such means as group dancing, rhythmic clapping and chanting, music making, and initiation rites.

These activities still foster trust and group cohesion. Consider the trappings of evangelical conversions, political rallies, rock concerts, and sporting events, Freeman notes. Shared, stressful activity can promote unity, as on sports teams, in combat units, and in work groups embroiled in competitive projects. Some calculated exposures to stressful situations veer closer to Pavlovian reeducation, as in military boot camps, cults, and even some fraternity and sorority initiations, Freeman asserts.

Scientists who study electrical activity in the brain generally take a dim or a highly cautious view of theories such as Freeman's. Some researchers who focus on the electrical output of individual neurons look askance at efforts to measure broad fields of electrical activity with sensors on the scalp or on the surface of the brain. For them, both Freeman's research techniques and his proposals lie beyond the pale.

Others employ so-called global measures of the brain's electrical activity, as Freeman does, but remain skeptical of his theoretical forays.

"I greatly respect Freeman's experimental work, but he's willing to interpret much more

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from the available data than I would," remarks neurobiologist Theodore H. Bullock of the University of California, San Diego.

However, scientists interested in group selection—the theory that natural selection preserves genetic traits that aid group functioning and survival (SN: 11/18/95, p. 328)—find Freeman's argument intriguing.

Freeman described his work at a symposium on group selection held at the Human Behavior and Evolution Society's annual meeting last June in Evanston, Ill.

"In my opinion, the most exciting paper [at the symposium] was by Freeman," says evolutionary biologist David S. Wilson of the State University of New York at Binghamton, who chaired the session. "I was blown away by the neurobiological basis of group-level organization that he was suggesting."

It remains to be seen, though, whether Freeman's theory will light up the brave new world of neuroscience or, like the rabbit that led Alice astray, head for some darker place. □