Neuroscience

Definition: What is Neuroscience?

Neuroscience begins with the study of the brain, spinal cord, and nerves and goes on to incorporate the study of genetics, pharmacology, biochemistry, and other powerful influences on nervous system development and function. A relatively new field of scientific inquiry established in about 1970, neuroscience includes research into neurological and psychiatric disorders and studies of aging, stress, sleep, memory, and movement. Cognitive neuroscience is a specialized branch that focuses on the mind, learning, and behavior.

Through their research, neuroscientists are working to help people with disorders that include Alzheimer's, depression, dyslexia, epilepsy, post-traumatic stress syndrome, spinal cord injury, stroke, and vision loss, among others.

New neuroscience tools and techniques are making it possible for researchers to determine-to a greater extent than ever before-what goes on inside the human brain.

These tools and techniques include fMRI (functional magnetic resonance imaging), computerized EEG (electroencephalograph), and brain implants (surgical implantation of microchips and transmitters within the brain).

Let's look at how the machines work and at both their medical and non-medical uses.

fMRI

The technique of fMRI (functional magnetic resonance imaging) reveals brain activity. By detecting an increase in blood flow, an fMRI tracks the specific areas of the brain that become active in response to stimuli, such as sounds or visual images.

Medical researchers are using fMRI to shed light on psychiatric disorders and learning disabilities, even addictions. For example, researchers in Hamburg claim to have found fMRI evidence that establishes

gambling as a non-substance related addiction.

Such information could be used to attempt to predict addictive behaviors before they ever arise, which raises ethical issues about labeling individuals and pre-emptive treatments.

But it is not only the medical uses of fMRI that concern ethicists. For example, fMRI is being used for **lie detection**. Researchers are finding that the ".cognitive differences between deception and truth have neural correlates detectable by fMRI." Traditional polygraph (lie-detector) tests measure heart rate and sweating and other physiologic responses under questioning, so a cool-headed liar can test out as truthful. However, the fMRI tracks increases in activity (in several areas of the brain) that occur with lying. Researchers are still determining if there is a way that the fMRI can be fooled. (However, they have already determined that it requires more brain activity for people to lie than tell the truth!)

Another use for fMRI, **neuromarketing,** takes advantage of its ability to determine a subject's positive or negative response to visual images. The machine can even characterize the response. For example, it can determine whether a positive response is warm and personal, such as one we might have when greeting an old friend, or more abstract, such as that of viewing a sunset. The fMRI is now being used to study responses of human test subjects to movie trailers, different makes of cars, and brands of cola.

Both American and European marketing agencies are developing fMRI neuromarketing techniques.

Computerized EEG/Brain Fingerprinting

An EEG, or electroencephalograph, detects brain waves by reading sensors placed in contact with the patient's scalp. When EEGs are connected to computers, the combination of technologies can detect an amazing amount of information stored in the brain.

Bin He, professor of biomedical engineering at the University of Minnesota, is developing a computer-EEG combination that will allow paralyzed patients to communicate using only their thoughts. As a patient-who is wearing a headpiece connected to the EEG-computer-thinks about moving either the right or left hand, the computer maps an image of the cerebral cortex, revealing the area of the brain that shows activity (which differ for each hand). Professor He can determine-with a single trial-which hand the person is thinking of. A future goal is to be able to determine a unique pattern of brain activity for many different thoughts.

A non-medical application of computerized EEGs, called **brain fingerprinting**, is used to detect whether a particular image-such as that of a crime scene-is stored in an individual's memory.

Designed by Brain Fingerprinting Laboratories of Fairfield, Iowa, the test does not measure heart rate, breathing, and sweating as does a polygraph (lie detector). Nor does brain fingerprinting determine truthfulness. It works by determining whether the subject has a particular memory stored in the brain.

When brain fingerprinting results were admitted as evidence in a criminal case in Iowa in 2003, a 1978 murder conviction was overturned. The results, which showed a mismatch between the crime scene and the memories in the convicted man's brain, triggered a confession of lying from the accuser.

Brain Implants

While the EEG contacts the only the patient's scalp, brain implants are surgically implanted directly into brain tissue. Most implants are used in patients with Parkinson's disease or other movement disorders. They work by sending electrical shocks to the brain that result in improved muscle control.

But with a new implant called Braingate, communication moves in the opposite direction. An implanted sensor transmits the brain's electrical signals out to a computer-interface, allowing the patient to operate the computer with thought commands. (See "Hardwired with Braingate" sidebar for information on the first patient.)

Other neuroscientists are developing microchip brain implants to ease the distress of patients with Alzheimer's, strokes and other memory-impairment disorders. While use in human patients is probably 15 years off, the researchers are confident that their chips already accurately mimic the activity of neurons in the hippocampus (a part of the brain that re-encodes short-term into long-term memory).

Like the fMRI and the EEG/computer interface, it's likely that the brain-computer interface will have non-medical applications in future, especially when the wireless technology is perfected.

Hardwired with Braingate

In June 2004, Matthew Nagle , a 24-year-old quadriplegic, alloweds urgeons to implant a sensor into his motor cortex (the part of the brain that controls muscle movements). The sensor was connected, via electrodes and fiberoptic cable, to his computer. Leading the exploration into the brain-computer interface, Nagel now operates his computer with much less effort than most of us-just by thinking about it. In an amazing end-around damaged nerves, the sensor transmits Nagle's own brain activity-in the form of electrical impulses-to the computer, which has been programmed in repeated trials to associate particular signals with specific requests from Nagle. The communication link allows Nagle to check his email and play computer games using thought commands.

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Ethical Issues

These tools show great potential to advance medical treatments, but scientists and ethicists are raising concerns about non-medical uses of these technologies because of their potential to invade our privacy. Once a person is hooked up to the new neuroscience machines, the instruments can detect personality

traits, lies, even memories.

The possibility that private information would become available to insurers, employers, and government or public databanks is of deep concern.

- A consumer rights organization, Commercial Alert says that neuromarketing uses fMRI medical technology "not to heal but to sell products." High on its list of concerns is the potential for "more effective political propaganda." Neuromarketing is expected to be utilized in the 2008 presidential campaigns.
    - Should we be able to use fMRI for commercial purposes such as marketing?
    - How does using the fMRI compare to other methods used to test marketing focus groups?
    - Does that fact that the fMRI can detect the subject's response without the subject actively giving the information affect your opinion about how it should be used?
- Brain fingerprinting, because it can detect whether a particular image-such as that of a crime scene-is stored in an individual's memory, is a non-medical application of computerized EEGs that is raising concern among ethicists:
    - Should brain fingerprinting become part of routine police investigations?
    - Should brain fingerprinting be used to test defendants in criminal cases?
    - Should a person have the right, when being investigated or charged with a crime, to refuse brain fingerprinting?

"Far more than our genomes, our brains are us, marking out the special character of our personal capacities, emotions and convictions. I don't want my insurance company to know my genome, but as for my brainome, I don't want anyone to know it for any purpose whatsoever."

-Stanford neurobiologist Donald Kennedy, former head of the Food & Drug Administration and editor-in-chief of *Science* magazine

- Brain implant technology helps those who suffer from movement disorders and holds promise for memory loss patients. However, ethicists are concerned that the technology has the potential to be used in non-medical ways to affect human behavior.
    - Should brain implants be used in the future to influence a person's personality?
    - Should brain implants be used in the future to increase intelligence?

"Computer control in the brain may be more than a far-off possibility. The question is how we decide to use brain-stimulating implants. Implanted brain stimulators already are used for Parkinson's disease, but what about to alter personality disorders? What about eventually trying to improve perception and intelligence? We must find methods to make us better off while protecting against misuse."

-Jeffrey P. Kahn, Ph.D., M.P.H. and Director of the Center for Bioethics at the University of Minnesota

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Links

The Society for Neuroscience is a nonprofit membership organization of scientists and physicians who study the brain and nervous system, online at http://web.sfn.org/Splash.cfm .

The website for the Human Neuroimaging Laboratory at Baylor College of Medicine has information on how the fMRI functions at http://www.hnl.bcm.tmc.edu/fMRI.html.

Commercial Alert's "Neuromarketing Overview" is available at http://www.commercialalert.org/index.php/category_id/1/subcategory_id/82/article_id/202.

Brain Fingerprinting Laboratories has a summary page on brain fingerprinting at http://www.brainwavescience.com/ExecutiveSummary.php.

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Suggested Reading

"Don't Even Think About Lying" Silberman, Steve. Wired (Issue 14.01) January 2006. http://www.wired.com/wired/archive/14.01/lying.html

"Functional MRI is yielding a clearer picture of what thoughts looks like"
Hamilton, Joan O'C. BusinessWeek online April 19, 2004. http://www.businessweek.com/magazine/content/04_16/b3879103.htm.

"Implanting ideas to store medical history"
Kahn, Jeffrey P. CNN ethics matters May 13, 2002. http://edition.cnn.com/2002/HEALTH/05/13/ethics.matters/index.html.

"Paralysed man sends e-mail by thought"
Khamsi, Roxanne. News@ Nature.com October 13, 2004. http://www.nature.com/news/2004/041011/full/041011-9.html#top.

"Bioethics & the Brain"
Roster, Kenneth et al. IEEE Spectrum June 2003. p. 34-39.

"Chips Coming to a Brain NearYou"
Sandhana, Lakshmi. Wired News October 22, 2004. http://wired.com/news/medtech/0,1286,65422,00.html.

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