Peering into Our Potential:
How Neuroscience Is Mapping New Paths to Healthy Living

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WE'VE LEARNED A LOT ABOUT THE HUMAN BRAIN: its average size and weight, its various regions, what areas are responsible for certain functions, and even how some of its inner circuitry works. New technology and approaches to brain research have yielded useful findings for a wide variety of fields—psychotherapy, education, law, economics, and nutrition, to name a few—and have also created new fields of study, including neuroethics, neuromarketing, and neurotheology. And although numerous unanswered questions follow every new discovery, neuroscientists are steadily revealing how we can use different capacities in our brain to enhance our well-being.

HOW THE BRAIN CAN HEAL US

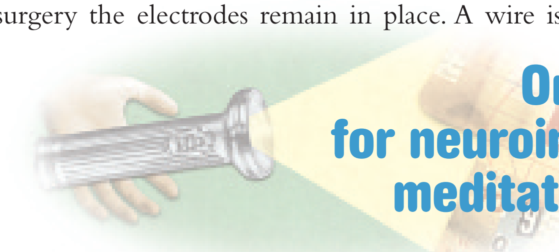
They say a picture is worth a thousand words, which certainly holds true when it comes to the brain. There are two types of neuroimaging, or picture-taking, of the brain: structural and functional. Structural imaging examines the anatomical structures of the brain and includes computed tomography (CT scan) and magnetic resonance imaging (MRI); functional imaging measures cerebral blood flow and receptor activity and includes single photon emission computed tomography (SPECT), positron emission tomography (PET), and functional MRI (fMRI).

One area where neuroimaging has proven to be highly effective is in examining the placebo effect. It turns out that the brain is quite capable of healing the body by itself when properly motivated. A study led by Jon-Kar Zubieta, MD, of the University of Michigan, used PET and MRI scans to examine endorphin activity in the endogenous opioid system, one of the brain's pain-relieving systems. Subjects were injected in the jaw with a saltwater solution to induce pain. Then they were told they would receive a pain reliever, which was actually a placebo, while their brains were scanned. The scans showed that endorphin levels rose when the idea of the pain reliever was introduced. The most pronounced effects were seen in the parts of the brain known to be involved in processing and responding to pain. This study, reported in the *Journal of Neuroscience* (August 2005), provided the first direct evidence that the brain's own pain-fighting chemicals, endorphins, play a role in the placebo effect and that this response corresponds with a reduction in feelings of pain. By observing the neurobiological mechanisms of the placebo effect, experts are uncovering clues for treating pain and disorders, and their findings may also alter the way clinical trials are conducted.

Neuroimaging is also providing psychotherapy with deeper insights and additional options for treatment. Observing how the brain reacts to different stimuli, researchers can refine clinical diagnoses and better predict treatment outcomes for many psychological disorders. For example, neuroimaging is revealing how the brain reacts to both psychotherapy and drug treatment, thereby helping to pinpoint which approach is most effective in different circumstances. A review in the *American Journal of Psychiatry* (May 2007) by Mary L. Phillips, MD, examines one particular study, led by Sidney H. Kennedy, MD, of the University of Toronto, using venlafaxine (an anti-depressant) and cognitive behavior therapy (CBT) to treat unipolar depression. By using PET scans to measure cerebral glucose metabolism, the researchers were able to effectively compare patients' reactions to medication, CBT, and both combined, and determined that there

were significant differences in response among those being treated. Building on these findings and existing data comparing the efficacy of pharmacotherapy and psychotherapy, researchers hope that further studies of cerebral metabolism will help identify those individuals who respond best to each intervention and eliminate the trial-and-error approach to mental disorders so patients can receive the best individual treatment sooner.

Another new area for psychotherapy and neuroscience is deep brain stimulation (DBS), a potential therapy for people with treatment-resistant depression. Electrodes are implanted inside the center of the brain to produce a constant, mild electrical stimulation to a targeted location called Area 25—shown to play a critical role in depression. Area 25 is connected to other areas that control sleep, appetite, and motivation, all of which can become disrupted when depression hits. The theory of DBS is that by aiming electrical pulses directly into Area 25, scientists can recalibrate the brain to eliminate depression. After surgery the electrodes remain in place. A wire is then threaded out of the skull, under the skin, and to the front of the chest where a tiny power pack regulates the stimulation and is adjusted externally by the psychiatrist with a device similar to a remote control.



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The surgery is still experimental, but results thus far have shown promise. Neurosurgeon Helen Mayberg, MD, led the first study of this procedure in May 2003, when she was with the University of Toronto. Of the six patients who underwent the operation, four responded significantly, with a renewed interest in activities that involved social interactions. Those four patients also met a specified response criteria—a 50 percent drop in the Hamilton Depression Rating Scale—three months later, then six months and again one year later. Mayberg plans to launch a new DBS research study in the near future at Emory University, where she now practices. "From a research perspective, we are also examining brain markers that might identify which patients might best benefit from such a procedure," Mayberg said in a recent interview with The Mental Health Research Association. "This experiment defines a potential paradigm shift in the way we think about antidepressant mechanisms of action."

One of the most established uses for neuroimaging has been in the study of meditation and its effects on the brain. Brain researchers have long been curious about the practice, and their investigations are revealing what practitioners have long known: Meditative disciplines change the workings of the brain, allowing people to achieve enhanced levels of awareness, focus, and well-being, and providing psychotherapists with another effective tool in treatment.

Led by Harvard psychologist Sara Lazar, PhD, researchers at Harvard, Yale, and MIT used MRI scans to compare the brains of 20 meditators with those of 15 nonmeditators (*Neuroreport* 16, 2005). The practitioners included four teachers of meditation or yoga, as well as professionals working in health care, journalism, and law. They used a form of Buddhist meditation known as insight meditation, or Vipassana, focusing on their sensory experience (rather than thoughts about their experience) for about forty minutes a day. Brain scans revealed that the cortex—the brain's outer layer, which is associated with attention and sensory processing—was thicker in the meditators.

"Our data suggest that meditation practice can promote cortical plasticity in adults in areas important for cognitive and emotional processing and well-being," said Lazar. "Further research needs to be done using a large number of people and testing them multiple times. We also need to examine their brains both before and after learning to meditate. Eventually, such research should reveal more about the function of the thickening; that is, how it affects emotions and knowing in terms of both awareness and judgment."

Similar and ongoing research led by Richard Davidson, PhD, a neuroscientist with the University of Wisconsin at Madison, uses brain images to expand the concept of neuroplasticity—that is, the brain's natural ability to form new connections. Davidson's studies show that mental training through meditation can itself change the inner workings and circuitry of the brain, allowing people to achieve different levels of awareness. In a study published in the *Proceedings of the National Academy of Sciences* (November 2004), researchers compared the brain activity of experienced Buddhist meditation practitioners with that of first-time meditators. The research was the result of a longtime collaboration between Davidson and the Dalai Lama, who dispatched eight of his most seasoned practitioners to participate in the study. The results showed that the Buddhist meditators had a much higher level of gamma-band rhythms than the nonmeditators. In fact, some of the monks produced gamma-wave activity more powerful than any previously reported in a healthy person, according to Davidson.

Also underway is the Shamatha Project, a longitudinal study of intensive meditation practice that seeks to illuminate meditation's effects on overcoming negative emotions, maintaining resilience in the face of stress, and improving relationships. The project's leaders, B. Alan Wallace, PhD, of the Santa Barbara Institute for Consciousness Studies, and Clifford Saron, PhD, of the Center for Mind and Brain at the University of California at Davis, anticipate that three months of meditation training will result in greater compassion as well as improved attention in participants.

Scientists used to believe that connections among brain nerve cells were fixed and couldn't change, but with the help of brain imaging they are learning that the brain can constantly develop and evolve. By examining how the brain works when meditating, neuroimaging has opened a new door into exploring higher states of consciousness.

DECODING ADOLESCENT BEHAVIOR

Neuroscience's investigations into the workings of the adolescent brain are yielding information beneficial to educators, therapists, and parents of teens, as well as to the teens themselves. For example, a series of studies conducted by Stanford psychologists Carol Dweck and Kali Trzesniewski and Columbia University's Lisa Blackwell showed that students who learned about the brain's neuroplasticity became more motivated and resilient in their academic performance. "When they studied, they thought about those neurons forming new connections," Dweck reports. "When they worked hard in school, they actually visualized how their brain was growing." Students who typically did not put in extra effort became determined to improve their academic performance and did so. "Children's beliefs become the mental baggage they bring to the achievement situation . . . A focus on the potential of students to develop their intellectual capacity provides a host of motivational benefits," writes Dweck, who recently authored *Mindset: The New Psychology of Success* (Random House, 2006).

A consultant for the California State Department of Education and an education professor at Pepperdine University, Raleigh Philp has spent the last decade studying the literature on brain research and helping educators to apply neuroscience to learning. Among the salient points he emphasizes in his work—which includes brain-compatible learning workshops and the recently published book *Engaging 'Tweens and Teens* (Corwin Press, 2007)—are the following:

- *The neocortex—the part of the brain responsible for language, planning, empathy, and executive functions—hasn't fully developed in teens, compromising their consistency in these areas while also making them open to new experiences and amenable to change.*

- *Since the prefrontal cortex is not completely developed, emotions—processed by the amygdala—dominate every aspect of learning, memory, and problem solving, and increase the likelihood of stress and risk-taking.*

- *Not only do teenagers process emotion more intensely than adults do, but their brains may interpret emotions differently, causing misunderstandings.*

- *The brain is highly influenced by experience and goes through a major pruning at ages 12, 13, and 14, also a time when neural networks and new skills develop more easily.*

- *Adolescents have short attention spans—15 to 20 minutes—requiring many educators to adapt lesson plans and alter the rhythm of learning.*

Philp advocates innovative use of music as one of many ways to work with the needs of teens in various circumstances. Playing upbeat music when students enter a class, for example, can arouse enthusiasm and energy for beginning something new. During transition periods between activities or during mindful exercises, such as silent reading or writing in journals, downbeat music can help to redirect the focus.

Indeed, research confirms music's profound effect on the brain. Robert J. Zatorre, PhD, and researcher Anne Blood of the Montreal Neurological Institute at McGill University explored how music triggers pleasure. When they scanned the brains of musicians reporting "chills of euphoria" while listening to certain music, they found that the music activated many of the same reward systems as those stimulated by food, sex, and addictive drugs. Participants' heart rate and respiration increased, and as these "chills" intensified, cerebral blood flow changed correspondingly. Philp observes how such research supports the contention that when music is effectively integrated into education, students will start to associate learning with pleasurable feelings and become more motivated during class.

DOPAMINE AND ADDICTION

Research on substance abuse and on the adolescent brain is presently converging with research in the area of addiction among all ages. The linchpin is neuroscientists' growing understanding of dopamine, the brain chemical involved in motivation, pleasure, and learning. The dominating theory on dopamine for the past twenty years has been that the neurochemical is a pleasure switch: Addictive drugs, such as cocaine and nicotine, create a flood of dopamine in the brain, which puts addicts in a state of bliss. But Nora Volkow, PhD, head of the National Institute on Drug Abuse, observes, "I've seen hundreds of addicted people, and never have I come across one who wanted to be addicted." Examining the MRIs of drug addicts, Volkow and other researchers are developing a new understanding of addiction: Dopamine not only tells us what is pleasurable, it also tells us what is relevant—that is, what to pay attention to in order to survive, be they messages about pleasure, pain, food, sex, or danger.

Drugs hijack the sectors of the brain where dopamine is involved, including the nucleus accumbens (NA), which is part of the pleasure center. When drugs enter the brain, dopamine surges through the NA, forcing the brain's motivational and attentional mechanisms to focus exclusively on the drug. Over time, an addict's brain adapts to the increase of dopamine by dampening the system down. Volkow's research has revealed that addicts have fewer dopamine D2 receptors, which are associated with motivation and reward behavior. With fewer receptors, the dopamine system is desensitized, so that the understimulated addict needs more and more of the drug to feel anything at all. At the same time, pathways associated with other interesting stimuli are left idle and lose strength. The prefrontal cortex—associated with judgment and inhibitory control—also stops functioning normally. This dynamic becomes a formula for substance abuse and addiction, and also suggests what might be happening with food addictions.

When Volkow and her colleagues examined the brains of ten obese people, they found the same dopamine-receptor deficiency that is evident in drug addicts. And since addictive cravings prompt us to satisfy pleasure, it makes sense that food cravings would have us seek foods that are high in flavor and often high in calories and fat. Because teenagers are particularly vulnerable to addictive behavior—the amygdala and nucleus accumbens dominate the prefrontal cortex during adolescence—this could help explain the often unhealthy relationship between teenagers and food and, of course, drugs.

A PROMISING FUTURE

Even this cursory review of neuroscience's investigations into psychotherapy, human development, education, music, and nutrition reveals the potential we now have to advance our individual and societal well-being. We not only have a greater understanding of the mysterious inner workings of the brain, but we have opened doors into improved psychotherapies, enhanced learning capabilities, and healthier relationships with ourselves and one another. Perhaps most exhilarating is the fact that we are only at the frontiers of this research. What other insights and breakthroughs await us as we continue to uncover the brain's secrets?

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