ON THE BRAIN

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Thoughts to Live By

Moral dilemmas have perplexed humans for millennia. And for nearly as long, philosophers, ethicists, and others who contemplate the human condition have struggled to understand how people grapple with decisions on morality.

Although the list of humanists captivated by this question may be long, the list of neuroscientists who investigate it is short. Among the handful of researchers on that brief list is Joshua Greene, the John and Ruth Hazel Associate Professor of the Social Sciences at Harvard University and director of Harvard's Moral Cognition Lab. It is in this laboratory that scientists take an analytical approach to deciphering moral judgment, using behavioral methods and functional neuroimaging to parse how our brains process decisions on moral issues.

Although Greene approaches his research empirically, he approaches the topic of morality humanistically. A philosophy major at Harvard and later at Princeton, Greene is steeped in two schools of philosophical thought: rationalism, associated with the work of Plato and Immanuel Kant, which holds that moral judgments are based on reason, logic, and evidence; and sentimentalism, exemplified in work by David Hume and Adam Smith, which argues that emotions are the root of moral decision making.

For his part, Greene thinks that neither reason nor emotion alone are the foundation of moral judgment, but that both play a critical role in how

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we make moral decisions. This dual-process theory claims that utilitarian or consequential moral judgments, such as those that promote the greater good, are controlled by cognitive processes that govern reasoning and self-control. The same theory

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posits that deontological moral judgments, that is, decisions that are considered morally good because some part of the decision, although not necessarily its outcome, is good, are driven by automatic emotional responses. Deontological actions grow from an obligation to act out of goodwill, thus some actions can be moral obligations regardless of the consequences they have for human welfare.

Tracking morality

In the cognition laboratory, Greene tests how the brain reacts to moral dilemmas by introducing research participants to the trolley problem, a traditional moral paradox. In this paradox, a runaway trolley hurtles down the tracks toward five people. Study participants may not warn the group of five that the trolley is coming, but the participants may flip a switch to divert the trolley to a nearby track. The decision, however, is not without moral issue, for one person walks along that track. Thus, death will occur whatever the decision; it is only the *number* of people who will die that remains within a participant's control. Participants who make a utilitarian moral decision flip the switch and elect to take one life to save five. Deontological decision makers refuse to flip the switch, for doing so would make the single person a mere means to an end, a morally unacceptable line of reasoning.

The moral test becomes more complicated when the scenario places the participant next to a man standing on a footbridge above the tracks. In this version of the paradox, the only way a participant can save the five people is to push the man off the bridge and onto the tracks, thereby stopping the trolley. How do participants generally respond to this dilemma? Most, says Greene, do not sacrifice the man on the footbridge, a decision that would be based on a "personal" choice, but

find it morally acceptable to turn the trolley onto the adjacent track and sacrifice the single person, a decision that Greene characterizes as "impersonal."

To experimentally test how the brain processes moral decisions, Greene and his colleagues introduced student participants to various moral dilemmas and took fMRI scans of their brains as they worked through their decisions. Areas associated with emotion and social cognition, including the prefrontal cortex and posterior cingulate cortex, which is along the brain's midline, lit up wildly when the students considered personal moral dilemmas, such as those likely to cause serious bodily harm. By contrast, regions such as the anterior cingulate cortex, which is involved in abstract reasoning and problem solving, showed increased activity when participants considered impersonal moral quandaries.

According to Greene, when participants are confronted with the trolley problem their brain scans illustrate his dual-process theory, especially when they are considering the footbridge complication. "When the more emotional system of the brain is engaged," says Greene, as when the participant must decide whether to push the man off the footbridge and into the trolley's path, "its responses tend to dominate judgment. This explains why people tend to make utilitarian judgments in response to the switch dilemma, but emotional ones in response to the footbridge dilemma."

In 2008, Greene took his research one step further by having participants' brains perform multiple operations while also assessing a moral dilemma, then measuring what effect this cognitive load had on moral reasoning. Study subjects performed a moral judgment task; they were asked to decide whether they would smother their crying infant rather than have the infant's cries expose them and others to danger, such as being found by enemy soldiers.

Neural imaging showed that participants took longer to approve of the fatal action when they were also engaged in a completely unrelated cognitive task: locating a particular number in a streaming list of numbers. But when faced with the life-taking decision alone, with no competing cognitive demands, the decision to save the baby was made comparatively quickly. Greene concludes that some of the cognitive processes that are required for finding the number are also needed to make utilitarian judgments, but not to make deontological decisions. The results, Greene's research team says, provide evidence that utilitarian moral judgments are driven by controlled cognitive processes while decisions based on the moral obligation to act from goodwill are made through more automatic, and thus faster, processes. In terms of moral decision making, we are both deontological *and* utilitarian, depending on the circumstances of a given situation.

A thought for the world

Imaging, and neuroscience in general, can tell us what is happening in the brain, but it cannot determine whether certain areas of the brain are dictating a particular judgment. Greene says that's because the notion of a center of "moral sense" or "moral faculty" does not exist. Instead, although multiple complex neural systems are at work during such decisions, the functioning of each system is not tied specifically to moral judgment.

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In his article in *The Cognitive Neurosciences, 4th Edition,* a seminal reference in the field, Greene wrote: "Our current neuroscientific understanding of moral judgment is rather crude… But, for all our ignorance, the physical basis of moral judgment is no longer a complete mystery. We've not only identified brain regions that are 'involved' in moral judgment, but have begun to carve the moral brain at its functional joints."

Greene says his goal as a scientist is to expose moral thinking for what it is—emotions and rationalizations shaped by our genes and the world around us. His hope is that by understanding how and why we make moral decisions, we can more readily assess the personal as well as the societal outcomes of the decisions we make.

Economics and the Brain

This article is part of a series on the internal and external forces that affect the brain.

Economists and neuroscientists may seem like strange bedfellows, yet as we learn more about how people make decisions, a field of study called neuroeconomics is making the two, if not soul mates, then at least fast friends.

Much of modern economic theory rests on the idea that humans make rational decisions, that we work from an established set of preferences as we navigate our financial choices. Economists call these "utility" decisions, for they presumably bring the fulfillment that comes with consuming needed goods and services. The economist Paul Samuelson, the first American to receive the Nobel Prize in economics, even wrote a book codifying the idea that we operate from a rational basis when making financial decisions. A generation of economists, in fact, has used this belief as the point of reference from which to observe economic behavior.

Neuroeconomics is not a "wholesale rejection of the traditional economic methodology. It is just a recognition that decision making is not always perfect. People try to do the best they can, but they sometimes make mistakes. The idea that a single mechanism maximizes welfare and always gets things right—that concept is on the rocks."

But many neuroscientists—and an increasing number of economists—are now taking a different approach to determining how and why we make the economic decisions we do; they are using fMRI to monitor brain activity during such decisions. This new perspective may help scientists explain the outcomes of what many consider to be irrational financial behavior: why our saving behaviors vary so widely, why there are such wild swings in the stock market, and why unions strike—an action that puts their members' jobs and wages at risk.

"Neuroeconomics provides a framework for modeling the decision making of economic agents—households, workers, and politicians," says David I. Laibson, the Robert I. Goldman Professor of Economics at Harvard University.

When discussing the field of neuroeconomics a few years ago, Laibson noted that it is not a "wholesale rejection of the traditional economic methodology. It is just a recognition that decision making is not always perfect. People try to do the best they can, but they sometimes make mistakes. The idea that a single mechanism maximizes welfare and always gets things right—that concept is on the rocks."

Set for instant gratification

Brain researchers who study human decision making have challenged the assumption of rationality in financial decision making, questioning longstanding economic theory by arguing that people who tend to lack self-control are often narrow-minded and so risk averse that they can overreact to the fear of losing money when making economic decisions.

The human brain can simultaneously process two different kinds of information—empirical and emotional. The rational model of decision making relies on the use of empirical information: structured, sequenced, reasoned, and well thought out. We identify a problem or an opportunity, analyze our options, assign a value to each option based on its intrinsic worth, and then take action. This process employs the frontal and parietal cortexes, areas that control so-called executive functions, including logical reasoning, planning, future-oriented thinking, and deliberative decision making. In humans, these brain areas are larger compared with those of other animals, and are among the last parts of the brain to evolve. For centuries, economists were secure in the belief that these large, late-evolved brain regions were the processing points for economic decisions.

Emotion-based decision making, which looks to information gathered from visceral reaction, instinct, and emotion, is typically a quick process, often even a subconscious reaction to such situations as heated arguments or life-and-death circumstances. Emotion overrides logic to support our decisions. The brain's limbic system—an area of emotional cognition that includes the amygdala and hippocampus—controls this form of decision making. The limbic system determines how we feel emotionally, how we respond to others (often in the form of empathy), and how we react when we believe we have been unfairly treated.

"Humans share the basic neural architecture of our mammalian cousins," says Laibson. "We reside somewhere in the space between a rat and a perfectly rational, forward-looking deity." The empirical and emotional approaches to decision making are both useful models of human behavior, he adds. "They each shed light on certain aspects of our cognitive function. We don't live at either extreme."

How does this rational–emotional tension apply to economic decision making? Several studies, including an important one conducted by Laibson, have begun to address this question. In a study reported in *Science* in 2004, Laibson teamed up with economists, psychologists, and neuroscientists at Princeton and Carnegie Mellon Universities to see what happens in the brains of people being confronted with a decision that involves an immediate or delayed reward. The researchers presented college students with a choice: receive a $15 gift card immediately or elect to receive a $20 gift card in a month. While MRI scans showed both options triggered activity in the prefrontal cortex, a region in which abstract thinking, planning, and problem solving are processed, the scans of students who chose the immediate reward showed greater activity in the limbic region.

The study reinforces Laibson's theory of "quasi–hyperbolic discounting," which says that many, although not all, people tend to seek immediate gratification even if it means a smaller reward rather than delaying gratification to receive a larger one. According to Laibson, the experiment points to the practical implications of our hunger for instant gratification.

Blending theories

The groundwork for the field of neuroeconomics has been laid throughout the past century and a half. Economists such as Francis Edgeworth, whose 1880s hedonimeter measured the happiness and pleasure derived from making decisions, and Frank Ramsey, whose psychogalvanometer measured economic utility, were early practitioners. Later came a generation of behavioral economists who studied cognitive and emotional factors that could influence economic decision making. Laibson says that today most economists are interested and curious, but also cautious, concerning the evidence being presented by neuroeconomics.

This discipline, however, won't supersede a century's worth of economic theory. And, say Laibson and others, that is not its intent. Instead, neuroeconomics proponents contend that the field introduces biological aspects into the equation, variables that they say have been missing from the study of economic decision making for far too long.

High on Love

It may well be one of the best feelings in the world: You're energized, elated, and euphoric. You simply want more.

Full–fledged, unabashed love—there's nothing like it. Or is there? Brain imaging is revealing that the neural mechanisms that control the formation of intense romantic love are strikingly similar to those that influence craving and pleasure, two key components of drug addiction.

"At the neuroimaging level, there are tantalizing similarities between love and addiction," says Hans Breiter, an HMS associate professor of psychiatry who studies the brain's reward circuitry. "A similar set of reward–aversion circuits turn on during the experience of love and also by use of drugs of abuse."

In a 2005 study, social anthropologist Helen Fisher of Rutgers University and her colleagues published a groundbreaking study that produced the first fMRI images of brains in the throes of romance. The researchers analyzed nearly 2,500 brain scans of college students who had viewed pictures of someone special to them. The scans were compared to ones that had been taken when the students looked at pictures of friends or acquaintances. The researchers found that, when compared to neural responses to pictures of friends, photos of people they romantically loved caused the participants' brains to spark with activity in regions rich with dopamine, including the caudate nucleus and ventral tegmental area.

These two areas are part of the brain's reward circuit, the dopaminergic system associated with

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focused attention, elation, energy, craving, and motivation, characteristics exhibited by both the lovestruck and the cocaine addicted. According to Breiter, other brain regions may also be involved in love and addiction, including emotional centers such as the amygdala and the cingulate gyrus as well as areas associated with reward and punishment behaviors, such as the orbitofrontal cortex. Some researchers call this broader brain response the "extended reward oversight system," or EROS—curiously, the name of the Greek god of love. "The more we look, the more involvement we find by more regions of the brain," Breiter adds. "In fact, some scientists think that very few regions of the brain are *not* involved" in love and addiction.

Fuzzy love

Some models of drug addiction rely on what Breiter considers to be the more fuzzy theories of love, including positive reinforcement, negative reinforcement, and incentive salience. In the positive reinforcement model, addictive drugs reinforce or increase the frequency of a behavior. Drugs like cocaine and heroin produce a pleasant, feel-good sensation that temporarily rewards the drug user's behavior—and increases the chances of repeat drug use. Negative reinforcement can also cause behavior to be repeated, not because the sensation is euphoric but because the behavior, the drug taking, temporarily banishes a bad feeling or situation. Drugs, including alcohol, are often used to fill a perceived absence, perhaps one linked with loneliness or stress.

A third theory, the incentive salience theory, focuses on need rather than reward. In short, it addresses craving. If a person's addiction seems to be extinguished but reappears when a stimulus associated with the drug is introduced—for example, pictures of drug paraphernalia—then the need, the "want," has become a motivational magnet, triggering a craving for the drug. That same craving can be exhibited by someone bitten by the love bug. The person in love simply can't get enough of their beloved, and, at times, seek their presence to the exclusion of all else.

Just as falling in love causes reactions in the brain, so too does falling out of love. Breiter says that being rejected by a lover, much like withdrawal from an addictive drug, can diminish motivation and trigger dysphoria, a feeling of discontent and indifference to the world around us.

Love signals

Neurotransmitters are brain chemicals that transmit signals from nerve cell to nerve cell. These chemical messengers can affect mood, appetite, anxiety, sleep, fear, and a range of other physiological and psychological reactions. Some are implicated in love and addiction. The brains of the newly in love, for example, are awash in dopamine, which triggers an intense rush of pleasure, focused attention, and increased energy.

Recent studies are investigating the role of other powerful hormones that act like neurotransmitters. Oxytocin is one such hormone. Sometimes referred to as the love hormone, oxytocin provokes the feelings of contentment, calmness, and security so often associated with mate bonding. Vasopressin, a hormone used to regulate the body's retention of water, also has some neurological effects and may aid in tightening bonds between sexual partners. Although Breiter says scientists are only scratching the surface of an understanding of the role that serotonin plays in love, researchers at University College in London recently added to that small body of knowledge when they found that people in love have lower levels of serotonin, much like people with obsessive–compulsive disorder. This finding may help explain why people so obsessively focus on a newly found lover.

Just as falling in love causes reactions in the brain, so too does falling out of love. Breiter says that being rejected by a lover, much like withdrawal from an addictive drug, can diminish motivation and trigger dysphoria, a feeling of discontent and indifference to the world around us. In addition, just like a drug high or the first mad days of love, rejection can trigger a rise in levels of neurotransmitters that can spur feelings of depression and even lead to such destructive behaviors as homicide, stalking, and suicide.

According to Breiter, understanding the neurobiology of love can help us do more than explain the storms of new passion. It also might give context and insight into the interactions of society in general. "Love has been the focus of inspiration throughout our history. And, in times of discontent—economic or political, as examples—it might also be the key to generating feelings that can help us through such difficulties."

Fueling the Brain with Vegetables

TURNS OUT, MOMS are right. Those vegetables that kids so famously balk at are indeed good for them. Studies show that a diet rich in vegetables may not only keep our brains younger but may also slow the cognitive decline sometimes associated with aging.

Scientists think that micronutrients, such as antioxidants, flavonoids, and B vitamins, including folate, B6, and B12, which are found in vegetables, are important for brain function. Antioxidants, in the form of beta-carotene and vitamins C and E, quash the activity of free radicals, which can damage brain cells in ways that can lead to disease. Folate helps preserve cognitive function as we age, and vitamins B6 and B12 control levels of homocysteine. At normal levels, homocysteine is used by the body to make proteins and build tissues, but high levels of this amino acid are associated with Alzheimer's disease. The plant-produced compounds known as flavonoids have anti-inflammatory properties that may also have a neuroprotective effect. Among the several types of flavonoids are the anthocyanidins, compounds that give fruits such as berries and grapes their deep red, blue, or purple color.

In a 2004 study, Jae Hee Kang, an HMS assistant professor of medicine and an epidemiologist at Channing Laboratory, and her colleagues found that women in their 60s who routinely ate green leafy vegetables, such as lettuce and spinach, and cruciferous vegetables, such as broccoli and cauliflower, experienced less memory decline during their 70s. Women who consumed the highest amounts—1.5 daily servings of green leafy vegetables and 1 daily serving of cruciferous vegetables—benefited the most. A separate study found that people at highest risk of heart disease who ate these vegetables, along with the heart-healthy mono- and polyunsaturated fats found in salad dressings, got a "bigger bang for their buck," says Kang, in terms of heart and brain health.

Mixed reports on supplements

Kang says that prior research had shown that micronutrient supplements might protect against memory decline. The findings, however, have been far from unanimous: Some research on individual dietary supplements has shown little to no association between supplements and memory function, while other studies have found a measurable association between the two. "It is likely that the adage, 'if a little is good, a lot is better,' doesn't apply," Kang says, indicating that heaping supplements on top of food as sources of micronutrients doesn't give the brain an extra boost.

In addition to vegetables, a host of other foods may help our brains. Indications are that turmeric, a plant whose rhizomes, the knobby underground stems from which the plant grows, can be dried and ground into a spice often used in curries, and pomegranate juice may improve memory and other aspects of cognition. Blueberries and blackberries, jam-packed with flavonoids, are powerful weapons in the fight against age-related neurodegenerative diseases. And scientists have discovered that chocolate, long reported to have cardiac benefits, can be rich in memory-improving flavanols, another antioxidant compound.

Focus on fish

Kang is now turning her attention to fish oil, especially omega-3 fatty acids, to see if they too can prevent memory decline. Her study involving more than 3,000 people won't be completed for several years, but shorter term studies have shown a positive effect among people at high risk of memory decline and those who already had cognitive impairment.

Omega-3s are highly concentrated in the brain and appear to be important for memory and cognitive performance. Some studies show that adults need an omega-3 fatty acid known as

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docosahexaenoic acid (DHA) for proper brain function. DHA is known to aid in the development of the nervous and visual systems in humans. Although the body cannot produce omega-3s, these fatty acids are plentiful in vegetables such as kale and spinach, certain vegetable oils, and fatty fish such as salmon, sardines, and mackerel.

Diet alone—even the two cups a day of green leafy or cruciferous vegetables that Kang recommends—won't ensure that your brain stays healthy as you get older. But a balanced diet combined with maintaining a healthy body weight and getting plenty of exercise may be the best recipe for maintaining a healthy brain.

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