



Brian Knutson says
stocks, like sex,
addle the brain.

COVER STORY

By Adam Levy

◀ Late at night, in a basement laboratory at Stanford University, Brian Knutson made a startling discovery: Our brains lust after money, just like they crave sex. It was May 2004, and Knutson, a professor of neuroscience and psychology at the California university, was sending student volunteers through a high-power imaging machine called an fMRI. Deep inside each subject's head, electrical currents danced through a bundle of neurons about the size and shape of a peanut. Blood was rushing to the brain's pleasure center as students executed mock stock and bond trades. On Knutson's screen, this region of the brain, the core of human desire, flashed canary yellow.

The pleasure of orgasm, the high from cocaine, the rush of buying Google Inc. at \$450 a share—the same neural network governs all three, Knutson, 38, concluded. What's more, our primal pleasure circuits can, and often do, override our seat of reason, the brain's frontal cortex, the professor says. In other words, stocks, like sex, sometimes drive us crazy.

**Scientists
plumb the
mind to learn
how fear and
greed drive
Wall Street.**

Mapping the Trader's Brain

PHOTOGRAPH BY MARKHAM JOHNSON

Knutson says he knows how heretical his findings are. Wall Street is dedicated to the principle that when it comes to money, logic prevails, that intellect matters in investing. The idea is enshrined in the economic theory of rational expectations, for which Robert Lucas won the Nobel Memorial Prize in Economic Sciences in 1995. Lucas, a professor of economics at the University of Chicago, maintains that people make economic choices based on all the information available to them and learn from their mistakes. As a result, their expectations about the future—from the price of Citigroup Inc. stock next week to the earnings of General Motors Corp. next quarter—are, on average, accurate.

Or so the theory goes. In practice, of course, investors do foolish things all the time. Some gamble away fortunes on money-losing investments, doubling down when logic tells them to fold, or letting winnings ride when the rational person would cash out. Others seem to have an uncanny knack for knowing when to buy and sell. In the 1970s, Richard Dennis parlayed an initial stake of several thousand dollars into a \$200 million fortune trading commodities in the Chicago futures pits. In the 1980s, hedge fund icon Paul Tudor Jones made \$80 million by betting against U.S. stocks just before the market crashed. In the 1990s, billionaire investor George Soros, the man who beat the Bank of England, made \$1 billion in an afternoon by shorting the British pound.

The question that keeps nagging Knutson is this: Why do some traders get rich while others walk away losers? The answer, he says, may lie somewhere in the 96,000 kilometers (60,000 miles) of neural wiring inside our brains. The results of the Stanford study, published in the September issue of *Neuron* magazine, have caused a stir among the small group of neuroscientists and psychologists who are mapping the human brain in hopes of understanding investor behavior. This controversial field, called neurofinance, may represent the next great frontier on Wall Street, says Daniel Kahneman, who won the 2002 Nobel Prize in economics for his pioneering work in behavioral finance, which fuses classical economic theory and studies of human psychology.

"The brain scientists are the wave of the future in the financial world," Kahneman, 71, says. "If you seek to maximize understanding, whether you're in academia or in the investment

community, you'd better pay very serious attention to them."

To proponents such as Kahneman, the potential of neurofinance seems virtually limitless. One day, brain science may help money managers spot shifts in investor sentiment, says David Darst, chief investment strategist for the \$700 billion individual investor group at New York-based Morgan Stanley.

Armed with brain scans, psychotherapists may be able to hone traders' natural impulses of fear and greed. Neuroscientists may even develop psychoactive drugs, or neuroceuticals, that make people better, more-profitable traders, Knutson and other psychologists say. Look at Prozac. In the space of a few years, Prozac and other drugs have not only revolutionized the treatment of depression but also profoundly changed the way we view the mind. People recognize that chemistry drives their brains, moods and behavior—and that chemistry can change them. Similar drugs, ones that improve a trader's decision making by 20–30 percent, may be just a few years away, says Zack Lynch, managing director of NeuroInsights, a San Francisco-based consulting firm that tracks the \$100 billion neurotechnology industry. If these neuroceuticals work, they could rock Wall Street. "The whole investment community will be scrambling to get these things," Lynch says.

So far, the hopes and claims of neurofinance have far outpaced its science. Few investment professionals have even heard of the field. Many who have dismiss it as hokum.

Attitude This mixture of traits makes for an effective trader.



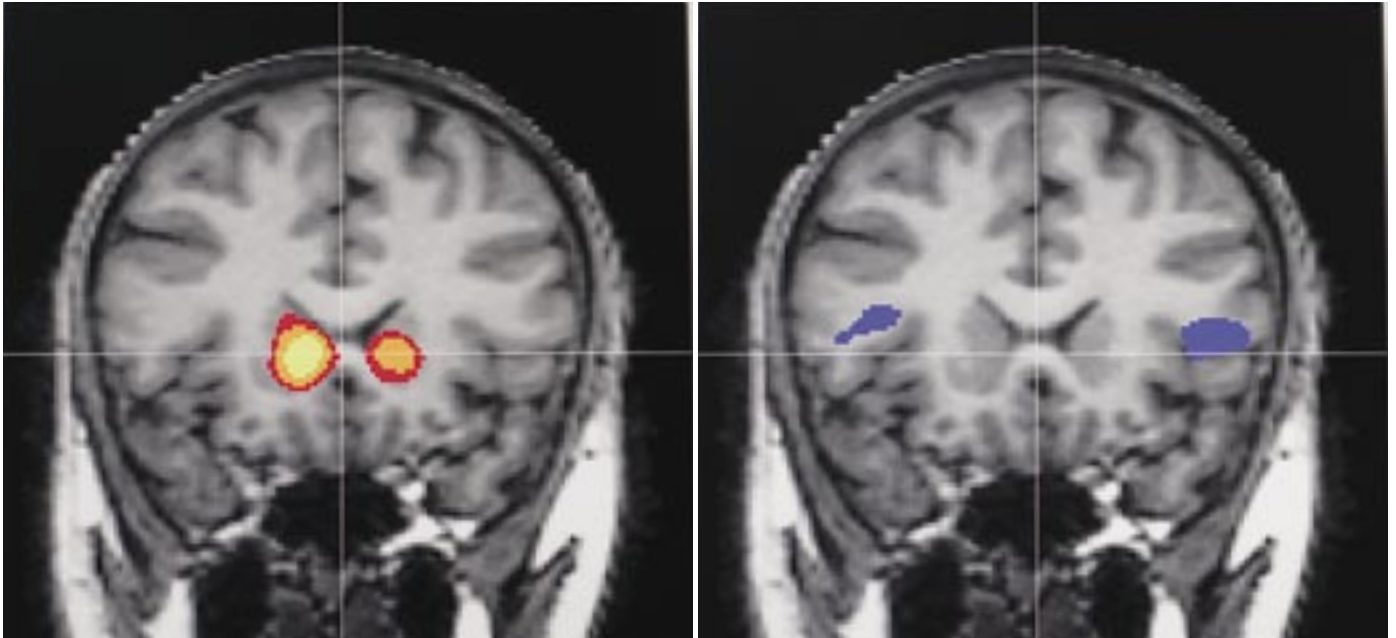
Source: marketpsych.com

"It's the latest malarkey," says Richard Michaud, president of Boston-based New Frontier Advisors LLC, which manages \$100 million in assets. Michaud, who has a doctorate in mathematics from Boston University, says neurofinance and its forerunner, behavioral finance, have no place on Wall Street. "I find these so-called disciplines to be more of a marketing tool, a way of taking an ages-old market valuation problem and calling it something space-age," Michaud says. "I doubt it will be fruitful."

Knutson's response: Just wait. "Investors want to beat the market and become better

traders," he says. "The first step is to know how the machinery works. The applications to exploit the machinery will soon follow."

People have been trying to explain how financial markets work for more than a century. In 1900, French mathematician Louis Bachelier argued that markets were essentially random. John Maynard Keynes, in his famous 1936 work,



Circuits: The brain's pleasure center, left, fires when people make risky trades. Other neurons, right, take over when people try to avoid losses.

General Theory of Employment, Interest and Money, likened the stock market to beauty contests that ran in newspapers of his day, in which readers were asked to pick the prettiest face. The key to selecting the winner, Keynes argued, isn't choosing the face you think is the most beautiful but rather anticipating the face other people will pick. American securities analyst John Burr Williams argued in 1938 that the price of financial assets reflects a measurable intrinsic value, a notion that fits with the value investing approach advocated by Benjamin Graham. The so-called efficient market hypothesis, popularized by economist Eugene Fama in the 1970s, holds, as Bachelier did, that price changes are random. In other words, no one can forecast markets accurately. According to Fama and his followers, technical traders, who believe they can predict prices by examining patterns of price movements, are wasting their time. Chartists can't beat the market. No one can, at least not for long.

For Wall Street, brain science eventually could mean big money, Morgan Stanley's Darst says. Securities firms spend millions of dollars annually researching companies and crunching numbers in an attempt to predict the financial future. "Meanwhile, we spend peanuts on human psychology," says Darst, author of *The Complete Bond Book: A Guide to All Types of Fixed-Income Securities* (Random House, 1975). "We have to take account of the deep atavistic and visceral traits and instincts that are triggering the buying and selling of securities."

The idea that something other than reason sometimes drives economic decisions is hardly new. *Extraordinary*

Popular Delusions and the Madness of Crowds, written by Charles Mackay in 1841, remains a Wall Street classic to this day. Mackay examined the history of alchemy, witch hunts, fortunetelling and speculative frenzies such as the mania over tulips that gripped Holland in the early 17th century, when the flower bulbs traded at a higher price than gold. His book shows how otherwise intelligent people sometimes succumb to mass idiocy. Terms used in psychology have become ingrained in the language of investing. A rush for junk bonds or Internet stocks is a "mania"; an economic collapse is a "depression." Keynes coined a colorful term for one of the vital ingredients of economic prosperity, the naive optimism that prompts people to cast aside their fears despite all experience: "animal spirits." In the 1970s, Kahneman began exploring

'Brain scientists are the wave of the future in the financial world,' says Nobel laureate Daniel Kahneman.



how investors systematically make judgment errors or mental mistakes. They follow the herd, trade excessively and react too slowly to unexpected news, he concluded.

Soros, 75, has a theory about why markets behave the way they do. He calls it reflexivity. The gist of it is that markets can't discount future events correctly because they actually help shape them. Consider the Nasdaq Stock Market boom and bust of the late '90s. Young, money-losing companies

depended on their ability to finance themselves in the capital markets. When stocks are climbing, such companies can raise money easily. A rising stock makes a startup more viable, which leads to an even higher stock price, which makes the company more viable still, and so on and so on. The same thing happens in reverse when stocks decline.

Soros's son, Robert, has offered his own explanation of his father's trading success. In *Soros: The Life and Times of*

neocortex—center of our higher mental functions—is capable of making 100 trillion connections. Scientists don't know how these billions of neurons give rise to consciousness and coordinated behavior. They don't understand the brain's electrochemistry. They've yet to determine how genes and experience, nature and nurture, shape the brain.

One August afternoon, as the brilliant California sun beats down on Stanford's sprawling, mission-style campus, Knutson sits inside his darkened second-floor office with the shades drawn. He's studying something on his computer. The image on his screen looks like a Rorschach ink blot, or maybe a halved cauliflower. It's a scan of a human brain—one of Knutson's trader test subject's—lit up in blue, yellow and pink.

Knutson has sandy hair cut school-boy short, a crooked grin and wire-rim

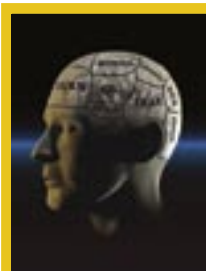
glasses. His baggy white oxford shirt is rumpled, and his shirttails trail outside his trousers. He rarely sits still and tends to rock and fidget while pattering about neurochemistry and brain connectivity. His appearance and mannerisms bring to mind a young, overcaffeinated Bill Gates. Papers are scattered on his office floor. An empty Peet's coffee cup sits atop his desk.

"This is so cool," Knutson says, pointing to the yellow area in the center of the scan. It's the nucleus accumbens—the pleasure center—of one of his volunteers.

Knutson has been trying to map the money mind since 1996. After graduating in 1987 from Trinity University in San Antonio, Texas, where he double majored in experimental psychology and comparative religion, Knutson earned a Ph.D. in experimental psychology from Stanford. He got involved in brain imaging while doing a postdoctoral fellowship at the University of California, San Francisco. "I figured if I can't delve into the brain, I'll never really know how it works," he says.

It was at the University of California that Knutson first began to discover how money plays on the brain. "We very quickly found out that nothing had an effect on people like money—not naked bodies, not corpses," he says. "It got people riled up. Like food provides motivation for dogs, money provides it for people." He eventually landed a grant to conduct brain scans specifically related to investing.

Later that August afternoon, Knutson hustles across campus to the Richard M. Lucas Center for Magnetic Resonance Spectroscopy and Imaging, home to Stanford's two functional magnetic resonance imaging machines, or fMRIs. Each of these \$2.5 million contraptions is the size of a small truck and weighs 12 tons. Unlike X-rays, MRI scans don't use radiation to peer inside the body. Instead, they use powerful magnetic fields to make the body's cells vibrate, generating electrical signals that are then interpreted by a computer and turned into



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a Messianic Billionaire (Knopf, 2002), a biography of the money manager written by former *New York Times* columnist Michael Kaufman, Robert Soros, 42, says of his father: "You know the reason he changes his position on the market or whatever is because his back starts hurting him. He literally goes into a spasm, and it's this early warning."

What makes a great trader? Alan Greenberg, chairman of the executive committee of Bear Stearns Cos., says the successful ones understand risk, absorb information and make quick, calculated decisions. They have the self-confidence to take a loss and move on, he says. Some of these qualities come down to instinct, says Greenberg, who joined New York-based Bear Stearns in 1949 and still sits on a trading desk. Even so, Greenberg doesn't buy neuroscientists' claims that such instincts are rooted in our brain. "There's smarts, there's guts and there's instincts," Greenberg, 78, says. "The other stuff—behavioral, neuro, whatever they call it—is horseshit."

Kenneth Griffin, founder of Chicago-based Citadel Investment Group LLC, says some people are natural traders. "Great investors understand risk and reward at an intuitive level," Griffin, 37, says.

Andrew Lo, a professor of finance and investment at the MIT Sloan School of Management, says conventional financial analysis fails to take into account human behavior. "Finance and economic research has hit a wall," says Lo, 45, who runs AlphaSimplex Group LLC, a Cambridge, Massachusetts-based hedge fund firm with \$200 million in assets. "We can't answer any more questions by running another regression analysis. Now, we need to get inside the brain to understand why people make decisions."

To most neuroscientists, the mind and the brain are one and the same. They see the brain as the physical basis for all our thoughts, beliefs and emotions. Yet researchers scarcely understand what goes on inside our heads. With 100 billion cells, each with 1,000 to 10,000 synapses, the

detailed images of slices of the body. Such devices are used on patients with conditions ranging from brain tumors to knee injuries. Unlike traditional MRIs, fMRIs can create moving images, not just static ones. They can capture the flow of blood through the brain, painting a picture of our mental activity in a palette ranging from hot pink to chromium yellow.

Before entering an fMRI, you must remove or put away anything that might contain metal: belts, shoes, cell phones, keys, coins and so on. While fMRIs and MRIs are generally considered safe—millions of imaging tests are conducted annually in the U.S. alone—accidents sometimes happen. The machines' electromagnets are so powerful that they've sent metal objects, including oxygen tanks and cleaning equipment, rocketing through the air.

Cleared of all metal, you lie face up on a table that moves in and out of a magnetic cylinder. Once inside, only a few inches of space remain between you and the surface of the cylinder. The confines can be so claustrophobic that a few of Knutson's subjects bailed out of his study. During their hour-long scans, Knutson's 19 volunteers—10 women and nine men—had to bite down on a piece of plastic to keep their heads still. They also had to wear plastic earphones, to drown out the whir of the fMRI, and wear video-display goggles so they could execute their mock trades.

Here's how the experiment worked: The subjects, who ranged in age from 24 to 39, were given \$20. In each round of the test, the volunteers got to choose among three investments. The first was a bond that was guaranteed to return \$1 per round. The second was a safe stock, with a 50 percent chance of earning \$10 per round and a 25 percent chance of losing \$10. The third was a risky stock, with a 50 percent chance of losing \$10 and a 25 percent chance of winning \$10. Knutson didn't tell his volunteers which stock was which, so his subjects had to rely on the stocks' history.

Three out of four times, the volunteers made wise, rational choices. Every fourth try, however, they exercised bad judgment, usually by chasing profit by selecting one of the two stocks when the bond would have been the smart choice or opting for the safety of the bond when they should have taken a gamble on one of the stocks. In each case, the fMRI captured what was going on inside their brains as they made their trades.

Wiring Traders

The S&P 500 is down 4 at 1293—sell! Ten-year Treasuries are up 1/4 to yield 4.45—buy! Your pulse pounds. Your palms sweat. And according to a 2004–05 study conducted at Stanford University, certain parts of your brain go into overdrive.

Stanford professor Brian Knutson and Camelia Kuhnen, a graduate student at the university's business school, designed an

experiment to determine how traders make decisions. They used a neural scanner to chart the brains of 19 healthy volunteers as those people executed mock stock and bond trades. The test subjects included doctoral candidates in finance and economics, as well as grad students in the humanities.

First, Knutson and Kuhnen created a computer game they called the Behavioral Investment Allocation Strategy task, or BIAS, to elicit a range of investment behaviors from their volunteers. The game consisted of 20 blocks of 10 trials each. During each trial, subjects first saw two stocks and a bond, waited a few seconds and then chose one of the investments when the word *choose* appeared on their video display. After each try, their earnings for that round and their total earnings were displayed.

Before the subjects entered the scanner, they played a practice version of the game for at least 10 minutes. They were then

shown the cash they could win by playing the game successfully. They were paid \$20 an hour and got to keep 10 percent of their winnings. "We needed to have the subjects involved, and there's no motivator like money," Knutson says.

The study found that the students made irrational choices 25 percent of the time. It didn't matter whether they were students of finance or philosophy. The scans showed that the brain's nucleus accumbens, the pleasure center linked to sex and drug addiction, is activated when we take trading risks. Another part of the brain, the anterior insula, lights up in brain scans when we try to avoid losses. Some of the students went home with \$40—a 100 percent return. Others lost all but \$5.

ADAM LEVY



Wired: MIT's **Lo** found that traders' pulses and breathing quicken when they take risks.

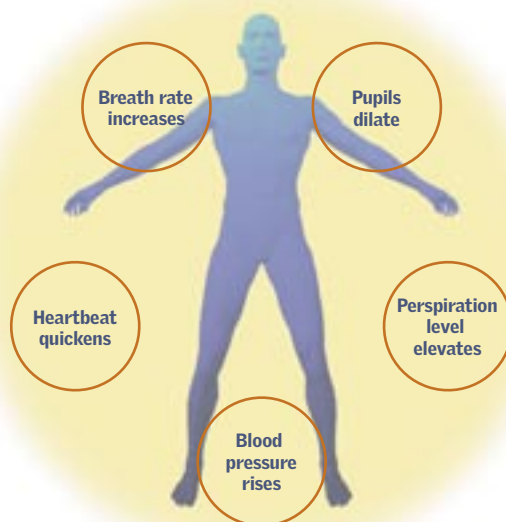


Morgan Stanley's **David Darst** wants to know what drives investors.

Before the students made a risky bet, investing in a stock that had burned them before, their nucleus accumbens flashed yellow on Knutson's screen. This part of the brain is driven primarily by dopamine, a chemical that scientists believe produces pleasure and euphoria. Dopamine fuels our reward response, and brains can't get enough of the stuff. When scientists insert an electrode into the nucleus accumbens of a rat, the rodent will press a lever that delivers a jolt to this region of its brain until the animal collapses from exhaustion or dies. Doctors who have performed similar experiments on humans during brain surgery have reported that some of their patients experience orgasms. All drugs of abuse, from cocaine to heroin, activate our dopamine circuits.

Before the volunteers made a safe investment, a different part of the brain, the anterior insula, was activated. While our nucleus accumbens may goad us on, our anterior insula is believed to hold us back with anxiety that can at times be irrational. The anterior insula is primarily driven by two other neurotransmitters, serotonin and norepinephrine, also known as noradrenaline.

High alert The body automatically responds when a person makes a risky trade.



Source: Bloomberg

While dopamine flows during our moments of pleasure, these two chemicals course through the brain when we're fearful or anxious. The sight of something disgusting or disturbing, such as a mutilated body, automatically triggers the release of these chemicals, Knutson says.

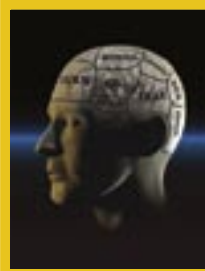
When we make trading decisions, our brain's centers for pleasure and angst wage battle. The first seeks profit; the second tries to avoid loss. Subjects who showed high activity in the anterior insula were 20 percent less likely to invest in a stock that had lost money before, even when the odds were good that they would profit. Such people might sell impulsively when markets turn against them, Knutson says.

Richard Peterson, a San Francisco-based psychiatrist, says Knutson's work might eventually lead to therapies and drugs that help override error-causing emotions. "This study pinpoints the neural targets we need to go after," Peterson, 33, says.

Wall Street is just one part of the business world that might profit from such brain science. It doesn't take a neuroscientist to know that salespeople and marketers try to mess with our heads all the time. They may not know it, but insurance agents who show prospects photos of fire-gutted homes are activating their marks' anterior insulae. Casinos that surround gamblers with food, drinks and prizes are appealing to the dopamine circuits of the pleasure center.

Gemma Calvert, who has a doctorate in brain imaging from Oxford University, is attempting to tap into consumers' brains. Her Oxford-based firm, Neurosense Ltd., has tried to help Omnicom Group Inc., a New York-based advertising company, figure out whether print, radio or television ads make the biggest impact on the brain. Volunteers watched TV, listened to radio and read magazine advertisements while Calvert studied their brains' reactions. The results, she says, were inconclusive. "We're not pretending we can find a consumer's 'buy button,'" Calvert says. All the same, brain science is still in its infancy, and its potential in advertising and marketing could be enormous, she says.

Not everyone says scientists should spend time and money plumbing the brains of traders and consumers. Neurofinance research ties up expensive medical equipment that should be used to heal people, says Gary Ruskin,



'There's smarts, there's guts and there's instinct,' Bear Stearns's Greenberg says. He says neurofinance is a sham.

executive director of Commercial Alert, a Portland, Oregon-based nonprofit organization that fights what its members see as the creeping commercialization of American culture. His group has called for a ban on using fMRIs for anything but fighting disease. "There's an opportunity cost of using these machines," Ruskin, 40, says. "I'd rather we use them to spot a tumor and save a life than earn an extra fraction of a percentage from stock trades."

Lo, at MIT, is unbowed. He says neuroscientists might be able to help traders conquer emotions that cloud judgment. Lo has studied traders at work and learned what people such as Bear Stearns's Greenberg have known for decades: Gut matters. In 2002, Lo wired 10 currency traders at a Boston brokerage to equipment that measured their heart rates, breathing, body temperatures, blood pressure and perspiration. During the course of a single day, the traders together made 1,200 split-second trades averaging \$4 million. Their pulses pounded, their breathing became heavy, their palms sweated. Lo concluded that greed and fear played a big role in the traders' decisions and that inexperienced traders were the most likely to make emotional mistakes. A similar study conducted by Lo in 2005 found that the most-successful traders were those who managed to keep their emotions on an even keel whether they were making money or losing money. "Emotions definitely count," Lo says. "Now, I want to dig deeper into the brain to better understand what is going on and see if we can refine our applications in the real world."

Knutson's Stanford study caused a buzz in September at the third annual conference of the Society for Neuroeconomics, held at the Kiawah Island Golf Resort in South Carolina. The three-day event drew 115 people, mostly from academia. The sole Wall Streeter was Arnold Wood, who helps manage \$4 billion at Martingale Asset Management in Boston. He says he's confident neurofinance will catch on among other investors.

"People scoffed at behavioral finance, calling it BS," Wood says. "But its underlying premise was right: Investors make mistakes, and the more we can understand about why and how, the sooner we can correct them." To Wood, neurofinance research reinforces a common-sense lesson: One should stop and think

before making a big trade. If nothing else, the findings of brain researchers have made him more aware of his emotions and motivations, he says.

For now, neurofinance is more science fiction than science fact. While brain scans have begun to back up the Nobel-winning theories of behavioral finance, scientists have a long way to go before their research translates into

profit on Wall Street, says Peterson, the San Francisco psychiatrist. "So far, neurofinance is 'all hat and no cattle,' as my Texan relatives might say," Peterson says.

Back at Stanford, Knutson says he's confident his research will pay off one day. Unlocking the mysteries of the human brain is the greatest challenge that scientists have ever faced, he says. "Brain imaging gives us the hope of opening up the black box," Knutson says, and money may be the key.

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Activist **Gary Ruskin** says scientists should help the sick, not Wall Street.