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SCIENCE DESK

Hijacking the Brain Circuits With a Nickel Slot Machine

By SANDRA BLAKESLEE (NYT) 1665 words

Compulsive gambling, attendance at sporting events, vulnerability to telephone scams and exuberant investing in the stock market may not seem to have much in common. But neuroscientists have uncovered a common thread.

Such behaviors, they say, rely on brain circuits that evolved to help animals assess rewards important to their survival, like food and sex. Researchers have found that those same circuits are used by the human brain to assess social rewards as diverse as investment income and surprise home runs at the bottom of the ninth.

And, in a finding that astonishes many people, they found that the brain systems that detect and evaluate such rewards generally operate outside of conscious awareness. In navigating the world and deciding what is rewarding, humans are closer to zombies than sentient beings much of the time.

The findings, which are gaining wide adherence among neuroscientists, challenge the notion that people always make conscious choices about what they want and how to obtain it. In fact, the neuroscientists say, much of what happens in the brain goes on outside of conscious awareness.

The idea has been around since Freud, said Dr. Gregory Berns, a psychiatrist at Emory University School of Medicine in Atlanta. Psychologists have studied unconscious processing of information in terms of subliminal effects, memory and learning, he said, and they have started to map out what parts of the brain are involved in such processing. But only now are they learning how these different circuits interact, he said.

"My hunch is that most decisions are made subconsciously with many gradations of awareness," Dr. Berns said. "For example, I'm vaguely aware of how I got to work this morning. But consciousness seems reserved for more important things."

Dr. P. Read Montague, a neuroscientist at Baylor College of Medicine in Houston, says the idea that people can get themselves to work on automatic pilot raises two questions: how does the brain know what it must pay conscious attention to? And how did evolution create a brain that could make such distinctions?

The answer emerging from experiments on animals and people is that the brain has evolved to shape itself, starting in infancy, according to what it encounters in the external world.

As Dr. Montague explained it, much of the world is predictable: buildings usually stay in one place, gravity makes objects fall, light falling at an oblique angle makes long shadows and so forth. As children grow, their brains build internal models of everything they encounter, gradually learning to identify objects and to predict how they move through space and time.

As new information flows into it from the outside world, the brain automatically compares it to what it already knows. If things match up -- as when people drive to work every day along the same route -- events, objects and the passage of time may not reach conscious awareness.

But if there is a surprise -- a car suddenly runs a red light -- the mismatch between what is expected and what is happening instantly shifts the brain into a new state. A brain circuit involved in decision making is activated, again out of conscious awareness. Drawing on past experience held in memory banks, a decision is made: hit the brake, swerve the wheel or keep going. Only a second or so later, after hands and feet have initiated the chosen action, does the sense of having made a conscious decision arise.

Dr. Montague estimates that 90 percent of what people do every day is carried out by this kind of automatic, unconscious system that evolved to help creatures survive.

Animals use these circuits to know what to attend to, what to ignore and what is worth learning about. People use them for the same purposes which, as a result of their bigger brains and culture, include listening to music, eating chocolate, assessing beauty, gambling, investing in stocks and experimenting with drugs -- all topics that have been studied this past year with brain imaging machines that directly measure the activity of human brain circuits.

The two circuits that have been studied most extensively involve how animals and people assess rewards. Both involve a chemical called dopamine. The first circuit, which is in a middle region of the brain, helps animals and people instantly assess rewards or lack of rewards.

The circuit was described in greater detail several years ago by Dr. Wolfram Schultz, a neuroscientist at Cambridge University in England, who tracked dopamine production in a monkey's midbrain and experimented with various types of rewards, usually squirts of apple juice that the animal liked.

Dr. Schultz found that when the monkey got more juice than it expected, dopamine neurons fired vigorously. When the monkey got an amount of juice that it expected to get, based on previous squirts, dopamine neurons did nothing. And when the monkey expected to get juice but got none, the dopamine neurons decreased their firing rate, as if to signal a lack of reward.

Scientists believe that this midbrain dopamine system is constantly making predictions about what to expect in terms of rewards. Learning takes place only when something unexpected happens and dopamine firing rates increase or decrease. When nothing unexpected happens, as when the same amount of delicious apple juice keeps coming, the dopamine system is quiet.

In animals, Dr. Montague said, these midbrain dopamine signals are sent directly to brain areas that initiate movements and behavior. These brain areas figure out how to get more apple juice or sit back and do nothing. In humans, though, the dopamine signal is also sent to a higher brain region called the frontal cortex for more elaborate processing.

Dr. Jonathan Cohen, a neuroscientist at Princeton, studies a part of the frontal cortex called the anterior cingulate, located in back of the forehead. This part of the brain has several functions, Dr. Cohen said, including the task of detecting errors and conflict in the flow of information being processed automatically.

Brain imaging experiments are beginning to show that when a person gets an unexpected reward -- the equivalent of a huge shot of delicious apple juice -- more dopamine reaches the anterior cingulate. When a person expects a reward and does not get it, less dopamine reaches the region. And when a person expects a reward and gets it, the anterior cingulate is silent.

When people expect a reward and do not receive it, their brains need a way to register the fact that something is amiss so it can recalibrate expectations for future events, Dr. Cohen said. As in monkeys, human dopamine neurons project to areas that plan and control movements, he said. Fluctuating levels of dopamine make people get up and do things, outside their conscious awareness. The number of things people do to increase their dopamine firing rates is unlimited, neuroscientists are discovering. Several studies were published last year looking at monetary rewards and dopamine. Money is abstract but to the brain it looks like cocaine, food, sex or anything a person expects is rewarding, said Dr. Hans Breiter, a neuroscientist at Harvard. People crave it.

Some people seem to be born with vulnerable dopamine systems that get hijacked by social rewards. The same neural circuitry involved in the highs and lows of abusing drugs is activated by winning or losing money, anticipating a good meal or seeking beautiful faces to look at, Dr. Breiter said.

For example, dopamine circuits are activated by cocaine; people become addicted when their reward circuits have been hijacked by the drug, Dr. Montague said.

Winning in gambling can also hijack the dopamine system, Dr. Berns said. Many people visit a casino, lose money and are not tempted to go back. But compulsive gamblers seem to have vulnerable dopamine systems, he said. The first time they win, they get a huge dopamine rush that gets embedded in their memory. They keep gambling and the occasional dopamine rush of winning overrides their conscious knowledge that they will lose in the long run.

Other experiments show that reward circuits are activated when young men look at photos of beautiful women and that these circuits are defective in women with eating disorders like bulimia. Bulimics say they are addicted to vomiting because it gives them a warm, positive feeling.

Music activates neural systems of reward and emotion. Older people with age-related impairments to the frontal cortex do poorly on gambling tasks and, experiments show, are prone to believe misleading advertising.

Neuroscientists say that part of the appeal of live sporting events is their inherent unpredictability. When a baseball player with two outs at the bottom of the ninth inning hits a home run to win the game, thousands of spectators simultaneously experience a huge surge of dopamine. People keep coming back, as if addicted to the euphoria of experiencing unexpected rewards.

One of the most promising areas for looking at unconscious reward circuits in human behavior concerns the stock market, Dr. Montague said. Economists do not study people, they study collective neural systems in people who form mass expectations. For example, when the Federal Reserve unexpectedly lowered interest rates twice last year, the market went up, he said. When it lowered interest rates on other occasions and investors knew the move was coming, markets did not respond.

Economists and neuroscientists use the same mathematical equations for modeling market behavior and dopamine behavior, Dr. Montague said. Neuroscience may provide an entirely new set of constructs for understanding economic decision making.