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# Let it Ride: the neuroscience of risk

**By John Pearson**

Are some people just born risk-takers, indifferent to chance, or is there something deep within all of us that drives us to gamble?

For a brief time in January of 2007, after saving a fellow passenger from an oncoming subway train, Wesley Autrey, a New York City construction worker, was a national hero. "I had to make a split decision," he told The New York Times the next day. "I just saw someone who needed help. I did what I felt was right."

Four months later, following a whirlwind season of interviews, public receptions, and talk-show appearances, his rise to prominence culminated in quintessentially American fashion: as a contestant on the hit NBC game show Deal or No Deal. The show, which features twenty-five "spokesmodels" toting twenty-five money-laden briefcases containing amounts ranging from one cent to $1 million, is essentially a glorified guessing game: Contestants open several cases each round, removing the corresponding prizes from play. Go all the way to the last case and win what's inside.

Along the way, however, aspiring millionaires must reject a series of escalating buy-out offers from the show's host (an eerily glabrous Howie Mandel), a twist that results in much agonized hand-wringing and tension-fraught commercial breaks. The average contestant, it may be observed, stands to win something in the low six figures. Nearly all eventually take a settlement.

Autrey, whose episode aired the following May, played fearlessly, and fared much better than most. With only three cases remaining—$25, $10,000, and $1 million—he was offered a whopping $305,000 buy-out, a near-record, and only $33,000 less than the average of the remaining prizes. As Mandel leaned in and whispered the show's pivotal phrase, "Deal â€¦ or no deal," Autrey glanced at family members just offstage before delivering his answer: "No deal." Turning toward the models, he called for case number 14. The amount inside: $1 million. A collective groan issued from the audience. Autrey's relatives appeared visibly deflated. Once again, Autrey was offered a buy-out —$5,000, almost exactly the average of the two remaining values—but again declined. The last case opened, his own, contained $25.

"It was the risk, you know?" he said in an interview after the show, "just like the chance I took that day." But was it? Did the same quality that allowed Wesley Autrey to risk his own life for a stranger's make him squander a lucrative sure thing? What possessed him to take such a reckless chance, one that seems so very wrong to the rest of us? Are some people just born risk-takers, indifferent to chance, or is there something deep within all of us that drives us to gamble?

Those are just the kinds of questions that Scott Huettel is trying to answer. Huettel Ph.D. '99, an associate professor of psychiatry, is co-director of Duke's Center for Neuroeconomic Studies, a think tank for researchers interested in decision-making and the brain.

"I think there are actually two types of neuroeconomics," says Huettel, "and they don't always coexist very easily. One is trying to use neuroscience to understand particular types of decision-making: Can we understand why people might choose a riskier option over a safer option? Or why they might choose to give up some of their money to help someone else? Neuroscientists are very excited about this because it gives them a whole range of interesting questions.

"The other type would be: Can we use neuroscience data to alter economic policy? So if we have some theory about decision-making, or about some type of particular economic policy, can we use neuroscience to better help with that? And that direction is not always well accepted. There's more resistance to whether neuroscience data can really help change the way economists think at a deep level."

Neuroeconomics is what's typically referred to as an "emerging" discipline, a term that suggests, at least in part, a certain lack of unifying view. Like many cross-disciplinary endeavors, its boundaries are defined more by individual researchers than any set of canonical ideas, and so it tends to incorporate a multiplicity of methodologies and aims. As a result, neuroeconomics winds up serving as a sort of big tent for economists, biologists, and other academics interested in how we make decisions.

For Huettel, for instance, coming from a background in psychology, the attraction of working with economics lay in its precision: "I was previously studying basic executive-control processing, and that was pretty much like decision-making, but perhaps you can think of it at a simpler, more psychological level. And what really excited me was almost a methodological point, which is that we can really do some very controlled, well-formulated tasks using economics. It provides a level of precision that we didn't always have in the psychological brand of tests."

Huettel's lab specializes in the technology known as fMRI, or functional magnetic resonance imaging, which involves combining multiple sequential images from the well-known tumor-scanning machines to reconstruct blood flow in the brain. This blood flow is linked with certain forms of brain activity, and thus offers a noninvasive method of acquiring information about brain function in real time. Made famous by the color-coded pictures used to illustrate popular science articles, its application is one of the fastest-growing areas of brain research.

What interests Huettel most are the social factors that attend decision-making. "I think the coolest sorts of studies are at the intersection of social information and economics," he says. "Aside from [the fact] that they're omnipresent, social situations may allow us to look at systems in a cleaner way. Even though it seems more complex, it may be that the systems involved in decision-making evolved to deal with that type of information, not gambles presented in terms of rewards and probabilities.

"And what these sorts of studies will suggest, I think, is that the concept of economic utility, the bedrock, is probably not strictly the case. That we didn't evolve to deal with money, we evolved to deal with a bunch of different rewards, and those rewards might conceivably be in different currencies."

One day last summer, in order to see the method in action, I met up with Vinod Venkatraman, a student of Huettel's, at a waiting area near the fish tank in the Duke Children's Hospital. He was there to rendezvous with a test subject, one of several dozen in the medical center's prescreened database, and lead her back to the secured wing of the hospital where the MRI scanners are housed.

As instructed, No. 7 (her subject number) came dressed in T-shirt and sweats—nothing metallic—since the principal component of any MRI scanner is a giant doughnut-shaped electromagnet, and within its field, even the smallest shards of metal become deadly projectiles. In fact, just to be eligible for MRI experiments, which pay a minimum of $20 per hour, subjects must undergo scanning for metal implants, a battery of medical history questions, and even a pregnancy test.

The MRI scanning room in the Brain Imaging Analysis Center is reached via a pair of secure-access double doors. A spacious waiting area-cum-control room, its walls are lined with desks laden with computers; a walk-through metal detector fronts the entrance to the scanner room proper.

Before No. 7 enters the scanner, Venkatraman gives her the standard orientation spiel: The experiment involves a series of lotteries, each with a mixture of prizes (both positive and negative) at varying probabilities. After an initial stage in which she is required only to think about the gamble, No. 7 will subsequently be offered a pair of modifications—something like an enlargement of the largest prize or a positive result instead of a no-money outcome—and will have to choose which one she prefers. The results of a subset of these gambles will be played out, and the results added to (or subtracted from) the base pay for the study, which represents her endowment.

As the study begins, Venkatraman and I watch together as the gambles and No. 7's subsequent choices appear onscreen. Most people, when presented with the option of modifying a gamble, prefer a guarantee of some gain to a larger potential prize, and an increased potential of breaking even to a smaller worst-case loss (though both depend on the amounts and probabilities involved). Since any decision involving risk implies at least some weighing of gains and losses, and since the brain appears to possess multiple (and interdependent) systems for evaluating each, Venkatraman and collaborators are hoping to detect in the fMRI signal interaction between these several reward systems. One of the systems, for instance, may be responsible for calculating what is known as expected value, the average reward earned per gamble; another, responsible for loss-aversion, may prefer a guaranteed return.

Right now it's not even completely understood how many such systems there are in the brain, or whether such a partition is even sensible. For the moment, the focus is on narrowing down the list of the key players, trying to understand which regions are most important for our willingness to take risks.

As Huettel puts it, "The basic reward systems of the brain are pretty much co-opted learning systems. They can become pathological in cases of addiction, in cases of gambling. There may be components that are helping us evaluate probability—how likely I am to be successful at a given action; other components that may be pushing us away from options that have negative consequences. I think what we have to recognize is that we evolved for very different environments than we are in now. In our evolution, we never had to deal with something like winning a million dollars. There was never a situation where one had to make decisions about quantities that large."

At close range, the eye of the rhesus monkey, macaca mulatta, can appear almost unnervingly human—wide with amazement, pupil darting back and forth—an illusion broken only by the long strands of fur drooping downward from its brows. That image, courtesy of a laser eye-tracking system mounted above the monkey's head, fills the screen of a computer monitor in a neural recording room in the Duke vivarium, part of the laser-and-mirror assembly used to track the millisecond shifting of the animal's eyes.

The monkey does not appear to notice. Staring through the transparent glass of his eyepiece, attending to the glow of a giant computer monitor, he appears unaware that at this same moment, in the room next door, his own brain is a subject of intense study, its electrical activity traced out across a computer monitor.

These monkeys, and these rooms, are part of the lab of neurobiologist Michael Platt, Huettel's co-director at CNS and president of the Society for Neuroeconomics. His 1999 Nature paper, which showed that neurons in an area of monkey brains known as LIP encoded the expected value of risky choices, became one of the founding documents of the field.

"What we think of as neuroeconomics is still being defined," Platt says. "Initially, neuroeconomics was defined by the people who were associated with the branding of the discipline, the branding of the society, twelve or fifteen people who met on Martha's Vineyard. This year, the abstracts are much broader in what they cover, in the methods they employ. I see neuroeconomics as just a way of getting a handle on the information that's used during decision-making."

For a biologist like Platt, the allure of neuroeconomics stems from a broader interest in the underlying mechanisms that allow our brains to choose. And the juncture at which those neurobiological questions take over from techniques like fMRI is at the level of the neurons themselves, the hundred billion or so cells bundled together to form the human brain. And while techniques for studying the activity of individual nerves have been around for nearly a century, such experiments generally require direct access to brain tissue, narrowing the pool of potential human subjects.

Most of the time, researchers must make do with so-called "homologues" of the human brain, close cousins like those of rhesus macaques. "The kinds of techniques that we're comfortable using in animals we would not be comfortable using in people," Platt explains. "We're not comfortable sticking electrodes in people's heads. But the neuroimaging methods we have now are not up to giving us the temporal and spatial resolution at the level of a single neuron.

"So that's the number-one reason we use animals. And we can actually [access] the fundamental units of information-processing in the brain while these animals are performing tasks that are similar, if not identical, to the ones we use in humans. We can tap into some of the basic principles underlying decision-making."

These days in the Platt lab, those experimental tasks are most often tied to gambling behavior and the social cues that affect it. "My own bias is that I'm really interested in social decision-making," Platt says. "A lot of it is traditional, straight neuroeconomics: What happens in your brain when you buy something? What neural systems are involved in mediating risk, in deciding what you're going to do when faced with a gamble? But there are a lot broader questions now, questions like, What happens when two people interact? What's the role of empathy in human behavior? How much of that is conscious, versus implicit? I think that is really interesting, but that's also one of the hardest things we can possibly approach. And it's something that's very hard to study in the laboratory, especially lying in an MRI magnet."

And so, on a typical day, half a dozen monkeys are busy performing up to ten separate experiments, their furtive, rapid eye movements, known as saccades, signaling choices paired with targets on large computer monitors. A typical experiment may involve presenting the animal with a pair of colored dots—one "safe," the other "risky"—corresponding to different amounts of a juice reward to be delivered through a tube to the monkey's mouth. In many setups, such as the one currently overseen by Ben Hayden, a postdoctoral researcher in the lab, these choices are balanced for expected value: On average, each yields the same amount of juice, but, depending on circumstances, the monkeys show a strong preference for one or the other.

In fact, in a study coauthored by Platt and former graduate student Allison McCoy '96, M.D. '07, Ph.D. '07, it was discovered that the monkeys were actually "risk-seeking" when rewards were small and the wait between gambles was short. In other words, when playing many times for small stakes, the monkeys actually preferred the risky to the safe option. On the other hand, in more recent work involving food rewards and longer waiting periods, Platt and colleagues have shown that monkeys, like humans and other animals, display risk-aversion, favoring the guaranteed payout of the safer target.

On the day I toured the lab, Hayden took me next door to the recording room, a four-by-eight closet jammed with electronic equipment. Several of the displays, like the closed-circuit monitor, allow researchers to watch the monkeys as they perform the task. The rest, including a large central screen, track signals from the recording electrode, a tiny, 200-micrometer-thick wire implanted into the monkey's brain.

As the experimenters inch this electrode through the tissue, hunting for cells, the data stream in in the form of characteristic neural "spikes" of electrical activity, the language of active neurons. Fed into an amplifier and played over speakers, a healthy cell makes a sound like the crinkling of Saran wrap, a dying cell, like the squeal of a deflating balloon. Hayden tells me the practiced ear can hear the difference between white and gray matter, layers III and IV of cortex, cells firing, cells dying—all within what, to the unitiated, sounds like pure white noise.

Later, when the data are sorted, they will be analyzed with a view to variations in each recorded cell's spiking frequency, the internal representation of the monkey's decision-making process. In Hayden's experiment, these data come from a region in the brain called the posterior cingulate cortex, the rear portion of a band of tissue that arches from the back to the front of the brain. The goal of his experiment is to determine whether the posterior cingulate, one of the brain's enduringly enigmatic regions, may encode notions of salience, the degree to which novel or surprising outcomes stick out in our minds.

In the case of a gambler, or a monkey, this may explain why risk is so alluring: The memory of the jackpot remains so piquant that our calculations of overall risk become skewed. If our brains recall the bells and whistles of the wins more easily than the frustration of the losses, we may gamble more readily—and at a greater disadvantage. On the other hand, when gambles are infrequent (and thus the losses more acute), we (and monkeys) begin giving greater weight to risk, opting for safety over larger, rarer scores.

In recent experiments, Hayden has selectively stimulated and inactivated neurons, examining their effect on risk behavior. On an even more microscopic level, others in the Platt lab are now studying how genetic factors, specifically those that control sensitivity to the neuromodulators dopamine and serotonin, affect our willingness to take risks. If Parkinson's patients, whose medicines are designed to remedy low dopamine levels in their brains, are anecdotally more susceptible to gambling addiction, might the genetic factors that regulate our chemical balances wind up with a significant role in how we play the odds?

Platt certainly believes so. In fact, as he reflects upon the future of neuroeconomics, he is increasingly skeptical of the notion that human decision-making will be reducible to a few key mathematical variables. "A lot of the assumptions that economists make are not that valid for the decisions we face every day," he says. "It's going to turn out to be a very complicated picture.

"We now appreciate that there's a lot more variation within each population and also between species; it's highly context-dependent; depends a lot on attention; depends on neuromodulatory factors, a lot of which you're born with, some of which depend on your current environment. I think we're providing a richer picture of what's going on."

And what about Wesley Autrey? Was he a savvy value-maximizer or an impulse-driven gambler? Did he succumb to audience expectations or an overactive reward system, perhaps a high serotonin susceptibility coded in his genes? Possibly none of these things. Possibly all of them.

From the standpoint of neuroscience, it's simply too soon to tell. With humans, who have the power to consider, reconsider, and override their impulses, there is always a complex interplay between the future and the present, our rational approach to the long run and our suspicion that the long run will never even out. The conundrum of chance, exacerbated by our own imaginations.

At least the monkeys never had to deal with that. As Autrey confided to a television interviewer after the show, "This was just as scary, if not more, than when I was underneath that train."

Pearson is a post-doctoral researcher in the department of neurobiology at Duke.

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