Neuroscience and Investing

In a great book, "**Inside the Investor's Brain**", by Richard L. Peterson, there is an insightful introduction into neuroinvesting.

> " "In terms of biological design for the basic neural circuitry of emotion, what we are born with is what worked best for the last 50,000 human generations. . . . The slow, deliberate forces of evolution that have shaped our emotions have done their work over the course of a million years; the last 10,000 years have . . . left little imprint on our biological templates for emotional life. "
>
> – Daniel Goleman, Emotional Intelligence

Investors' emotions and motivations are often unconscious, but they are nevertheless powerfully influential over decision making. Fortunately, new tools in psychology and technologies in neuroscience are revealing the deep neural origins of investors' emotional biases and suggesting techniques to ameliorate their effects on judgment. The neural and mental foundations of financial decision making, beginning here with the brain origins.

Some psychiatric disorders manifest through repeatedly poor financial decision making. Compulsive stealing, hoarding unneeded items, shopping out of control, and making wildly speculative gambles are all characteristics of different types of mental illness. When I was training as a psychiatrist, we occasionally evaluated patients who had no known neurological, addictive, or mental disorder but who nonetheless demonstrated chronically poor financial judgment.

At < ?xml:namespace prefix = st1 ns = "urn:schemas-microsoft-com:office:smarttags" />San Francisco General Hospital, the psychiatry consultation team was called to assess the decision-making capacity of a patient named Lee.

One year earlier, after months of increasing headaches, visual abnormalities, and difficulty concentrating, a tumor had been detected in Lee's brain. Lee was 53 years old and a partner in an accounting firm at the time. He was suffering from a rare, benign tumor of the brain called a meningioma. These tumors arise in the meninges, the thin but dense membrane that separates the brain from the skull. In Lee's case, the tumor had swelled upward from the base of his skull, displacing the brain tissue along the midline of his frontal lobes. It was the size of a lemon by the time it was discovered.

Neurosurgery was performed and successfully led to the tumor's removal. As in many cases like this, some normal brain tissue had been starved of oxygen by the tumor, and the dead tissue was also removed from the brain. As a result, Lee lost part of his brain's orbitofrontal cortex (OFC).

A few weeks after surgery, Lee returned home from the hospital and tried to go back to life as usual. Even though he had lost part of his brain, Lee was still an intelligent man. His IQ remained superior, and his neuropsychological testing showed no significant motor, perceptual, visuospatial, or calculation deficits.

However, according to his wife, he demonstrated some unusual behavior during his first two months at home. He made a few large, unnecessary purchases on his credit card, including two new cars and a boat. His wife asked him to stop making such purchases, as they already had what they needed. He was agreeable to this request, and returned one of the cars and the boat. Yet he continued to make large purchases at an alarming rate, quickly maxing out his credit card limits and further distressing his wife.

His performance at work was characterized by an inability to multitask. He often became totally involved in doing one activity all day even though many others urgently needed his attention. His performance dropped off, and over six months it became clear that he couldn't continue to manage his current projects. He left his workplace, taking early retirement.

After retirement, he continued to make bad investment decisions. He bought several vacation time-shares with little money down, encouraged by slick sales pitches. He bought penny stocks based on fax and e-mail promotions. He lost large sums of money in most of these investments. After several months, he could no longer afford his mortgage payments. He and his wife were on the brink of bankruptcy and divorce.

We were seeing Lee one year after his surgery. As psychiatrists, it was our job to determine if Lee was still competent to manage his own medical, legal, and financial decisions. If not competent, some of these decisions could be taken over by his wife.

Lee was intellectually aware that he had been making very risky investments with his limited resources. He acknowledged that this was completely new behavior for him. Previously, he had been a conservative investor, and he didn't like to gamble. Now he knew how he should feel about the financial risks he was taking, but he didn't feel afraid. In fact, he didn't feel much of anything about risk. He didn't restrain himself from taking large speculative risks because the investments didn't feel risky to him.

Our team determined that Lee was normal in every way except in his assessment of risk. He was not inhibited by fear, and he was easily enticed by potential opportunity. Lee's situation illustrates that risky decision making is rooted in somewhat fragile neurological processes. Most people are occasionally tempted to invest in speculative ventures or to purchase prohibitively expensive luxury goods, but they exercise self-restraint due to the potentially negative consequences of excessive debt. Because they are afraid of the consequences, they refrain from indulgence. During background research we realized that Lee was experiencing similar impairments to a group of patients studied extensively by neurologist Antonio Damasio at the University of Iowa.

DAMASIO AND THE IOWA GAMBLING TASK

Lee had a lesion in the OFC of his brain. Damage in other areas of Lee's brain could have led to similar problems as he was experiencing if it had affected the broad brain circuit, part of which was removed from Lee's OFC, called the "loss avoidance system." When a brain tumor or other event leads to damage in part of the loss avoidance system how individuals perceive and process risky situations is altered.

In the early 1990's then at the University of Iowa, the neurologist Antonio Damasio took an interest in several patients with OFC lesions in his neurology clinics. His patient group had lesions of the ventromedial prefrontal cortex (the midline aspect of the OFC). Like Lee at my hospital, these patients retained their basic intelligence, memory, and capabilities for analytical reasoning and for logical thought, but they made poor decisions in risky situations.

Many of these patients reported that they knew when they should feel afraid, but they had difficulty both (1) experiencing emotions and (2) associating their feelings with anticipated consequences. Essentially, they had a deficit in their ability to integrate emotions and thinking.

It turns out that the part of the brain these patients were missing, the OFC, evaluates the relevance of emotional input to one's decision making. Darnasio's patients could not understand what emotional information was important. Just like Lee, they knew when they should be afraid, but they could not use fear to help them avoid taking a dangerous financial risk.

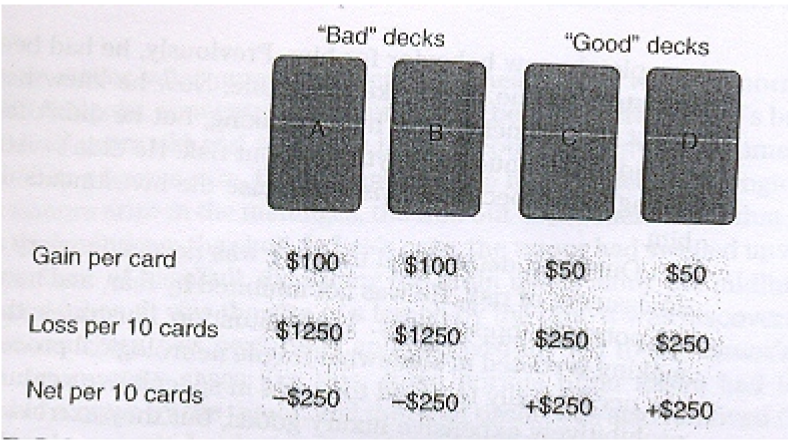

FIGURE 1. The Iowa Gambling Task. Notice that the net return per deck is negative for decks A and B and positive for decks C and D. Additionally, the range of gains and losses is much smaller in decks C and D.

Damasio wanted an instrument to detect his patients' problem with risk processing. He designed a card-playing game, called the Iowa Gambling Task, to measure physiological and behavioral responses to risk in these patients. The participants were connected to electrophysiological arousal monitoring devices (as in lie-detector tests) such as a skin conductance response (SCR) monitor. In the task, four decks of cards were laid out in front of brain-lesioned patients and normal controls. The subjects then selected cards from any of the four decks with the overall goal of maximizing their financial gain. See Figure 1. for a depiction of the card decks, outcomes, and odds for each deck.

Subjects were not told the overall odds or payoffs of the card decks. They were simply told to play the game and to try to make as much money as possible. The two decks on the left, "A" and "B," yielded either cards valued at $100 or -$1,250. The two decks on the right yielded cards valued either $50 or -$250. The expected value of each card in decks A and B was -$250 while for decks C and D it was $250.

Damasio found that the patient group was more likely to choose cards from decks A and B (the "bad" decks). The patients did not generate anticipatory SCRs to the risky decks (A and B), and they played deficiently overall. "Even after several of them realized which decks were bad, they still made the wrong choices." Without the ability to integrate emotion and reason in the OFC, the patients' danger assessment of the "bad" decks was intellectually intact, but it did not alter their decision making, and they continued to choose cards from the losing decks.

Unlike the brain-damaged patients, normal subjects learned to avoid the losing decks. After flipping the first 10 cards, normals began to show physiological "stress" reactions on the SCR measurements when hovering over decks A or B. Patients never showed such responses. Furthermore, even though the normal subjects experienced a physiological stress reaction after 10 card flips, they could not consciously identify that decks A and B were the money-losing decks until over 40 card flips later. Normals began to flip more cards from the "good" decks C and D before they were consciously aware that these decks were "good." That is, normal people had "gut" stress reactions to the losing decks after 10 flips, and changed their behavior to prefer decks C and D. Yet they only articulated a "hunch" which were the losing decks after 50 card flips. They could explain their hunch with certainty only after 80 flips.

Damasio's research implies that people need feelings to signal when to avoid losses in risky environments. When making risky decisions, there is a gap between what the emotional brain (the limbic system) knows about risk and one's conscious awareness of the actual danger. Intuitive decisions, where "gut feel" drives judgment, arise from such limbic knowledge. In the brain-damaged gamblers, a brain' region that integrates risk-related feelings with reasoned decision making had been taken off-line.

THE BRAIN: STRUCTURE AND FUNCTION

In order to gain insight into the brain-lesioned patients' deficiency in risk processing, it's useful to pause for a basic tutorial on how the brain operates. The human brain is the product of millions of years of evolution, and it is designed to efficiently and effectively interpret information, compete in a social hierarchy, and direct activity toward achieving goals while avoiding danger. However, our brains evolved in a stone-age world where dangers and opportunities were largely immediate, and social interactions were limited to other members of the clan. Now, as the modern world becomes more interconnected and fast paced, it is apparent that the stone-age brain is not optimized for managing the complexities of modern life.

In a generalization that will be repeated throughout this book, the brain can be conceptualized as having three anatomical divisions. Each division is like the layer of an onion, with complex processes such as analytical decision making in the outer layer, motivations and drives arising from the middle layer, and life-sustaining physiological processes originating in the innermost core. This conceptual schema is termed the "Triune" brain.

The cortex is the brain's logistical center. It is the director of executive function and motor control. The part of the cortex called the prefrontal cortex is of most interest to this discussion. The prefrontal cortex is involved in abstract thinking, planning, calculation, learning, and strategic decision making. Another part of the cortex, called the insular cortex, is evolutionarily distinct from the neocortex. In this book, when using the word cortex, I am broadly referring to the neocortex and the prefrontal cortex, but excluding the insular cortex.

The brain's limbic system is the emotional driver of the brain. The limbic system is the source of primitive motivations and emotions including fear and excitement. Both the cortex and the limbic system are displayed in Figure 2. The third division of the brain is called the midbrain (a.k.a. "the reptilian brain"). The midbrain manages the body's basic physiological processes, including respiration and heart rate, and it will not be discussed further in this book.

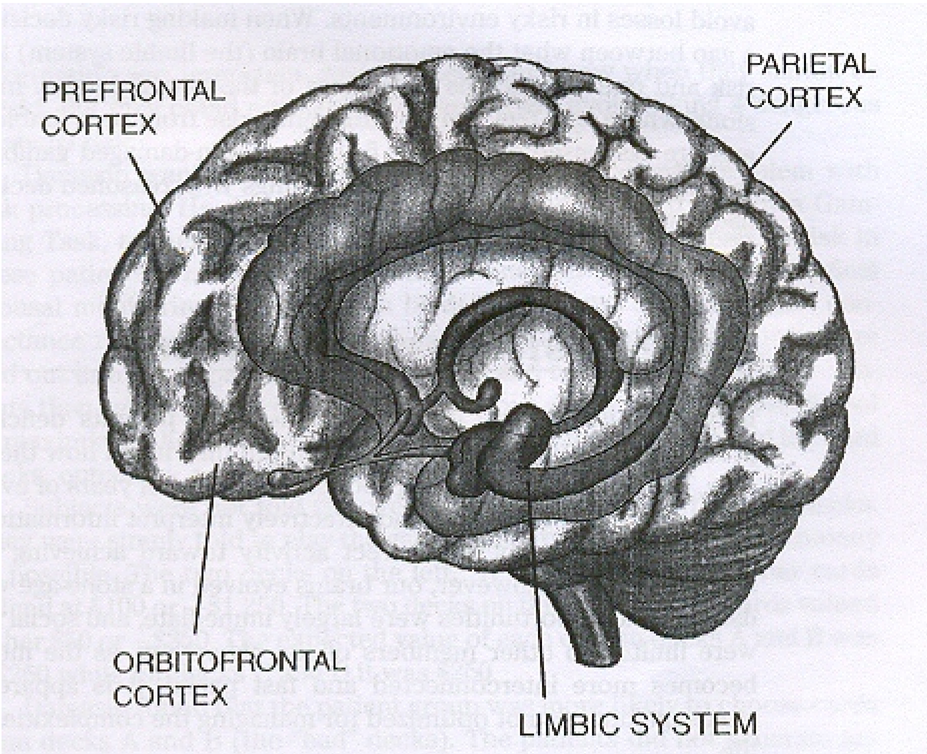

FIGURE 2. A depiction of the whole brain. The limbic system is seen situated underneath the cortex. The prefrontal cortex lies behind the forehead. The orbitofrontal cortex (OFC) is located behind the eyes and above the sinuses. The parietal cortex is situated at the posterior of the brain.

'Running across the three brain divisions are neural circuits that operate two types of goal-directed behavior: (1) reward pursuit and (2) loss avoidance. The existence of reward approach and loss avoidance systems has been hypothesized since the time of Aristotle in ancient Greece. Prior to the late twentieth century, both the reward and the loss systems were thought to drive organisms toward pleasure and away from pain. Currently, scientists believe that these systems encompass complex brain processes involving emotions, cognitions (thoughts), and actions. While the reward and loss systems are largely independent, when one system is highly activated, it may trigger a reciprocal deactivation of the other.

First, I will describe the reward system. Objectives we want to achieve and items we want to possess are called “rewards,” and the pursuit of such rewards is headquartered in the brain’s “reward system.” The reward system is involved in scanning the environment for, evaluating, and attempting to procure desired gains (rewards).

The reward system is comprised of neurons that predominantly communicate via the neurotransmitter dopamine. Dopamine has been called the “pleasure” chemical of the brain, because people who are electrically stimulated in the reward system report intense feelings of well-being. Illicit drug use causes dopamine release in the nucleus accumbens (part of the reward system), which is why street drugs are colloquially called “dope.” The reward system coordinates the search for, evaluation of, and motivated pursuit of potential rewards. See Figure 3 for a depiction of the reward system.

The motivational systems allow us to quickly assess and value potential opportunities and threats in the environment. When we perceive something valuable, our reward system is activated, and we desire it. Many items and goals are valuable to us. We value pleasant tastes (especially fatty, sweet, and salty foods). We value sex appeal and generosity in others. We value status symbols (such as luxury goods and sports carsI5). We value laughing and loved ones, and we value revenge and the punishment of deviants. These valued events all activate the brain’s reward system.

“A Second motivational circuit governs “loss avoidance.” The “loss avoidance system” is activated when we become aware of threats or dangers in our environment. Anxiety, fear, and panic are emotions that arise from the loss avoidance system, and pessimistic and worried thoughts are the cognitive sequelae of loss system activation.

The anatomy of the brain’s loss system is less well defined than that of the reward system. The loss system is thought to consist of the anterior insula (pain and disgust), the amygdala (emotional processing), the hippocampus (memory center), and the hypothalamus (hormone secreting center). See Figure 4.

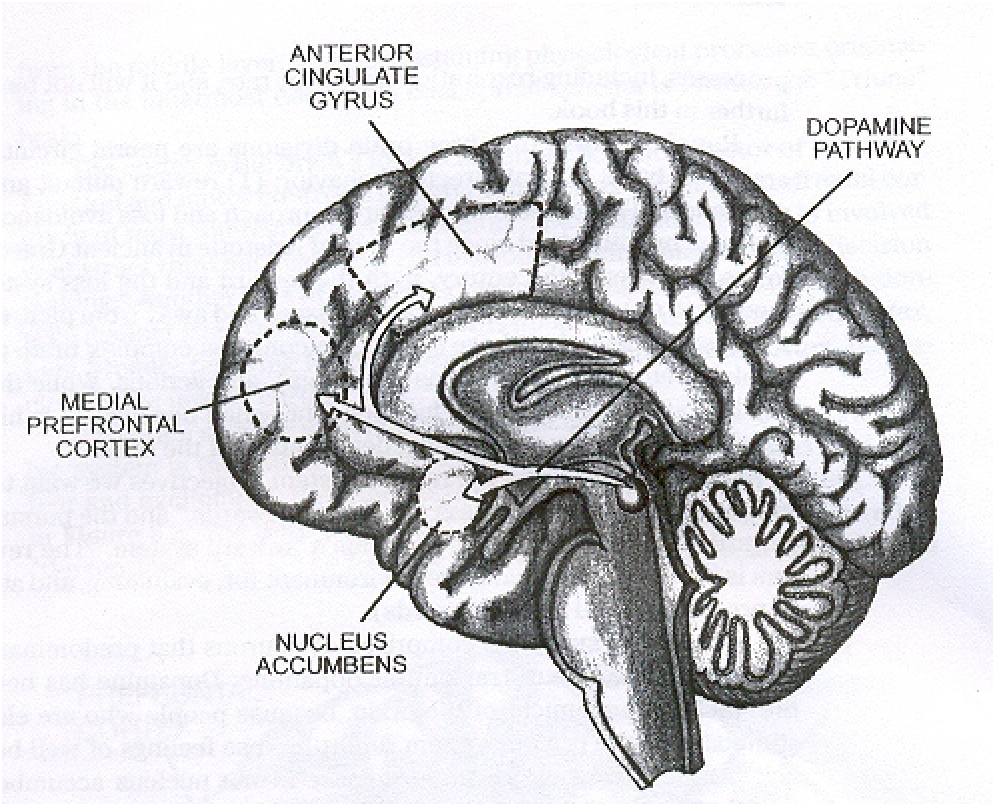

FIGURE 3. The brain's reward system. A bundle of dopamine neurons in the midbrain sends projections throughout the prefrontal cortex.

Loss system activation affects the entire body through bloodstream hormone and neurotransmitter release. The perception of a threat activates the hypothalamus-pituitary-adrenal axis (HPA axis), which results in stress hormone and epinephrine ("adrenaline") secretion into the bloodstream. The body's sympathetic nervous system (SNS) prepares the whole body for the "fight-or-flight" response to danger with nerve signals transmitted to every major organ system. When under threat and experiencing fear, signs of SNS activation include trembling, perspiration, rapid heart rate, shallow breathing, and pupillary dilation. The SNS is also responsible for the physical signs and symptoms of panic.

Because the reward and loss systems influence thought and lie beneath awareness, they often direct behavior automatically through subtle emotional influences on judgment, thinking, and behavior. In Damasio's patients, the interface between fearful feelings generated by the loss avoidance system and reasonable thought generated by the prefrontal cortex was interrupted. Fortunately, investigators have a number of tools for assessing the health of the brain's reward and loss avoidance systems.

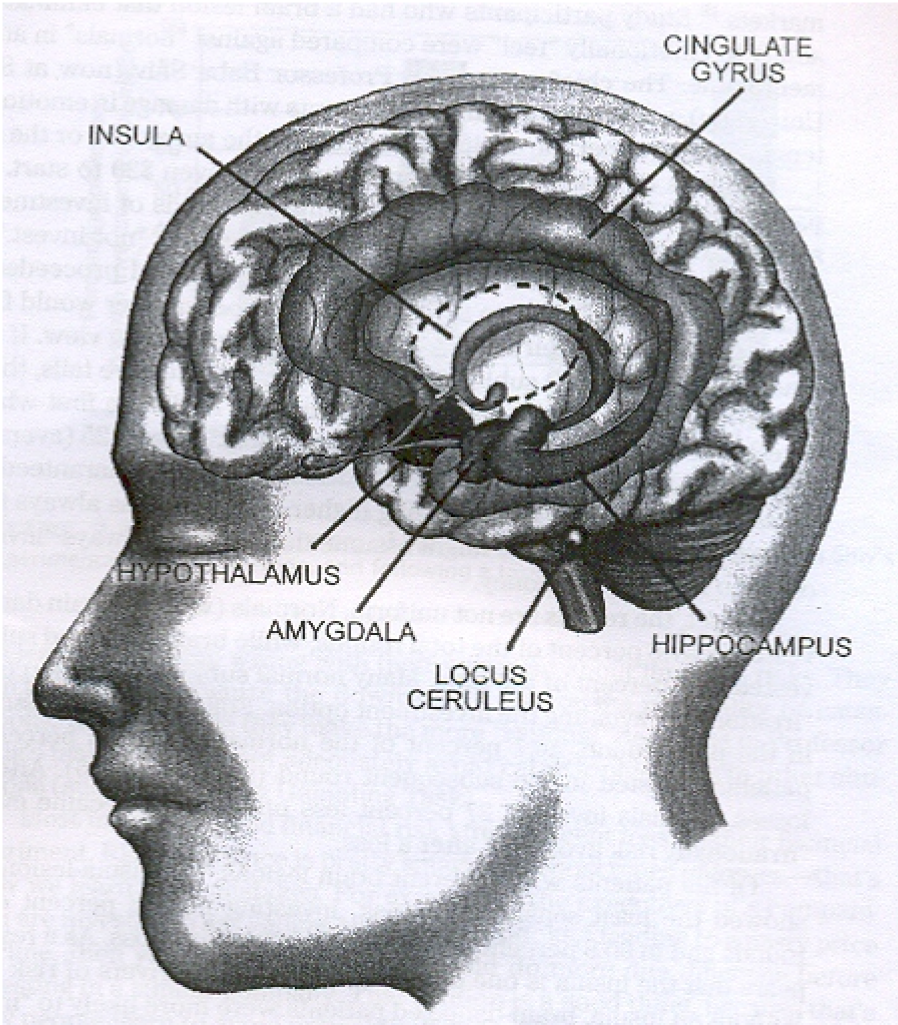

FIGURE 4. An illustration of several components of the brain's loss avoidance system.

THE BRAIN-DAMAGED INVESTOR

According to a 2005 wan Street Journal article, "Lessons from the Brain-Damaged Investor," brain-damaged traders may have an advantage in the markets. Study participants who had a brain lesion that eliminated their ability to emotionally "feel" were compared against "normals" in an investment game. The chief researcher, Professor Baba Shiv (now at Stanford University), used a mixed sample of patients with damage in emotional centers including the orbitofrontal cortex, the amygdala, or the insula.

In Shiv's experiment, each participant was given $20 to start. Participants were told that they would be making 20 rounds of investment decisions. In each round, they could decide to "invest" -or "not invest." If they chose not to invest, then they kept their $1 dollar and proceeded to the next round. If they chose to invest, then the experimenter would first take the dollar bill from their hand and then flip a coin in plain view. If the coin landed heads, then the subject lost the dollar, but if it were tails, then $2.50 was awarded. On each round, participants had to decide first whether to invest. The expected gain of each $1 "investment" was $1.25 (average of $0 and +$2.50), while each "not invest" decision led to a guaranteed $1. The expected value of the gamble being higher ($1.25), it was always the most rational choice. Thus, one might assume that subjects always "invested" in order to make more money.

In fact, the results are not uniform. Normals (without brain damage) invested in 57.6 percent of the total rounds, while brain-damaged subjects invested 83.7 percent of the time. Many normal subjects (42.4 percent) were "irrationally" avoiding the investment option. Following an investment loss in the prior round, 40.7 percent of the normals and 85.2 percent of the patients invested in the subsequent round (see Figure 5). After recent losses, normals invested 27 percent less often. They became even more "irrationally risk avoidant" after a loss.

Of the patients with different brain lesions, the insula-lesion patients showed the least sensitivity to risk, investing in 91.3 percent of all the rounds and in 96.8 percent of the rounds following a loss. As a result, it appears that the insula is one of the most important drivers of risk aversion. Without an insula, brain-damaged patients were more likely to "invest."

On the lighter side, neurologist Antoine Bechara ventured that investors must be like "functional psychopaths" to avoid emotional influences in the markets. These individuals are either much better at controlling their emotions or perhaps don't experience emotions with the same intensity as others. According to Professor Shiv, many CEOs and top lawyers might also share this trait: "Being less emotional can help you in certain situations."

Now you still might be wondering, "Is there a brain area that sabotages my investing?" The answer is not clear. It turns out that the lesion patients can have pretty miserable financial lives–accumulating credit card debt, not showing up to work on time, falling for Internet scams, and ultimately declaring bankruptcy. Even though they score normally on IQ tests, there is clearly something wrong with their judgment about financial risks. They can't seem to recognize the downside of risk or the possibility of catastrophic loss. So while they make the more "rational" decisions in Professor Shiv's tasks, they cannot adequately avoid catastrophic risks in other situations (such as the Iowa Gambling Task).

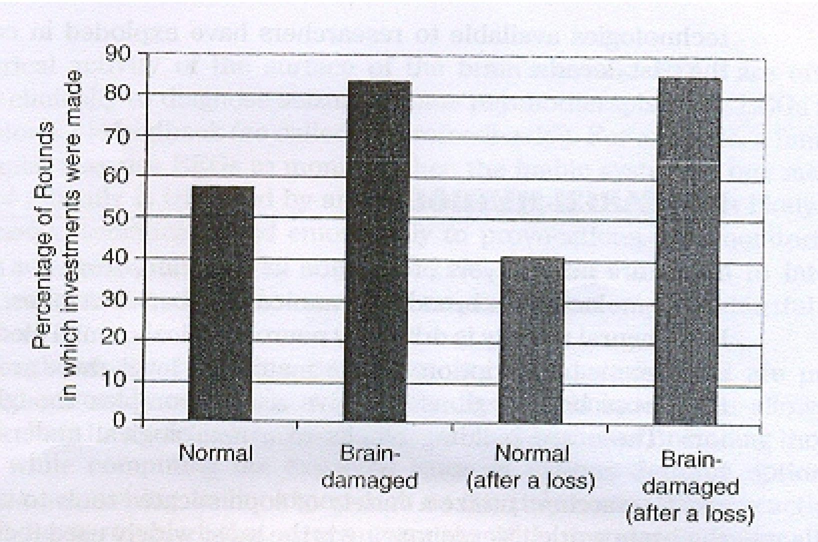

FIGURE 5. Investment choices of brain-damaged and normal subjects in Shiv's experimental task, on average, and following a loss.

Most investors avoid financial risk after a recent loss, to their financial detriment. Risk avoidance is pretty smart after most types of losses-that's how we learn from mistakes. For example, if the executives of a company you are invested in are caught "cooking the books," leading to a nasty price decline, then you might be more wary and do more due diligence before investing in a similar company. That caution is a good thing, because that's how people learn to avoid unhealthy risk.

In the markets, most investors take away lessons where none exist. They learned to avoid technology stocks after the losses of 2001, even though the bear market losses should have had little impact on non-Internet stock performance going forward. After suffering bear market losses, most investors wait for price "confirmation" before jumping back into stocks. They may even sit out the market until new highs are reached. Of course, waiting for confirmation means missing much of the price move, but that's the price many people are willing to pay for enhanced confidence.

Neuroscience and Investing

So far you've seen how researchers used a card game (Iowa Gambling Task) and a coin-flipping gamble (Shiv's task) to assess financial decision-making behavior in brain-damaged people. Many other techniques have been used in decision-making research. As you'll see below, the technologies available to researchers have exploded in complexity over the past decade.

RESEARCH METHODS

There are many levels of function in the brain, from the actions of individual molecules to broad communications between lobes. At a molecular level, neural activity is driven by neurochemicals, small electrical currents, and genetic transcription. On the anatomical level, there are neural circuits that cross brain regions and give rise to complex thoughts and behaviors. These are building blocks of a neurological understanding of the brain.

Researchers utilize a variety of sophisticated tools to understand how the brain works. Neuroimaging is the most widely used technology for understanding decision making. Most of the neuroimaging studies cited in this book use functional magnetic resonance imaging (fMRI). fMRI allows researchers to visualize changes in oxygenated blood flow, which serves as a proxy for brain metabolism. fMRI can yield resolution of brain voxels as small as 2 x 2 x 2 millimeters over time intervals of two seconds. Positron emission tomography (PET), which is an alternative neuroimaging technique to fMRI, has a larger spatial resolution of approximately 3 x 3 x 3 millimeters and can detect changes in glucose metabolism and blood flow only when a radioactive tracer has been injected into the subject.

Other investigative technologies include behavioral measures, subjective reports, psychological tests, and electrophysiology. Electrophysiology involves measurements of heart rate, blood pressure, galvanic skin response (sweating), and other physical variables, many of which are indicators of reactive brain activation in limbic and midbrain regions. Pupillary eye measurements allow researchers to directly monitor the activity of the SNS. As previously mentioned, the SNS is involved in the "fight-or-flight" response.

Electromyograghs (EMGs) measure electrical activity during muscle contraction. When EMGs are used on facial muscles, very subtle states of happiness and concern can be measured. For example, analysts who are excited about an investment idea have greater activation of their zygomatic facial muscles when they talk about that investment. The zygomatic muscles control smiling. The frontalis muscle on the forehead is activated by concern, revealed in a furrowed brow, and is more active in traders during stressful market volatility.

Historically, many researchers used electroencephalograms (EEGs) for experimentation. An EEG is a test used to detect fluctuations in the electrical activity of the surface of the brain's cortex. EEGs are often used clinically to diagnose seizures. Some psychotherapists use EEGs for emotional biofeedback (so called "neurofeedback"). For example, a family therapist may use EEGs to monitor when the limbic system of one member of a family is triggered by another. The triggered member is likely to respond automatically and emotionally to provocations. Self-monitoring EEG activations allows the triggered family member to learn to interrupt and prevent automatic emotional responses that might be hurtful to another.

Single-neuron recording techniques are very invasive and are performed primarily on monkeys and rats. Such techniques have allowed researchers to model the activity of tiny neuronal bundles, including those used while computing the expected value of various decision options. Genetic sequencing technologies such as the polymerase chain reaction (PCR) have revealed that genes correlate with prominent personality and behavioral traits. Assays of blood and cerebrospinal fluid allow researchers to measure hormones (such as those mediating trust and the stress response) and neurotransmitters (including those involved in impulsiveness).

A research technique most often used by neurologists is the study of patients with specific brain lesions. Lee is an excellent example of this type of patient. Small brain lesions secondary to focused strokes or tumors can cause isolated impairments. These impairments can teach us a great deal about the function of specific brain regions.

The human brain contains approximately 100 billion neurons with 100 trillion connections between them. The neuron count inside our heads is comparable to the number of stars in our galaxy, the Milky Way. With this extraordinary complexity, it is unlikely that we will ever have a "model" of what it is to be human. No amount of brain research can adequately portray a feeling, a memory, or an experience.

Describing the mind in terms of brain circuits, personality traits, and genetic influences is deceptive. Individuals are not pieces thrown together into one predictable whole. Each person is different, unique, and incomprehensibly complex. They each nurture their own authentic interests, hopes, and aspirations. The human brain is the complex organ that gives rise to who we are, and its mysteries remain largely uncharted.

NEUROSCIENCE PREVIEW

Neuroscience and Investing

The following is a very quick and general description of many of the brain regions. It is quite dense with information, and you don't need to internalize this all at once.

The functions of the prefrontal cortex, reward system, and loss system in financial decision making are discussed in this book. Much of optimal financial psychology lies in the self-awareness and self-control of limbic (emotional) impulses. By exercising "emotional intelligence," one can maintain flexibility in the face of opportunity and danger. Emotional intelligence is derived from the prefrontal cortex and the strength of its connections to the limbic system.

The prefrontal cortex has several regions that assist with different aspects of emotion management. The prefrontal cortex assists with planning for the future, following rules, directing focus and attention, executive decision making, and exerting self-control. More specifically, the orbitofrontal cortex (OFC) integrates reason and emotion, while the anterior cingulate cortex (ACC) resolves decision conflicts and prioritizes emotional information as either relevant or unimportant.

The limbic system has two major divisions of relevance to investing-the reward pursuit and loss avoidance circuits. Reward pursuit involves everything from how people value various prospects to how positive and motivated they feel toward obtaining desired goals, to their search for novelty. The loss avoidance system underlies fear and hesitation and drives the avoidance of perceived threats.

The reward system is the origin of several important financial biases. Increased reward system activation can generate optimism, overconfidence, and excessive risk-taking. The major regions of relevance in the reward system are the nucleus accurnbens (NAcc) and the medial prefrontal cortex (MPFC).

The NAcc is the brain's center of lust and desire. The NAcc is activated by the anticipation of earning, money, and it drives pursuit of the items or investments that one wants. High NAcc activation drives excessive financial risk taking. The MPFC, which is one terminus of the dopamine neurons of the reward system, is activated by trust and certainty, satisfaction when rewards are received, learning how to obtain rewards, and learning from successes and mistakes.

Hypoactivation or desensitization of the reward system results in a propensity to feel apathetic, have low energy, and engage in compensatory excitement and novelty-seeking behaviors such as pathological gambling and compulsive shopping. Short-term gains energize dopamine flow in the reward circuit.

Activation of the brain’s loss system results in stress, anxiety, disgust, pain, and even panic. The behavioral bias of loss aversion is fueled by fears of disappointment and regret, and arises from amygdala activation. The anterior insula is an area of primitive cortex that governs the experiences of disgust, pain, and loss. Anterior insula activation precedes excessive risk aversion in one investment experiment. The physical and mental effects of stress are generated by hormonal and chemical pathways in the loss system.

In particular, the mental origins of emotions, expectations, beliefs, and self-deception are described.”