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# Eight Lessons from Neuroeconomics for Money Managers

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The 1970s ushered in the ascendance of the rational school of thought in economics. In particular, the development of the theory of rational expectations (Lucas 1972) led to substantially improved predictive models in economics and finance. By the 1980s, dynamic general equilibrium expectation models were being used to understand macroeconomic phenomena, such as business cycles and consumption patterns, as well as to characterize variations in financial markets and guide economic policies. The Nobel Prizes awarded to economists Robert Lucas, Jr., Edward Prescott, Finn Kydland, Harry Markowitz, Myron Scholes, Robert Merton, and William Sharpe reflect the importance of this research.

By the late 1980s, the dominance of rational expectations models had led many economists to categorically accept the assumption that human decisions are made with full foresight and rational deduction. In finance, the logical conclusion was that traded assets are always (or nearly always) fairly priced because investors consider all relevant outcomes and their related probabilities of occurrence. In other words, the theory of rational expectations led to the conclusion that markets are *efficient* because investors use all relevant information in forming their investment decisions. The development of index funds has been largely a result of the conclusions drawn from rational expectations models.

Recently, however, a revolutionary change has occurred in financial economics. The field of cognitive psychology—and, more recently, behavioral neuroscience—has allowed economists to observe the limits of human cognitive abilities and to appreciate the extent to which human biases often result in decisions starkly at odds with those predicted by models of rational choice. Even casual observation shows that human beings often behave, particularly in the financial markets, in ways vastly different from what is predicted by economic theory.

More than 200 years ago, in “The Theory of Moral Sentiments,” Adam Smith characterized human beings as struggling between an “impartial spectator” and the “passions” (Smith 1759). This characterization will sound familiar to any modern-day student of psychology or cognitive neuroscience. Now we can measure these psychological constructs physiologically. In many respects, we have come full circle back to Smith: Modern neuroscience has shown us that

our brains are indeed characterized by a struggle between our need for novelty and instant gratification (i.e., the passions) and our uniquely human ability to “know better” (i.e., the impartial spectator). Smith’s ideas have been proven correct by modern neuroscience.

The new transdisciplinary field of neuroeconomics (Zak 2004; Zak forthcoming) identifies the brain regions that are most active when people are making economic decisions. This advance allows neuroeconomists to explain a number of prominent behavioral anomalies, or deviations from rational choice. The rapid development of the techniques used to measure brain activity, in conjunction with the decline in their costs, has produced a plethora of new findings in neuroeconomics since 2000. Neuroeconomics is providing an understanding of why real people, rather than “economic agents,” behave the way they do. Furthermore, this emerging field has caused a growing body of economists to openly question the appropriateness of putting *homo economicus* into every economic model.

Modern neuroscience has shown that the vast majority of human information processing and decision making occurs on autopilot. The brain’s autonomic mechanisms often execute decisions with little deliberate thought. The reasons the brain processes much information without conscious deliberation are discussed in Lesson 7, but in short, the brain is resource constrained. As a result, the brain does not invest its scarce resources to fully optimize every decision. In economic terms, the costs associated with fully evaluating every option often exceed the benefits of doing so. Hence, our brains have evolved to work largely without the need for conscious “intervention” into their operations.

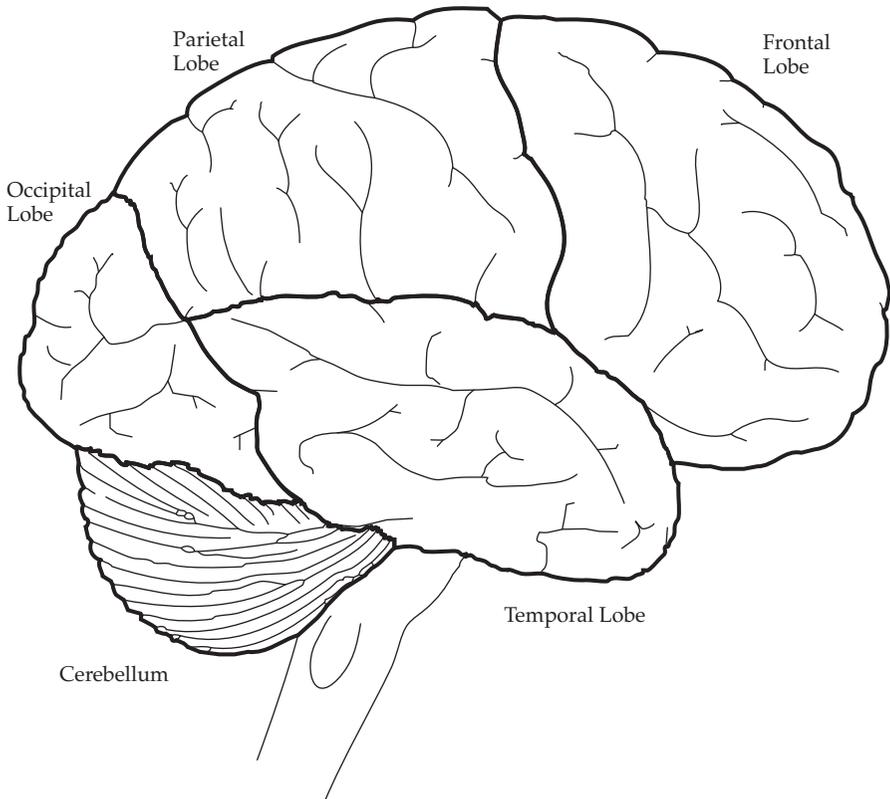
Depending on the situation, the brain’s automatic responses can be adaptive or maladaptive. Automatic processes in the brain react strongly when environmental conditions suddenly change; change may provoke such emotional responses as fear or hostility, for example. When these automatic processes occur, the brain increases the body’s heart rate, blood pressure, and respiration, which sets off a cascade of “fight or flight” responses. When people are emotionally aroused, decisions narrow to the immediate; the primary objective in such a situation is to seek safety. When trading in financial markets, these evolved responses may be maladaptive. That is, as we discuss in Lesson 2, our brains treat volatility in markets as equivalent to spotting a lion on the savannah. Our automatic reaction is fear when the market falls precipitously or when returns are highly volatile.

This article not only identifies how the brain reacts to market conditions but also provides solutions for maladaptive responses. Importantly, how the brain responds to stimuli can change with training and experience. Our

intention is to make financial professionals conscious of the brain's automatic processes so that they can train themselves to override those processes that negatively affect portfolio performance and focus on the brain processes that can enhance performance.

The human brain shares autonomic functions with other animals but differs primarily in the large and evolutionarily new prefrontal cortex. This is the area of the brain in the foremost part of the frontal cortex that lies directly behind the forehead. (The general organization of the brain is shown in **Figure 1.1**) Our deliberate thought and “executive functions,” such as planning actions and evaluating outcomes, take place in the prefrontal cortex. This brain region engages cognitive resources to make decisions and recruits older brain regions

**Figure 1. General Organization of the Human Brain**



<sup>1</sup>Zak (2004) provides a primer on brain structure and function.

to provide access to memories (what have I done previously? what have others done?), affective states (how do I feel about each option?), and calculations of expected risk and return (what do I expect to get? how much risk am I willing to bear?). Experience, then, is a two-edged sword. To conserve brain resources, memories allow the brain to automate responses to similar tasks. At the same time, memories provide a store of related decisions and outcomes from which to draw comparisons and potentially change strategies. The key issue is when to engage our cognitive resources to undertake new analyses that may change decisions and when, instead, to use memories and experiences of past similar events when making choices.

## **Eight Lessons from Neuroeconomics**

We present eight lessons from the recent literature in neuroeconomics that we hope will improve the practice of money management. As part of each lesson, we present practical applications for investment professionals. The sources of these lessons are cited, but additional information on the brain and investing can be found in Peterson (2007) and Shermer (2007).

**Lesson 1: Anticipating Rewards.** As any gambler knows, and modern neuroscience has now shown, what keeps the gambler coming back to the tables is the anticipation of reward.

Receiving a reward is pleasurable in the brain—and even more so if the reward is unexpected. Because the human brain evolved in an environment of scarcity, acquiring such primary rewards as food or sex is highly reinforcing: It makes us feel good, so our brain reminds us to keep doing it. Recent research by Knutson and Bossaerts (2007) has shown that acquiring money is similarly rewarding in the brain.

Acquiring resources is essential for the survival of all animals, and the evolutionarily old brain region that encodes rewards is found even in reptiles. This midbrain region, found near the brainstem at the base of the brain in Figure 1, is known as the “wanting” system because it motivates us to expend effort and accept risk to acquire things we need. To do this, the wanting system makes the pursuit of rewards highly pleasurable; it engages our emotions. Indeed, many drugs of abuse, such as methamphetamine and cocaine, hijack this area of the brain. The emotion investors feel when they anticipate a gain from investing is similar to the rush associated with drug use.

Yet, the activity of the brain’s wanting system occurs largely outside of our conscious awareness. This brain system adapts to the environment in which we find ourselves, so the “drug” no longer provides the same high; we thus seek to acquire more. As a result, making the same or similar choices is no longer

pleasurable. In other words, after an investor makes dozens of million-dollar trades, doing so becomes routine and the brain begins to process this type of decision automatically. When the brain becomes accustomed to making large trades, there is little novelty associated with this activity, and therefore, the emotional valence to large trades is diminished.

When an investor faces a new choice—a new market, a new asset class, or a larger than normal trade—the wanting system kicks back in and refocuses the investor’s attention on acquiring reward. In a literal sense, then, we are biologically driven to seek novelty.

The brain’s reward system is also hungry; it is constantly on the lookout for possible reward targets. As we mature, we learn how to say “no” to some of these rewards. The prefrontal executive regions of the brain modulate how strongly rewards are felt and how the anticipation of rewards affects behavior. Unfortunately, the prefrontal regions are the last to mature in humans; full maturity is not reached until people are 30 years of age. Furthermore, the prefrontal region “wires up” more slowly in men than in women. This lag is one reason that young men take more risks than young women. Communication between the prefrontal cortex and reward system requires experience to work effectively.

Even in those who are over 30, the prefrontal modulation of reward anticipation can be clouded by circumstances. Recent research has revealed that when the wanting system is in high gear, the reward signal swamps the prefrontal weighing of costs and benefits (Knutson, Wimmer, Kuhnen, and Winkielman 2008). In this experiment, a group of heterosexual men were shown pornographic photographs of women, stimulating the viewers’ reward systems. Then, the men were asked to choose portfolios of risky stocks and safe bonds that would earn them money. Compared with men who saw nonpornographic pictures, those who viewed pornographic pictures had overactive wanting systems and chose riskier portfolios.

Investors who skydive, use illegal drugs, or drive too fast may also be overstimulating their reward systems. Periods of excessive risk taking, often accompanied by high leverage, can result from reward system overactivation and may negatively affect the performance of their investments.

■ *Application:* The pleasure of investing must be modulated so that excessive risk taking does not occur. Excessive risk taking is more likely when an investor has had several recent successes that push the wanting system to seek greater and greater rewards. For this reason, managers should monitor indicators of daily trading volume to prevent excessive trading. Assiduous use of risk budgeting and risk limits is essential to identify traders who are taking excessive risks.

Knowing that they are susceptible to trading for the thrill, the high, means that investment professionals themselves should learn to recognize when trading becomes sport. This is the time to throttle back on risk or manage a different portfolio. This self-analysis is critically important in highly volatile markets with high, often speculation-induced, share volumes. High volumes are likely to stimulate the reward system, as we discuss in Lesson 4.

**Lesson 2: Balancing Risk.** Modern portfolio theory (MPT) describes the yin and yang of risk and reward, the distinct and theoretically independent components of active money management. Return is defined as the realized outcome of a random variable (the market outcome), and risk is defined as the expected statistical deviation from expected return (volatility). Consistent with MPT, Knutson, Fong, Bennett, Adams, and Hommer (2003) showed that risk is processed in an evolutionarily new brain region that monitors body states and activates when a person experiences painful or aversive stimuli.

We literally *feel* risk in the same way that we feel fear when riding a roller coaster, disgust when we smell rotten food, or pain when we slice a finger while cooking. Our brain system says “stay away” from these things. Like all parts of the brain, the risk system also adapts to experience: The prefrontal cortex tells us that the roller coaster is safe, and we choose to go on it even though we know it will frighten us. Experience is essential for modulating emotional responses to visceral signals. Lo and Repin (2002) discovered that all traders have heightened fear responses when the markets are volatile by measuring physiological responses in professional foreign currency traders while they worked. Importantly, fear responses were reduced with trading experience. Experience reduces the weight put on fear signals by providing memories that we can use to relate the present state of arousal to similar signals and their associated outcomes. When fear is so high that we have little experience with which to compare it, the desire for safety can lead to excessive risk aversion.

The prefrontal cortex integrates information on reward and risk to generate a physiological utility calculation. That is, three primary brain regions are involved in a trading decision: the wanting system, the risk-aversion system, and the integration of these systems into a utility function. (Yes, the foundational notion in economics, utility, is a real physiological entity in the human brain.) The three regions that inform decisions are in broadly different areas of the brain: The wanting system is in the evolutionarily ancient midbrain; the risk system is in the newer temporal lobe of the brain; and utility calculations occur in the last area to evolve in humans, the prefrontal cortex.

■ *Application:* Because distinct brain regions process risk and reward, a disconnect can occur between them and the brain’s utility function in the prefrontal cortex. This disconnect could result from a lesion (scar) on the

connecting fibers or simply from fewer connections for communication existing between regions, as could be the case in chronic risk takers. Cross-talk between other brain regions can also dull the communication between risk and reward regions when choices are being weighed. Furthermore, the brain may encode the risk associated with investing other people's money differently from the way it treats risk when one's own money is at stake. This may reduce risk aversion for professional money managers.

Recall rogue trader Nick Leeson, who caused the collapse of Barings Bank after losing \$1.4 billion on futures contracts. Leeson took excessive risk to offset losses from highly leveraged investments gone sour, doubling-down just like a gambler playing a losing strategy. The Bank of England's report stated:

Barings' collapse was the result of the unauthorized and ultimately catastrophic activities of, it appears, one individual that went undetected because of a failure of management and other internal controls of the most basic kind. (U.K. Parliament 1995)

Leeson may have become so accustomed to substantial risk that his visceral avoidance signal was muted.

In highly trending markets, the brain's risk monitor may also be underactive. Traders may undertake too little risk. Risk taking is appropriate for investment professionals, and managers should be alerted if traders have the bulk of their portfolios in cash for an extended period of time. This behavior is the equivalent of a deer freezing when headlights illuminate it on a country road; freezing may be adaptive in some circumstances, but it is often maladaptive for investors.

To combat the possibilities of traders' taking too much risk or not enough risk, firms should have systems in place to monitor risk levels by sending alerts if risk is too high or too low. A simple way to do this is to have a manager who gets a risk report on each trader daily.

**Lesson 3: Wait for It.** Human beings are the only animals known that can delay gratification for more than a few minutes. Recent studies in neuroeconomics have shown that forgoing a current payoff to get a larger, later return requires intense activity in the prefrontal cortex (McClure, Laibson, Loewenstein, and Cohen 2004).

Even with our large prefrontal cortices, we find waiting hard to do. With immediate rewards available, the midbrain wanting system is in high gear. Worse yet, Shiv and Fedorikhin (1999) showed that individuals' ability to exercise self-control fails in the presence of other demands on the prefrontal cortex. When markets are volatile, investors' deliberative prefrontal cortices are heavily taxed. This is precisely the situation in which an investor is more likely to make decisions based on immediate gratification and little deliberation, rather than on the basis of the bigger, later payoff.

■ *Application:* Volatility absorbs our cognitive resources as we cope with a multitude of information—much of it noise. Trading effectively in volatile markets often requires that we slow down decisions and look for opportunities deliberately. Going with our “gut instincts” has some merit—it draws on our visceral memories of related events—but it assesses our memories imperfectly and with hindsight bias (we may just have been lucky last time, so repeating our actions has no guarantee of success). In a volatile-market situation, making no decision is preferable to making a poor decision. When cognitive load is high, a good decision often entails stepping away from the situation and coming back later. This behavioral truth is precisely the reason behind the three-day waiting period for the purchase of a handgun. Recognizing the danger of cognitive overload when monitoring multiple streams of information requires that we train ourselves to step back and reflect before pulling the investment trigger.

**Lesson 4: Following the Herd.** Human beings are hypersocial creatures. Most of us like to be around other humans (at least some of them!). One of the values of being hypersocial is that we learn from each other easily and naturally. Studies have shown that social attachment occurs when the brain chemical oxytocin is released (Zak, Stanton, and Ahmadi 2007). Oxytocin is evolutionarily old and activates both emotion and reward pathways in the brain (Zak forthcoming). Like it or not, we are a herd species, and our brain makes us feel good when we follow the herd.

What was beneficial for our ancestors on the African savannah does not always serve us well in financial markets (Shermer 2007). Social learning is great when mastering calculus or riding a bicycle, but herd behavior in markets is typically detrimental. Herd behavior violates the “all else being equal” rule in economics in that investor decisions are not independent, and mispricing is thus likely to occur. Trading does not occur in a vacuum; often traders buy an asset because they see it going up in value. As more investors jump on the bandwagon, herd mentality results in a price bubble.

Our brains have evolved to make us desperately want to follow the crowd. Riots, overly popular restaurants, and asset market bubbles are the results. Herd behavior can occur even when individuals do not coordinate with each other but trade only on the basis of private information and prices (Bikhchandani, Hirshleifer, and Welch 1992).

■ *Application:* We know mathematically that all asset bubbles must burst, ultimately restoring equilibrium. The key issue, of course, is the timing of the rupture. Except for those who get into and out of a market quickly, profits often are found in going against the herd (just ask Warren Buffett). But evaluating alternatives while others follow trends goes against our nature because our brains bias us to follow the crowd. Desperate buying and panic selling are the

inevitable consequences of herd mentality. Instead, investment professionals should discount their evolved bias toward following others and be contrarian. This approach will make them feel alone and exposed—two things our ancestors feared the most. The primitive fear response can be suppressed, however, by the deliberative prefrontal cortex—and through practice.

Investment professionals should be aware of their natural instinct to follow the crowd and consider whether their purchase of an asset is based on its fundamental value or the fact that it is in vogue at the moment. Conscious awareness of the herding bias will help to suppress the instinct to follow the crowd. Join the herd in dining out—but not in investing.

**Lesson 5: The New New Thing.** As discussed in Lesson 1, anticipation of gains activates the reward regions of the brain. Unfortunately, this reward system is multipurpose. *Any* new information we stumble upon will cause it to activate. Focusing on “the new new thing” (the motto of James H. Clark, the man who founded, among other companies, Silicon Graphics International and Netscape Communications) will continually “juice” this system.

Our brains are designed to seek out novelty and make finding it rewarding; this drive is what makes us want to acquire new information. Acquiring new information is obviously useful, and it evolved to be rewarding for important reasons, but how much of the “new new” is needed by investment professionals? As discussed in Lesson 3, the brain is subject to information overload that can impair decision making. Furthermore, discriminating between signal and noise in information flows is not easy, especially in these Bloombergian days of continual news feeds. Yet, our brains bias us to search for the new new thing—constantly.

■ *Application:* Novelty and reward are confounded in the brain, so it is important—but can be difficult—to keep them from being confused with each other when making investment decisions. Constant information flows rev up the wanting system, leading to increased risk taking, as discussed in Lesson 1. In addition, information flows demand cognitive resources in the prefrontal cortex as we seek to categorize and sort. This demand reduces such executive functions as evaluating and executing decisions. The (perhaps surprising) conclusion is that it is best to turn off Bloomberg and CNBC when making investment decisions. Listening to classical music will probably result in better decision making than trying to concentrate over the incessant banter of television commentators. Financial news has its place, but much of today’s financial news is noise rather than signal and can impair financial decision making.

Of course, receiving new information is important in making up-to-date decisions. Eliminating Bloomberg entirely may not be the answer, but for most traders, viewing can be limited to once or twice a day. Adding some noise to

your decision making via news feeds can actually improve decisions because it moves the deliberations away from the brain's automatic responses. At the same time, following established trading rules is essential, and one should not be distracted by rumor and innuendo—two things that stimulate the brain's wanting system.

**Lesson 6: Checking References.** Psychologist Daniel Kahneman was awarded the Nobel Prize in Economics in 2002 for his many clever experiments that called into question traditional rational expectations utility theory. For instance, Kahneman showed that the subjective value of an outcome is determined relative to a reference point (see, for example, Kahneman and Tversky 1979). The brain works similarly, making comparisons of relative value rather than absolutes as it seeks to sustain balance, or *homeostasis*.

Studies in monkeys (Platt and Glimcher 1999) and humans (Knutson and Peterson 2005) show that rewards are evaluated relative to a baseline of what one already has. As a result, people are *reference dependent* decision makers. For example, several studies have shown that after a gain, people take on more risk: The brain's reward system is cranked up and wants more. Similarly, after losses, many people increase their risk exposure to get back to their break-even reference point, just what Nick Leeson did at Barings Bank. Taking additional risk because of a focus on a reference point may lead to decisions that are not warranted.

■ *Application:* Clear the slate. Avoid radically changing positions in the presence of recent losses or gains except as guided by previously chosen stop-loss or limit orders. Understand that the reference point bias can work against the effective application of trading rules. In addition to avoiding herd behavior as described in Lesson 4, investment professionals should not use a colleague's profits or positions as reference points for their own trades. Other investment professionals may have different risk profiles, liquidity, or time horizons. Comparing performance with that of a colleague only clouds a manager's ability to objectively assess a situation. Investment professionals should analyze investments on their merits alone and ignore the path they took to get where they are today.

**Lesson 7: Rational Rationality.** All biological systems are economical: They have limited resources to accomplish necessary goals and, therefore, have evolved ways to use resources efficiently.

Our brains economize on scarce metabolic resources in two primary ways. The first is the cellular basis for learning: Brain circuits that are repeatedly used develop a bias to activate when they encounter the same or similar stimuli (Haier, Siegel, MacLachlan, Soderling, Lottenberg, and Buchsbaum 1992). This process in the brain leads, of course, to biases in behavior. Once something is learned, extra effort is needed to unlearn it. The phrase "think outside the box" is used precisely to encourage people to unlearn behavior that has become routine.

The second energy-saving technique the brain uses is to perform tasks we do repeatedly without conscious direction. In fact, nearly all of our brain processes occur outside our conscious awareness. Because of this ability, we can drive a car and talk or listen to the radio at the same time: We do not need to be consciously aware of driving—until the driver in the car in front of us slams on the brakes. Both learning and unconscious processing cause us to perform tasks on autopilot without burning the extra energy needed to consciously deliberate on best options.

This means that the human brain is a lazy Bayesian updater. Although large deviations from expectations (for example, the market crash of 1987) do lead to an updating of beliefs, small deviations do not cause us to integrate new information into our decision scaffolding. The human brain is “rationally rational” (Zak 2007, 2008a) rather than perfectly rational or irrational. The model of rational rationality predicts that for a range of decisions, “good enough” will prevail. Rational rationality is the brain basis for what Herbert Simon, Nobel laureate in economics, called “satisficing.” Unless the expected benefits or costs are high, rational rationality uses memories of similar situations to serve as beliefs to guide decisions. Belief-based decisions do not use the full complement of cognitive resources to analyze available options.

■ *Application:* Investment professionals are paid to go beyond what nonprofessionals do in markets. Unfortunately, the longer these professionals do their job, the less effort their brains will put into it—rational rationality. Therefore, when new circumstances arise, investment professionals may continue to treat them as the “same old, same old.”

The brain can be fooled by occasionally changing things around. Move to a new office or turn the desk a different way. Open or close the blinds, take a walk, put on music, read a different kind of book, or simply take a vacation. These changes can be enough to knock the brain out of its inertia and get an investment professional to start thinking differently. Just eat a good breakfast for energy; the brain runs on glucose, so a hungry brain is learning impaired.

**Lesson 8: Portfolio Love.** Zak’s lab has shown that the human oxytocin-mediated empathy (HOME) circuit is extraordinarily powerful (Zak 2008b; Zak forthcoming). HOME leads us to “attach” and care about not only our families (the classic purpose of oxytocin and the physiological basis for love) but also complete strangers—and even cars, pets, and houses. The key is exposure. If we are around anyone or anything long enough, we develop either an aversion or an attachment to him/her/it. This attachment behavior is part of the evolution of humans as hypersocial creatures.

Although HOME allows us to live and work with those unrelated to us by motivating us to cooperate with others, HOME is constantly looking for targets and releasing rewarding neurochemicals when we find one. Unfortunately, companies and their stocks can also activate the HOME brain circuit. What is important for survival is rewarded in the brain, but it is not necessarily rewarded in markets. This brain bias manifests as the endowment effect: We value what we own more than what we do not own.

■ *Application:* Because HOME is so powerful, concentration using the prefrontal cortex is needed to override its attachment effects. Your portfolio does not love you, and you should not be too attached to it. Recognizing this bias is the first step.

It is hard to detach from a portfolio that was painstakingly chosen and nurtured. One way to deal with this bias is to have an investment professional who did not choose the portfolio be the one to manage it. This action protects us from our natural tendency to defend our creations, often beyond the bounds of stated risk–return metrics. Managing someone else’s portfolio makes it easier to apply the trading rules he or she has developed. Investment firms can, and have, instituted swapped portfolio management.

Quantitative asset management, whereby trading decisions are driven by computer models, is another way of taking the emotional attachment out of holding particular stocks. Because buy and sell decisions are driven by computer algorithms, human emotion is entirely removed from the investment process. The goal is to apply strict trading rules without the financially maladaptive influence of portfolio love.

## **Conclusion**

Unfortunately, we human beings are characterized by numerous biases that can cloud our ability to make good investment decisions. These traits were selected through evolution for their ability to propagate the species, but they sometimes work against profitable performance in financial markets. Neuroeconomics research is now uncovering the brain basis for behavioral biases. Awareness of these biases can help investment professionals learn to use the important signals the brain receives from markets (for example, a response to increased risk) while minimizing or ignoring signals that detract from performance (for example, portfolio love).

Investment professionals need to use all the brain resources at their disposal to think clearly and deliberately when making investment decisions. One of the characteristics that distinguishes humans from other animals is our large prefrontal cortex. Most of our analytical power resides in the prefrontal cortex, but it is also metabolically expensive to use. When we are mindful of the brain's evolved biases, our prefrontal cortex can be fully engaged to integrate information from *all* the brain regions. Acknowledging and integrating all information regularly will improve financial analysis and portfolio performance.

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