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Neuroscience: Overview and Research Methods

Overview of Neuroscience

“Scientists have learned more about the brain in the last [few decades] than in all previous centuries because of the accelerating pace of research in neurological and behavioral science and the development of new research techniques.” (NINDS, 2014, Introduction section, para. 2). The advances in our collective understanding of neuroscience have direct relevance to consumer finance as it relates to making financial decisions. Other researchers have previously written summary articles to aid interested readers in better understanding the application of neuroscience to economics, commonly called neuroeconomics (see Camerer, Loewenstein, & Prelec, 2004; Goetz & James, 2008; James, 2011). To better understand this line of research and its methods, a brief overview of the brain is provided. Although the brain is very complex, a simplified

categorization of some of the main components and their primary functions can provide some helpful context.

A few of the main components of the brain are the brain stem, the cerebellum, and the cerebrum (Lundbeck Institute, 2011; NINDS, 2014). The brain stem connects the spinal cord to the brain, and the cerebellum is on the back of the brain stem. The brain stem and cerebellum are primarily responsible for vital functions of the body, including breathing and circulation (Lundbeck Institute, 2011; NINDS, 2014). However, these functions are less involved in making financial decisions. As such, most neuroscience research related to financial decision making focuses on components related to the cerebrum.

The cerebrum includes two hemispheres, known as the right and left hemispheres. Each hemisphere comprises four lobes, with each lobe having a relatively greater involvement in specific functions (Lundbeck Institute, 2011; NINDS, 2014). The foremost lobe, just behind the forehead, is the frontal lobe. Among other functions, the frontal lobe is involved in planning, logic, and the integration of inputs from other parts of the brain (NINDS, 2014). Just behind the frontal lobe on the top of the head is the parietal lobe, which is primarily involved in sensory input, especially touch, movement, taste, and smell (NINDS, 2014). On each side of the brain, below the parietal lobes and behind the ears are the temporal lobes. Among other functions, the temporal lobes aid in auditory processing and

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memory formation (NINDS, 2014). The temporal lobe is also involved in emotion (Lundbeck Institute, 2011). The fourth lobe, the occipital lobe, is located in the back of the cerebrum. The occipital lobe is involved in visual processing (NINDS, 2014).

The outermost layer of the cerebrum is a thin layer of tissue known as the cerebral cortex or gray matter (Lundbeck Institute, 2011; NINDS, 2014). The cerebral cortex is where most information processing takes place (NINDS, 2014). Information processing, therefore, largely takes place on the surface of the brain. In order to accommodate more surface area within the confined space inside the skull, the cerebral cortex is quite wrinkled (Lundbeck Institute, 2011; NINDS, 2014). Not surprisingly, neuroscience research related to financial decision making often focuses on functions and processing performed in the cerebral cortex of the frontal lobe. A common area of focus in these studies is the prefrontal cortex and its subcomponents within the frontal lobe. For example, activation of the medial prefrontal cortex (mPFC) is associated with high-level reasoning and a measure of strategic reasoning (Coricelli & Nagel, 2009). Activation of the ventromedial prefrontal cortex (vmPFC) is correlated with making judgments about the values of goods and services (De Martino, O'Doherty, Ray, Bossaerts, & Camerer, 2013).

Near the center of the brain beneath the cerebral cortex, and still considered part of the temporal lobe, is the limbic system (Lundbeck Institute, 2011). The limbic system is involved in connecting the cerebrum with the brain stem and other parts of the brain. Although the limbic system serves as a pathway among major components of the brain, the limbic system is also involved in memory formation and emotional responses and processing (Lundbeck Institute, 2011; Phan, Wager, Taylor, & Liberzon, 2002). Some of the specific parts of the brain often included as part of the limbic system include the orbitofrontal cortex (O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001), the amygdala, and the insula (Dreher, 2007). These structures within the limbic system are involved with emotion and are often the subject of neuroscience research related to financial decision making.

Neuroscience Research Methods

Neuroscience research methods can vary depending on whether the researchers are focusing on the structure or the function of neurological components. They can also vary depending on their degree of invasiveness. Modern neuroscience research methods include a large variety of techniques, most of which can be grouped into four main types: case studies, descriptive studies, manipulative studies, and screens (Carter & Shieh, 2010). Case studies in neuroscience often involved the intense study of an individual who experienced an event that cannot, or should not, be repeated (Carter & Shieh, 2010). A famous neuroscience example of a case study is that of Phineas Gage, who miraculously survived a traumatic lesion of his frontal lobe. Descriptive studies focus on observing neurological properties, whereas manipulative studies examine the effect of experimentation with neurological processes (Carter & Shieh, 2010). Screens attempt to identify the role of various neurological components on a particular process (Carter & Shieh, 2010). In other words, screens are commonly employed when focusing on the function of one or more neurological components.

The neurological study of financial decision making builds upon previous research employing methods in each of these four types. An understanding of the structure of the brain and the primary functions of its components is requisite to have any hope of gaining additional insight about the neurological processes involved in making financial decisions. However, research investigating financial decisions often employs a screen method, where researchers attempt to identify which areas of the brain are employed when performing a particular financial task or decision.

Arguably the most common category of screen methods used in neuroscience research related to financial decision making is whole brain imaging, where researchers attempt to capture images of the entire brain in order to analyze what structures of the brain are used when making specific decisions. James (2011) provides a helpful overview of some of the neuroscience methods commonly used in consumer finance, including the electroencephalogram (EEG) and functional

magnetic resonance imaging (fMRI). James (2011) also highlights the advantages and disadvantages of these methods.

Presently, much neuroscience research related to consumer finance employs fMRI methods. When an area of the brain is used, neurons in that area fire, and oxygen is burned. Subsequently, the body increases the flow of blood to that region, resulting in a rush of oxygenated blood. Deoxygenated blood has a stronger attraction to magnets than oxygenated blood. As such, researchers can identify which areas of the brain are being used at a particular time by noting the fluctuations of the paramagnetic properties of brain regions in the images. Different parts of the brain are activated to process information depending on the particular task being performed, and researchers hope to gain insight about the decision-making process by identifying which regions are employed for a particular task (for a lengthier discussion of fMRI research methods, see Friston, 2003; James, 2011).

The Dual-Self Model

The dual-self model (Fudenberg & Levine, 2006) can be a helpful framework to understanding neuroscience research related to financial decision making. Similarities to the dual-self model can be seen in the areas of the brain described previously. Some parts of the brain focus more on the rational, cognitive, higher-level processing, and some parts of the brain are more involved in emotional processing.

The dual-self model has been described in a variety of ways, each emphasizing similar yet different aspects of two selves within the mind. Others have described the idea of two distinct systems as the planner-doer model (Thaler & Shefrin, 1981), the affective and deliberative systems (Loewenstein & O'Donoghue, 2004), the System 1 and System 2 model (Kahneman, 2011), the cognitive-experiential self-theory (CEST) (Epstein, 1994), and the elephant-rider analogy (Haidt, 2006; James, 2011). The CEST theory and the elephant-rider analogy provide a

good introduction to these models and are described in more detail here.

CEST characterizes a dual system that competes for control of consumer's actions and inferences. CEST emphasizes two interdependent systems of information processing which are defined as rational and experiential processing (Epstein, 1994). The rational system is logical, analytic, and involves a conscious appraisal of events. The experiential system involves preconscious, impulsive processing. Processing in the rational system is slower, and action is more delayed, compared to the experiential system. Although the rational system is described as rational, decisions from the rational system are not always rational. Optimal decisions may actually originate from the experiential system (e.g., consider "fight" or "flight" responses). The term *rational* is used to capture the idea of higher-level cognitive processing.

James (2011) provides a helpful overview of the dual-self model by describing it as an elephant and a rider. The elephant-rider model is an analogy first introduced by Buddha that Haidt (2006) also uses to describe the mind. They argue that human cognition is less like a computer system and more like a rider on an elephant's back. The rider represents the rational system. The rider is slow, thoughtful, and has the perception of control. However, the elephant, which represents the experiential system, is stronger, quick, and reactive. If desired, the elephant has the power to supersede the rider's decisions.

The rational and emotional systems within our brain are both beneficial and work in tandem with one another. For example, the quick responses of the emotional system can be helpful in finding quick resolutions to unimportant decisions, like when to schedule a meeting (Damasio, 1994). Damasio (1996) expands on this idea as part of his somatic marker hypothesis. The somatic marker hypothesis states that emotional processes can guide reasoned decisions (Bechara & Damasio, 2005), which may or may not result in more advantageous decisions (see Bechara, Damasio, Tranel, & Damasio, 1997; Damasio, 1994; Shiv, Loewenstein, Bechara, Damasio, & Damasio, 2005).

Neuroscience Research Related to Consumer Finance

What follows is a description of some of the findings of neuroscience research that are related to various aspects of consumer finance and financial decision making. Some of this research identifies specific areas in the brain that are used when making various financial decisions. Other times, the research identifies aspects related to the cognition involved in making financial decisions. In other words, the cited research may focus on the structural use of the brain or the functional use of the brain.

Purchase Decisions

Knutson, Rick, Wimmer, Prelec, and Loewenstein (2007) investigate the areas of the brain that are involved with purchase decisions. While participants were lying in an fMRI machine, they were shown a product, followed by a price for that product. After the price was displayed, they were presented with an option to purchase the product for the specified price. Product preference activated the nucleus accumbens (NAcc), which plays a role in learning, reinforcement, rewards, and gain prediction. Prices that were perceived to be excessive activated the insula and deactivated the mPFC prior to the purchase decision. The insula is associated with the anticipation of physical pain, negative arousal, and loss prediction. The mPFC is associated with perceptions of value, gain outcomes, and gain prediction errors.

Noteworthy in this research is that excessive prices activate the region of the brain that is also involved in experiencing physical pain. Individuals also activate the reward center of their brain when they have a preference for a product, suggesting that the anticipation of receiving a particular good is rewarding and that utility from consumption can begin before a good is consumed. Taken together, these findings suggest that paying for goods activates the pain area of the brain, while the anticipation of consumption activates the reward center of the brain. In other

words, these findings suggest that individuals consider not just the satisfaction they might derive from consuming a particular good, but they also consider the pain they experience when the price is excessive. Utility, therefore, may be viewed as the net result of anticipated satisfaction from consumption after accounting for the pain of paying. For additional insight about the pleasure-seeking reward system and the pain avoidance system in the brain, see Peterson (2005).

The Framing Effect

The framing effect is a cognitive bias in which consumers construct different representations based on how situations are presented. A common example of the framing effect is the tendency for consumers to avoid uncertainty when it is framed as a gain but seek uncertainty when it is framed as a loss (Tversky & Kahneman, 1981). Greater cognitive effort is expended when individuals select an uncertain gain compared to a certain gain (Gonzalez, Dana, Koshino, & Just, 2005). However, there is no difference in the cognitive effort expended when someone selects an uncertain loss or a certain loss (Gonzalez et al., 2005). Brain activation in the prefrontal and parietal cortices during these decisions about uncertainty suggests that working memory and imagery are involved in the process (Gonzalez et al., 2005). Activity in the orbital and medial prefrontal cortices predicts a reduced susceptibility to the framing effect (De Martino, Kumaran, Seymour, & Dolan, 2006; Kahneman & Frederick, 2007). In other words, individuals with more activation in the areas of the brains associated with higher-level processing are less susceptible to the framing effect.

These findings provide support for a cognitive explanation for the framing effect. In other words, the framing effect appears to be more than merely a mental game but rather the framing effect can impact the cognitive processes involved in making decisions. Further, individuals may be attempting to visualize the outcomes of their choices, which may be difficult to do when the outcomes are uncertain.

Loss Aversion

Loss aversion is the tendency for individuals to overweigh losses compared to similar gains, relative to an arbitrary reference point (Kahneman & Tversky, 1979). The amygdala plays a key role in processing losses (Bechara, Damasio, Damasio, & Lee, 1999; Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001). Two individuals with focal bilateral amygdala lesions displayed a dramatic reduction in loss aversion during a series of monetary gain and loss gambles (De Martino, Camerer, & Adolphs, 2010). Loss aversion also correlates with amygdala activity in response to losses relative to gains under mixed gambles (i.e., the outcome could be a gain or a loss) (Sokol-Hessner, Camerer, & Phelps, 2013).

Trepel, Fox, and Poldrack (2005) propose that the anticipation of a loss (e.g., selling a product) evokes negative emotion whereas losing money (e.g., buying a product) does not. The amygdala is not active when consumers estimate purchase prices; however, the amygdala activates when consumers estimate sale prices, which may indicate a stronger sense of loss aversion when selling goods one already possesses (Reimann, Schilke, Weber, Neuhaus, & Zaichkowsky, 2011). Since consumers also experience a loss (i.e., money) when they buy a product, these findings may seem counterintuitive. However, consumers tend to value items they possess more than similar items they do not possess, which is known as the endowment effect (Kahneman, Knetsch, & Thaler, 1991). As a result, consumers who understand the tendency to systematically overvalue items they possess can adjust their expectations accordingly.

Distinct neural mechanisms help consumers anticipate gains as compared to losses (Khoshnevisan, Nahavandi, Bhattacharya, & Bakhtiary, 2008). More specifically, risk-seeking decisions (e.g., gambling in a casino) and risk-averse decisions (e.g., buying insurance) may be driven by different neural systems. An anticipation of reward can lead to an increase in the likelihood of consumers switching from risk-averse to risk-seeking behavior, which might explain why casinos surround their guests with cues such as inexpensive food, free alcohol, and

advertisements for large jackpots (Khoshnevisan et al., 2008).

Neuroscience also provides guidance on overcoming loss aversion. When consumers perceived their monetary choices as part of a holistic process, instead of viewing it in isolation, they reduce their loss aversion (Sokol-Hessner et al., 2009). Sokol-Hessner et al. (2009) defined the holistic approach as emphasizing choices in their greater context, such as by creating a financial portfolio. For a lengthier review of the neuroscience literature related to loss aversion, see Rick (2011).

Risk Tolerance

Many studies find that men tend to have higher levels of risk propensity than women (Croson & Gneezy, 2009; Dohmen et al., 2011; Powell & Ansic, 1997), but the underlying reason is largely unknown. Zhou et al. (2014) find evidence that the resting-state neural correlates of risk propensity may differ between men and women. These findings provide a neural explanation for a well-known gender difference. Understanding that men and women neurologically process risky decisions differently can impact the approach taken to discuss risk and properly account for it in financial decisions.

Hyperbolic Discounting

McClure, Laibson, Loewenstein, and Cohen (2004) provide a possible neural explanation for hyperbolic discounting. They hypothesize that “short-run impatience is driven by the limbic system...whereas long-run patience is mediated by the lateral prefrontal cortex...” (McClure et al., 2004, p. 504). The ventral striatum (vStr), medial orbitofrontal cortex (mOFC), medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), and the left posterior hippocampus all activate more in the presence of immediate rewards. An interaction also exists between choice and brain areas, where greater activation in the limbic system is associated with choosing early, while the limbic system has less activation

(relative to areas involved with all decisions) when the delayed reward is chosen.

These results suggest that hyperbolic discounting may merely be the manifestation of the dual-self model within every consumer. Emotions tend to dominate decisions in the near future, whereas emotion plays less of a role in delayed rewards. As a result, consumers may benefit from making long-term decisions while those decisions are still in the future. For example, the Save More Tomorrow™ savings program developed by Thaler and Benartzi (2004) finds that individuals are more willing to increase future savings rates than they are to adjust current savings rates. They use this finding to develop a program that allows employees to commit to increase retirement contributions in the future, often when they receive a salary increase.

Home-Country Bias

Retail investors and fund managers tend to exhibit a home-country bias (Strong & Xu, 2003; Uppal, 1992). Home-country bias occurs when an individual invests more heavily in companies that operate in the country in which he or she resides. When analyzing brain activity while making portfolio choices between funds of different national origins, home-country investment selections were correlated with amygdala activity (Kenning, Mohr, Erk, Walter, & Plassmann, 2006).

These findings suggest that loss aversion may have a role in the home-country bias. Investors may be averse to the uncertainty of investing in companies in foreign lands. This uncertainty aversion supports other findings that suggest that individuals tend to invest more in companies familiar to them (Huberman, 2001).

Financial Market Bubbles

Neuroscience also plays a role in investment decisions. For example, researchers in one study had participants engage in a market-trading simulation game (De Martino et al., 2013). In some of the trials, the experiment resulted in

a boom-or-bust type of investment bubble, where the share price of the hypothetical asset increased far above its intrinsic value. In other sessions, the share price stayed near its intrinsic value. In all of the trials, participants were asked to imagine they were participating in the market, in which they were to invest part of their \$60 endowment. Some of the subjects participated in the boom and bust trials, whereas others did not. Increased activity in the vmPFC was correlated with a greater likelihood of riding a bubble but not correlated with purchasing additional shares at inflated prices. During financial bubbles, participants experienced an increase in dorsomedial prefrontal cortex (dmPFC) activity, which is where inferences about others' mental states are processed.

These findings suggest that during a market bubble, investors may think about why others are investing. Alternatively, investors may view the entire market as one collective mental state (De Martino et al., 2013). Although projecting others' intentions may be helpful in other situations, doing so in investment decisions may be a contributing factor to financial market bubbles and their ultimate decline.

Mortgage Default Decisions

After the housing bubble burst in the late 2000s, many homeowners owed more on their mortgages than the home was worth, resulting in a negative equity position. Many homeowners in this situation made the calculated financial decision to stop making payments on their mortgage. However, some homeowners did not exercise this option and continued to pay their mortgages, even when it would have benefitted them financially. Seiler, Walden, and Lane (2012) investigate a neurological explanation for how individuals make this mortgage default decision.

A negative equity position is the primary economic determinant in the decision to strategically default on a mortgage. Most homeowners focus on a negative equity position rather than the potential loss of a down payment (and the repayment of any principal) when deciding whether or

not to default on the mortgage (Seiler et al., 2012). Homeowners who have a significant negative equity position have higher activation in the anterior cingulate cortex, which is associated with cognitive dissonance (Seiler et al., 2012). Activation in the left lingual gyrus, which is associated with autobiographical thinking, was greater for homeowners who were more willing to default (Seiler et al., 2012).

These findings suggest that when homeowners are severely underwater, they may experience a conflict between a moral obligation to honor a mortgage contract and a desire to strategically default on a poor financial investment (Seiler et al., 2012). Homeowners who decide to default likely engage in a lot of thinking about what that will entail, how their lives will be different as a result of defaulting, and how they can reconcile the decision with their moral compass. Conversely, homeowners who decide not to default are able to maintain the status quo, which requires significantly less self-reflection and does not create a dissonance with their moral compass (Seiler et al., 2012).

Age and Financial Decisions

Weierich et al. (2011) provides a review of fMRI studies regarding age and its impact on financial decision making. Their main hypothesis is that the use of affect (i.e., relying on feelings to guide decision-making; following your gut reactions) increases with age and likely contributes to sub-optimal financial outcomes. They also highlight that the hippocampus has a role in imagining what the future will be like by combining elements from the past (i.e., memory). The hippocampus reduces in size and function with age, leading older adults to be more general (i.e., less detailed) in their future forecasts. The insula in older adults is also activated less when anticipating losses. Further, older adults have less activation in the amygdala in response to negative pictures.

These findings suggest that the susceptibility of making sub-optimal financial decisions increases with age. As a result, consumers may benefit from involving trusted children and/or

other trusted family members in financial decisions later in life. Also, consumers may benefit by forming relationships with trusted financial professionals earlier in life. By doing so, a consumer can protect their future self from their future self who may be more likely to make sub-optimal financial decisions than their current self, family members, or trusted professionals (with the caveat that the trusted professional provides quality financial advice).

Choosing a Financial Advisor

James (2013) investigated the role that professional financial designations have on an investor's advisor selection decisions. Prior to participating in a stock market simulation, participants selected a financial advisor, some of whom had the CFP® certification and others did not. The simulation involved presenting a return for the market (which could be a positive or negative return) and a corresponding return for the participant's investment portfolio. Depending on the relation between the two returns, the impression was that the advisor may have underperformed or outperformed the market, or had a return fairly similar to the market. At any point during the simulation, participants were allowed to change their advisor.

Changing financial advisors was more likely to occur during periods of relative underperformance (James, 2013). When the selected advisor did not have the CFP® certification, brain activation immediately prior to changing advisors was greater in the dorsal anterior cingulate cortex, which is associated with error detection, as well as the inferior parietal and middle frontal gyri, which are associated with number comparisons. The findings suggest that individuals are more likely to search for errors when their advisor does not have a certification. They are also more likely to make numerical comparisons of their advisor's returns to the market. Conversely, individuals who select an advisor with a certification are arguably more likely to trust their advisor and the advisor's abilities.

Newest Research

Neuroscience research on consumer financial decisions continues to move forward, and the newest research is yet to be published. For example, Frydman (2014) uses neural predictors regarding the role of the vStr in prediction errors. Using these predictors, Frydman (2014) finds evidence that social learning and relative wealth perceptions play a role as peer effects in investing simulations, providing neural evidence of the role of social interactions in investment behavior.

Conclusion and Future Research

Developments in research methods have allowed researchers to explore the neural aspects of making various financial decisions. Much neuroscience research on financial decisions uses fMRI methods, largely to identify which parts of the brain are being used when making a particular financial decision, and to consider what functions those regions of the brain tend to play. For example, Knutson et al. (2007) finds that prices that are perceived to be excessive activates the pain region of the brain, whereas preferred goods activate the reward region of the brain. The results of McClure et al. (2004) suggest that hyperbolic discounting can be explained by the competing priorities of the limbic system and the lateral pre-frontal cortex. Other neuroscience research has focused on investment decisions and the use of professional financial advisors.

Neuroscience research has also analyzed financial decisions involving risk and uncertainty. For example, the results of Gonzalez et al. (2005) suggest that individuals often try to visualize the outcome of financial decisions, which is hard to do when the outcomes are uncertain. Sokol-Hessner et al. (2009) suggest that individuals are less susceptible to loss aversion when they view financial decisions in light of a greater context, rather than focusing on the outcome of a single financial decision. Zhou et al. (2014) find evidence that gender differences in risk tolerance may have a neural explanation.

Despite all that has been discovered, the field of neuroeconomics is still relatively new and largely unexplored. Numerous new discoveries are yet to be made. Ideas for neuroscience research often spring from observing behavioral anomalies and seeking a neurological explanation for why individuals tend to exhibit behavior that runs contrary to what would seem theoretically optimal. For example, insurance is a useful financial tool, used to transfer the risk of catastrophic financial events, such as a premature death, long-term disability, or substantial liability claim. However, many individuals have limited interest in insurance policies that provide protection from such catastrophic events (Kunreuther & Pauly, 2004). Seeking a neural explanation for this wide-spread underinsurance may be helpful in identifying ways to improve the financial protection of consumers.

A similar situation exists regarding longevity annuities. Many individuals would benefit from having protection against outliving one's assets, yet relatively few people purchase longevity annuities, or even have an interest in doing so in the future (Guillemette, Martin, Cummings, & James, 2016). A neural explanation analyzing annuity purchase decisions may help financial engineers design annuity products that are advantageous yet more palatable to both the rational and emotional systems in the brain.

Countless other research possibilities exist, but one more is mentioned. Although researchers may find neuroscience research fascinating and intriguing, little is known about the efficacy of an awareness of the workings of the mind. In other words, does having an awareness of the existence and functions of both the rational and emotional systems within the brain help individuals make more informed decisions? Exploring this question would help neuroeconomic researchers better understand the benefits of performing such research.

A better understanding of the neuroscience of financial decision making may help researchers and practitioners alike. Researchers can arguably formulate more accurate frameworks and models for their own analyses if they have a

better understanding of how individuals make financial decisions. Practitioners can apply these principles in their work with clients by educating their clients on their existence. When making financial decisions, hired professionals are often less emotionally involved in the decisions and can help encourage more rational arguments. Practitioners can also confront unfounded emotional responses to financial decisions. More directly, the reader may benefit personally from having a better understanding of how his or her own brain works as he or she makes financial decisions.

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