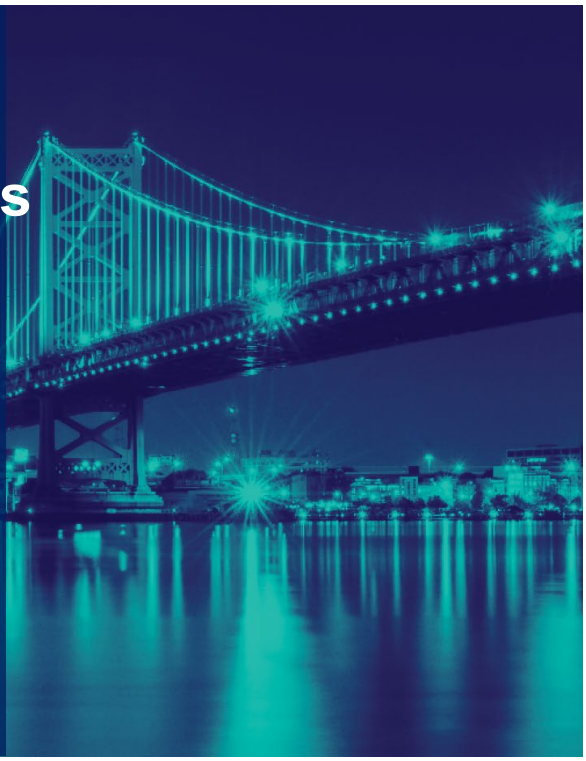
FEDERAL RESERVE BANK PHILADELPHIA
Consumer Finance Institute

Summary of the Symposium on Neuroeconomics and Financial Decision-Making *Foundations and Applications in New Domains*



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The Consumer Finance Institute conducts research on how people earn, spend, save, and invest, as well as how credit markets and payment systems affect the economy. Our goal is to foster a healthy consumer sector, a stable financial system, and a resilient regional and national economy.

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Humans think they are usually rational when making financial decisions. But what is really going on in the brain when spending and investment choices are made? On August 6, 2019, the Federal Reserve Bank of Philadelphia's Consumer Finance Institute (CFI) hosted a symposium called Neuroeconomics and Financial Decision-Making: Foundations and Applications in New Domains. The goal of the symposium was to enable Bank researchers and other experts to learn about the research methods and findings of this new field and how they can be applied to the study of financial decision-making and core central bank functions. The symposium brought together experts in the field of neuroeconomics, including ***Colin F. Camerer****, Robert Kirby professor of behavioral finance and economics at the California Institute of Technology;* ***Gregory Samanez-Larkin****, assistant professor of psychology and neuroscience at Duke University;* ***Camelia M. Kuhnen****, professor of finance at Kenan-Flagler Business School at the University of North Carolina at Chapel Hill;* ***Vinod Ventrakaman****, professor of marketing at the Fox School of Business at Temple University; and* ***Joseph W. Kable****, Baird Term Professor of Psychology and Marketing at the University of Pennsylvania.*

Session 1: A Neuroeconomics Primer

Colin F. Camerer started the conference with an overview of the interdisciplinary field of neuroeconomics. The study of neuroeconomics traces its roots as far back as 1999, when neuroscientists Michael Platt and Paul Glimcher published the results of a five-year study of decision-making in macaque monkeys.[1] Platt and Glimcher found that the monkeys were coding their reward expectations in a primitive portion of the brain traditionally associated with stimulus response. The finding was not only controversial — their results suggested that primates were able to perform many of the risk/reward calculations that humans could do — but it was also groundbreaking, paving the way for the study of decision-making in neuroscience, and subsequently, the branch of economics now known as *neuroeconomics*.

Neuroeconomics differs from economics, Camerer explained, because much of economic theory is driven by concepts of constrained optimization. In such an environment, a consumer maximizes

[1] Michael Platt and Paul Glimcher, "Neural Correlates of Decision Variables in Parietal Cortex," *Nature* 400 (1999): 233–238.

her utility by choosing the basket of goods she will purchase, subject to her budget constraint. A choice between two options available under a given budget constraint is decided by weighing the expected utility (i.e., satisfaction or pleasure) each choice brings to the consumer. Thus, if the utility function remains stable, economists can expect that the consumer will make the same choice over and over again. In contrast, neuroeconomists believe that the real engine of human decision-making resembles a feedback loop of prediction and learning. The brain predicts things that are going to happen and learns from surprises. As a result, neuroeconomists do not expect choices to be stable over time, although they may converge to the same choices made under constrained optimization.

In neuroeconomics — and decision neuroscience more generally — brain activity is observed via tools such as *functional magnetic resonance imaging* (fMRI). Such tools are used to map regions of the brain or circuits within the brain where activity is correlated with the values of hidden variables underlying our decisions, such as discount rate, mental state, and subjective probability. These variables all exert a direct but unobserved influence on the choices humans make. Once neuroeconomists know where in the brain a particular variable is being coded, they can run causal experiments that measure the effect of neural stimulation on decision-making. Camerer gave an example in which researchers stimulated the *dorsolateral prefrontal cortex* (*DPFC*) — an area of the brain associated with executive function and decision-making — which had the effect of making test subjects more impatient in choosing between money now or money later.[2] The researchers had, in effect, caused the test subjects to more heavily discount future consumption.

Camerer then connected neuroeconomics with financial markets by describing his work on bubbles in asset markets. Bubbles are typically characterized by peak-to-trough swings in asset prices of around 50 percent, he said, with a slow rise and rapid crash. Camerer and his colleagues were able to generate asset bubbles in a series of market experiments involving 20 participants and two assets — a risk-free asset and a risky asset that converted into a specified amount of cash after 50 periods.[3] Although market equilibrium prices could be calculated with some straightforward

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[2] Bernd Figner, Daria Knoch, Eric J. Johnson, Amy R. Krosch, Sarah H. Lisanby, Ernst Fehr, and Elke U. Weber, "Lateral Prefrontal Cortex and Self-Control in Intertemporal Choice," *Nature Neuroscience* 13 (2010): 538–539.

[3] Alec Smith, Terry Lohrenz, Justin King, P. Read Montague, and Colin F. Camerer, "Irrational Exuberance and Neural Crash Signals During Endogenous Experimental Market Bubbles," *Proceedings of the National Academy of Sciences* 11:29 (2014): 10503–10508.

algebra, the researchers found that, by period 33, the price of the risky asset had typically risen three to four times above its fundamental value, before falling rapidly. When the researchers looked at differences in brain activity using the fMRI, they found that blood flow into the *nucleus accumbens* (part of an evolutionary-conserved part of the brain called the *basal ganglia*) was strongest when participants bought or sold a share. Increased blood flow to the nucleus accumbens made participants feel exuberant when prices rose, causing them to buy more stock and driving the price higher.

Camerer suggested that, in some cases, a market crash may be triggered when traders begin to form the intuition that prices will soon fall, causing them to sell off their positions. Neuroscience suggests that intuition may reside in the *insular cortex* (part of a region of the brain that helps humans understand and feel what's going on inside the body). In one study, participants with high levels of activity in the insular cortex (interpreted as a signal of fear or financial uncertainty) exited the market earlier and made the most money. Their exits, however, often contributed to steep price declines.

Session 2: Financial Decision-Making Across Adulthood

Gregory Samanez-Larkin detailed research on cognitive functions among older adults. He pointed out that more than half of the wealth in the stock market is held by people over the age of 65. Because this segment of the population is growing rapidly and will live longer than previous generations, their financial behavior has an increasingly large impact on the economy. "If they're screwing these things up, it can really screw things up on a broad scale," he said. Samanez-Larkin said that policy experts are uncertain about the effect of such a large and wealthy segment of the population spending their assets in retirement. The finance industry is worried that older adults will be more susceptible to fraud and may have a harder time making financial decisions.

Research indicates that older adults have different emotional reactions to financial news. They are more likely to consider the nonfinancial (e.g., social or health) consequences of financial decisions. He said people may become more positive and trusting as they age. Finally, older people compensate for age-related cognitive loss with knowledge gained from years of experience. The result, Samanez-Larkin said, is that some forms of decision-making improve while others deteriorate, and that decisions vary widely across contexts and among individuals.

Samanez-Larkin noted that research has found evidence of an age-related positivity effect. He cited a study where adults participated in a simple financial task in which participants could win or lose money. Each participant saw a preview of the potential win or loss associated with their decision, before any gain or loss was actually realized. The researchers examined brain activity when a person is thinking about the possibility of winning or losing money (*anticipation*), and when the actual win or loss occurs (*outcome*). They found that younger adults overreacted to the prospect of loss, whereas older adults had a dampened response, and this was reflected both in brain activity and participants' subjective reports. However, he said, older adults tended to become more upset than younger adults when they actually lost money, even after controlling for real-world wealth.

Samanez-Larkin's research has helped debunk the notion that older people are more patient and more risk averse than younger ones. His studies show that when older adults take financial risks, they're particularly drawn to positively skewed ones in which there is a very low chance of winning a large amount and a high chance of losing a small amount. He noted that people who accept such risks in simple laboratory experiments also tend to exhibit inferior financial skills in the real world. In a separate study, his team found that signal variability in a part of the brain called the *striatum* (which includes the nucleus accumbens, discussed previously) increases with age and could help explain why some older adults make these very risky choices.

His research has also found that older adults can be impulsive when thinking about the nonfinancial consequences of their decisions. Older adults are less patient when they're thinking about how such decisions would affect their family and friends or their own health. Thus, individuals can be impulsive in certain contexts even if they are patient in others.

Session 3: Understanding Economic Expectations: From Neuroscience to Household Finance and Macroeconomics

Camelia M. Kuhnen continued the theme of heterogeneity in decision-making across individuals and circumstances. She focused on four issues regarding the brain and financial decisions.

First, she pointed out that the brain regions responsible for processing information on gains is different from the region responsible for processing loss information.[4] Kuhnen explained that the nucleus accumbens keeps track of positive things we learn that are somehow relevant to us and tends to activate more with a positive surprise, such as a gain in the stock market. Another part of the brain, the *anterior insula*, seems to care more or react more to negative information, including counterfactual information that tells us that things are not going as well as we think they might be. These two brain structures are very different and evolved for different purposes, Kuhnen said. As a result, their response to information being provided and coded within them is very different.

One implication of this finding is that the process of learning about preferences over choice sets involving gains is different from the process of learning in the loss domain. Specifically, humans tend to have a higher degree of pessimism in the loss domain.[5] Kuhnen suggested that this pessimism may help explain why recovery from an economic recession may drag on for years. In a recessionary environment, people tend to interpret new information in an overly pessimistic manner, causing them to invest and spend less than they otherwise would.

Kuhnen then drew a parallel between global economic recessions and depressed local economic conditions. Her research has examined the relationship between economic adversity and learning processes. Individuals from low-socioeconomic status (SES) backgrounds — measured by income and education — tend to form overly pessimistic beliefs about financial investments and economic opportunities.[6] As a result, individuals from low-SES economic environments tend to invest less in human capital (education, training), equity markets, real estate, and new business formation, all of which are contributing factors to widening wealth inequity in the U.S.

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[4] Camelia M. Kuhnen and Brian Knutson, "The Neural Basis of Financial Risk Taking," *Neuron* 47:5 (2005): 763–770.

[5] Camelia M. Kuhnen, "Asymmetric Learning from Financial Information," *Journal of Finance* 70:5 (2015): 2029–2062.

[6] Camelia M. Kuhnen and Andrei C. Miu, "Socioeconomic Status and Learning from Financial Information," *Journal of Financial Economics* 124:2 (2017): 349–372; and Sreyoshi Das, Camelia M. Kuhnen, and Stefan Nagel, "Socioeconomic Status and Macroeconomic Expectations," *Review of Financial Studies* 33:1 (2020): 395–432.

This finding relates to her third point: that life adversity and environmental instability influence how people form beliefs and expectations about future economic conditions.[7] Individuals from low-SES environments are more uncertain in their expectations of future economic conditions, causing them to engage in precautionary behaviors and resulting in an underinvestment in financial assets offering greater return in exchange for greater risk, such as equity markets.[8]

Kuhnen suggested that financial literacy programs may reduce uncertainty and help individuals feel more knowledgeable about their investment decisions. She cautioned, though, that policy interventions and communications from the central bank and other policymakers could be interpreted differently by households with a high degree of financial uncertainty compared with those with less uncertainty. Kuhnen suggested that policymakers take this into consideration when crafting messages targeted at the general public, and they should tailor messages to target audiences to offset how different households react to uncertainty.

Kuhnen stressed that not all individuals from low-SES environments will respond in the same way to economic and environmental adversity. Non-cognitive character traits, such as *self-efficacy* (belief in one's ability to achieve and succeed) can help offset the effects of negative shocks on the brain's learning process and can affect people's future financial health. Research has found that the brains of individuals with high self-efficacy scores are better able to cope with adversity. Financially, such individuals are less likely to have delinquent bills and debts.[9]

Session 4: Decision Strategies and Financial Decision-Making

Humans use an adaptive algorithm for decision-making that is based on context, individual differences, current capabilities, and other factors, said **Vinod Venkatraman**. He explained that activity in distinct regions of the brain can be used to predict the choices we make. Certain regions of the brain track probabilities, while other regions track losses and others track gains, with choice

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[7] Melissa L. Sturge-Apple, Jennifer H. Suor, Patrick T. Davies, Dante Cicchetti, Michael A. Skibo, Fred A. Rogosch, "Vagal Tone and Children's Delay of Gratification: Differential Sensitivity in Resource-Poor and Resource-Rich Environments," *Psychological Science* 27:6 (2016): 885–893.

[8] Itzhak Ben-David, Elyas Fermand, Camelia M. Kuhnen, and Geng Li, "Expectations Uncertainty and Household Economic Behavior," National Bureau of Economic Research Working Paper 25336 (2018).

[9] Camelia M. Kuhnen and Brian T. Melzer, "Noncognitive Abilities and Financial Delinquency: The Role of Self-Efficacy in Avoiding Financial Distress," *Journal of Finance* 73:6 (2018): 2837–2869.

being the outcome of the interaction of all these regions.[10] For example, Venkatraman pointed out that the insular cortex, which acts as a hub linking large-scale brain systems, will dominate the choice of someone who places greater weight on avoiding losses, leading the person to choose the *loss-minimizing* option from a set of lotteries.[11] The DPFC shows greater activity with the parietal cortex when people choose the *probability-maximizing* option. The DPFC shows greater connectivity with the insula and ventromedial prefrontal cortex when people make value-maximizing choices, such as gain maximizing or loss minimizing.

Venkatraman discussed choice architecture and how presentation and framing influence our choices. As one example, he said older people are much more influenced by the order in which information is presented than are younger people. Thus, if gains are shown first, older adults are more likely to choose gain-maximizing options than are young adults. This finding, he said, suggests that changing the order in which information is presented can vary the choices people make.

Likewise, how a question is worded can drastically change the response elicited. For example, when people are asked what age they expect to live until, their median response is 10 years more than when asked the age at which they think they'll die. Venkatraman suggested that when people think of "die by," they are primed to focus on their vices, and that negativity tends to dominate their life expectancy estimate. But when people think of living, they focus on all the positive and healthy activities they're engaged in, leading to longer life expectancy estimates.

Venkatraman's findings have significant implications for choice architecture (that is, the design of how to present choices to consumers and how that presentation impacts decision-making). He noted that what works in one context may not necessarily work in another. For policymakers, the correct framing of questions can lead to better information for financial planning. For instance, if

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[10] Vinod Venkatraman, John W. Payne, James R. Bettman, Mary Frances Luce, Scott A. Huettel, "Separate Neural Mechanisms Underlie Choices and Strategic Preferences in Risky Decision Making," *Neuron* 62:4 (2009): 593–602.

[11] Consider a person choosing between two lotteries. Lottery A has a 50 percent chance of losing $10 and a 50 percent chance of winning $15, and Lottery B has a 50 percent chance of losing $8 and a 50 percent chance of winning $10. The *loss-minimizing* option is Lottery B, since a loss of $8 is less than a loss of $10. The *gain-maximizing* option is A, since a gain of $15 is greater than a gain of $10. The *probability-maximizing* option is the one that maximizes the probability of winning any amount of money. In this example, the person choosing this option would be indifferent between Lottery A and B, in which case they might default to the gain-maximizing or loss-minimizing options.

people think they will live longer (the "live by" question), they are more likely to be interested in annuities and delaying the start of Social Security benefits.

Session 5: The Effects of Neurological Heterogeneity, Cognition, and Affective Response on Risk Tolerance and Time Preference

In economics, many decisions that people face involve tradeoffs between consumption at different points in time. That includes saving for retirement versus going on vacation or deciding when to switch from accumulating wealth (*saving*) to decumulating wealth (*spending*) during retirement. **Joseph W. Kable** discussed the effects of neural systems and cognitive abilities on time preference and risk tolerance.

The neural systems involved in remembering the past are the same systems that are activated when people imagine the future and try to assimilate potential futures into their present lives. Kable and his colleagues tested the hypothesis that variability in memory and imagination systems in the brain are related to variability in discounting (the better you can envision the future, the more patient [higher discount rate] you will be, and vice versa).

Kable explained that adolescents tend to have less cortical thickness (brain mass) than mature adults in certain areas of the cerebral cortex (an outer layer of brain tissue that is associated with a host of brain activity including attention, thought, memory, language, and consciousness). Cortical thickness in these regions is associated with patience, such that individuals with thinner cortex mass tend to exhibit a greater degree of impatience and will discount future consumption at lower discount rates than more mature adults. Similarly, an area within the brain's medial temporal lobe called the *entorhinal cortex* seems to be particularly important for placing memories in context (i.e., in time and place). There is a relationship between thickness in the entorhinal cortex and discount rate, such that individuals with a thicker entorhinal cortex tend to have lower discount rates than individuals with a thinner entorhinal cortex.

Kable noted that, within the 60- to 90-year-age range, age itself does not predict discounting. Rather, research suggests that cognitive abilities, specifically episodic memory abilities, explain the heterogeneity researchers observe in discounting in older adults. Study participants with low

episodic memory abilities — the ability to recall old memories of everyday events — tend to have higher discount rates, and vice versa.

Kable then discussed his findings on neural structure and risk tolerance. The structure of the brain in a subcortical area called the *amygdala* is strongly related to risk tolerance. He noted that this area is different from the brain structures related to discount rates. Individuals with more gray matter in the amygdala, whether in the left amygdala or the right amygdala, have a higher tolerance for risk.

He said that functional communication between the amygdala and other areas of the prefrontal cortex is correlated with risk tolerance. Research has demonstrated a direct relationship between the degree of functional communication observed in a person at rest and their degree of risk tolerance.

Kable noted that *diffusion tensor imaging* — an imaging technique used to estimate the degree of brain network connectivity — has shown that the structural connections between the amygdala and the medial prefrontal cortex in the right hemisphere are also predictive of the degree of risk tolerance. He said by combining these three metrics, we can predict about 5 percent to 10 percent of the variance in risk tolerance among individuals.

Session 6: Group Discussion

The five participants were asked how forward guidance issued by Federal Reserve (Fed) policymakers can be made more effective using the panelists' knowledge of the brain.

Communications from the central bank to the public concerning the future path of interest rates are known as *forward guidance*. In some instances, the central bank may pledge to keep interest rates lower than usual to boost optimism in households and businesses and stimulate a return to typical spending and investing behaviors. A recent paper, however, found that people don't always respond as expected.[12] Households and businesses might interpret a commitment to low rates as

[12] Philippe Andrade, Gaetano Gaballo, Eric Mengus, and Benoît Mojon, "Forward Guidance and Heterogeneous Beliefs," *American Economic Journal: Macroeconomics* 11:3 (2019): 1–29.

bad news, thinking that things are much worse than they'd imagined if the central bank believes it must keep interest rates lower than usual.

Additionally, the Great Recession and housing crisis affected certain parts of the U.S. (in particular, Michigan and the so-called sand states of Arizona, California, Florida, and Nevada) more than other states. The panelists were asked whether they believed the Fed could employ a different communication strategy to ensure consumers and businesses had the same interpretation, no matter where they live.[13]

Kuhnen noted that there are many reasons why households might respond differently to Fed guidance. She suggested that different reactions among households may not reflect a misinterpretation of the forward guidance, but rather each household's perception of its personal economic situation or that of its community. Households living in sand states may have interpreted forward guidance within the context of their own financial experience and responded in ways that were contrary to the Fed's intended message.

According to Kuhnen, since research shows that households are generally inattentive to news about the Fed, a better strategy might be for the Fed to focus on reaching the banks it supervises. Kuhnen suggested that the 12 regional Federal Reserve Banks — dispersed geographically throughout the country — should talk to their local banks about issues that are specific to their locality because doing so could help make Fed guidance more locally relevant.

Camerer suggested that forward guidance communication faces an inherent conflict, since it often requires a simple message, precluding Fed officials from tailoring the message for multiple audiences. According to Camerer, the Fed should focus on repeating the same simple message over and over again in trusted media like television or the business press. He also pointed to the economics literature on hierarchical models in which different groups have different levels of sophistication in understanding the economy. He suggested the Fed focus on the most strategic groups (e.g., large companies, retailers, and large banks) and allow their reactions to filter down to households and less sophisticated groups.

[13] The views expressed by the panelists are their own and do not reflect the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.

Conclusion

On August 6, 2019, CFI hosted a symposium on neuroeconomics and financial decision-making. In his opening remarks, Patrick T. Harker, president and chief executive officer of the Federal Reserve Bank of Philadelphia, noted the importance of seeking new insights into familiar questions. Neuroeconomics certainly fits the bill. In its relatively brief time as a recognized interdisciplinary field, neuroeconomics has introduced an entirely new toolkit and trove of new insights into the study of economic decision-making.

During the symposium, researchers at the forefront of neuroeconomics shared the results of groundbreaking research on topics including price bubbles in asset markets, financial decision-making in older adults, the effects of environmental instability on beliefs and expectations, choice architecture in financial planning, and how neural systems and cognitive abilities affect time preference and risk tolerance.

As the field of neuroeconomics continues to mature, CFI will continue its efforts to promote a collaborative relationship between Bank researchers and neuroeconomists.