

**Behavioral and Social Research Program  
National Institute on Aging  
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**Neuroeconomics and Aging: Directions for Research**

**Statements from August 2005 Teleconference Participants**

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## John T. Cacioppo, University of Chicago

### Social Neuroscience

Improvements in living standards, public health efforts, and medical technology have made population health a notable success story in developed nations. Life expectancy at birth has risen steadily over the course of the twentieth century. Along with this improvement came a shift in the kinds of illnesses that cause death. In the early twentieth century, most people died from acute infectious diseases such as diphtheria or scarlet fever and many of these deaths were in childhood. Most people today will never suffer from these diseases, but will instead die late in life from chronic degenerative conditions such as heart disease or cancer. The combination of longer lives and increased prevalence of chronic conditions has raised concerns that people will spend their later years sick and disabled. Stroke, for instance, is now the primary cause of long-term disability, and the cost of prescription medicines for chronic health conditions strains personal and government budgets.

According to Congressional Budget Office figures, federal spending on the elderly constituted 35% of the federal budget in 2000 but is projected to be 43% of the federal budget by 2010 and 48% of the federal budget by 2015 – less than ten years from now. The bulk of this spending is on the federal government's two largest healthcare programs, Medicare and Medicaid. While social security spending is projected to rise from \$492 billion in 2004 to \$888 billion in 2015, expenditures on Medicare and Medicaid are projected to rise from \$473 billion last year to \$1.2 trillion in 2015. To put this in perspective, the Congressional Budget Office projections in 2005 indicate that by 2010, annual federal spending (in 2000 dollars) will be \$2,541 per child and \$21,122 per adult over 65 years of age (Cacioppo, 2005). Among the possible solutions to this crisis are to: (a) get control of health care costs, (b) capitalize on the strength of an elderly workforce, and (c) improve the health care decisions by middle aged and older adults. These solutions depend on older adults remaining healthy and functional.

A critical challenge facing researchers today, therefore, is to identify the social, behavioral, and biological factors that raise or lower the likelihood of remaining healthy and functional for the entire life span. Doing so will require examination of the influences on health and well-being of genetic predispositions and social exposures, individual level psychological processes, neurobiological mechanisms and operations, and peripheral vascular, endocrine, and cellular processes. To reach the necessary answers will require more integrative multi-level analyses of population-based samples over extended periods of time. It will require going beyond multidisciplinary research, in which different levels of expertise are brought together to solve a problem, to synergistic interdisciplinary research. Accordingly, new ways of thinking about phenomena, hypotheses, and theories may be as important to future developments in aging research as methodological and statistical innovations.

## Alan Sanfey, University of Arizona

In the past 30 years or so, great strides have been made within the field of Psychology in understanding and documenting principles by which people make judgments and decisions. This research endeavor, with its roots firmly in the pioneering work of Tversky, Kahneman and colleagues, had as its goal the outlining of a descriptive theory of decision-making – how people actually make judgments and decisions, as opposed to the predominantly prescriptive or normative models which had held sway to that point. Despite some criticism that this so-called “heuristics and biases” approach to judgment and decision-making has overly focused on the failings of our decision processes, it is unarguable that the remarkable success of this approach has quite dramatically improved our knowledge of how we make judgments and decisions.

However, it is notable that, with very few exceptions, research has not systematically examined judgment and decision-making across the lifespan. With older adults progressively more independent and taking responsibility for significant decisions concerning, for example, medical and financial issues, it is increasingly important to understand the fundamental issues regarding decision behavior in aging. The relative paucity of research in this area offers, I believe, some exciting opportunities for researchers interested in questions in the area of aging, a few of which I will briefly outline below.

1) Perhaps the most fundamental work to be done is an investigation of the basic judgment and decision phenomena in an older population. Many basic decision principles have been well-established in the populations typically studied by decision researchers (i.e. college undergraduates), and it would seem that one very important step is to examine whether these principles are valid across the lifespan. For example, when making decisions, it is well known that people demonstrate *risk-averse* tendencies, that is, they tend to steer clear of alternatives which offer a degree of uncertainty. Is this decision style also observed in older adults? In general, I believe it would be worthwhile to assess older adults on a battery of “standard” decision tasks, investigating questions of attitudes towards risk, gains and losses, estimates of probabilities, and susceptibility to biases. Perhaps a good starting point would be an examination of whether the tenets of Prospect Theory - the notions of a reference point, steeper functions for losses than gains, and diminishing returns for gains – also hold for older adults.

2) On a more general level, there is increasing interest in explaining decision behavior in terms of more basic cognitive functions such as perception, memory, attention, and so on. An advantage of this approach is that it allows construction of more detailed process models of judgments and decisions, offering the opportunity to move from discussing decision “effects” to a deeper understanding of decision-making. Approaches of this nature could also tie-in with the developing work on understanding these cognitive processes as they change throughout the lifespan.

3) Related to the above point, describing judgment and decision-making in terms of the underlying neural substrate offers an exciting development for the future. The rapidly developing field of neuroeconomics is seeking to integrate psychology, economics and neuroscience in an effort to specify the brain basis of decision-making. While this field is in its infancy, paradigms which are emerging from it could well be useful in understanding decision behavior across the life-span. One particular question of interest is the role of emotion in decision-making, an issue

largely ignored until relatively recently. Specifically, research could be useful in asking whether emotional processes bias decision behavior in older adults in a similar fashion to that of the typical (younger) studied population.

4) Finally, another direction of interest has emerged from behavioral economics, which offers a wealth of simple but interesting tasks that can yield interesting insights into decision-making. One aspect in particular is the set of tasks which investigate decision behavior in a social context. Tasks such as the Trust Game, the Prisoner's Dilemma, and the Ultimatum game, all add the notion of social interaction to the decision task, which often leads to interesting changes in behavior as compared to playing these games in isolation. Tasks like these improve the ecological validity to the standard decision tasks, and researchers can also take advantage of the rich set of data which have been gathered to date in younger populations.

## Paul Slovic, Decision Research

As some of you know, I have been working with Ellen Peters, Melissa Finucane, and other colleagues for several years, studying the role of affect in judgment and decision making. It appears that affect, defined simply as feelings of goodness or badness associated with a stimulus, is an important source of information that motivates many important judgments and behaviors. Dual process theories of thinking, of which there are many, contrast affect as an element of experiential processing with deliberate, analytic thinking. Both modes of thinking interact in what we have characterized as “the dance of affect and reason.” We have begun studies to examine whether the nature of this dance differs in younger vs. older persons and we believe this is a promising direction for future research to take. One hypothesis is that, as we age, we rely relatively more heavily upon affective information rather than deliberate analytic processing, which places greater demands upon memory, attention, and energy. Is this so? If it is, does it impair all decisions by the elderly—or only some types of decisions? Could it be that the life experiences of the elderly convey a form of wisdom that stands them in good stead when making decisions about things that are familiar to them? Does it also help them in more novel settings or is it detrimental there? Researchers in the field of judgment and decision making have devised many tasks to decide and evaluate performance, including some that are diagnostic of the weight accorded to affective vs. analytical information. These tasks provide a rich opportunity for studying age-related differences in judgment and decision processes.

An important quality that has been too much neglected in the study of decision making is competence. Peters, Finucane, and I have begun to study this. Individual differences in physical performance clearly diverge with age (some people decline more than others). The same thing appears to happen with mental competence, including judgment and decision making skills. Before we begin to process information relative to a decision, we need to acquire that information and comprehend it. Finucane et al. (2002) observed severe declines in older adults’ comprehension and consistency, even when education, income, gender, health, and other covariates were taken into account. Not surprisingly, older persons had much more difficulty using comparative information to inform health plan choice. It is critical that we understand the distribution of different types of information processing and decision making competencies across the age range. It is clear that an immense amount of information is currently disseminated, at great expense, to elderly consumers in a form that, in combination with consumers’ limited competencies, is useless to them. Research is needed to combat this wasted effort and identify how to help elderly people make the judgments and decisions upon which their quality of life depends.

This is but a brief introduction to these research directions. Some selected references are:

Finucane, M.L., Slovic, P., Hibbard, J.H., Peters, E., Mertz, C.K., & MacGregor, D.G. (2002). Aging and decision-making competence: An analysis of comprehension and consistency skills in older versus younger adults considering health-plan options. *Journal of Behavioral Decision Making*, 15, 141-164.

Hibbard, J.H., Slovic, P., Peters, E., Finucane, M.L., & Tusler, M. (2001). Is the informed-choice policy approach appropriate for Medicare beneficiaries? *Health Affairs*, 20(3), 199-203.

Peters, E., Finucane, M. L., MacGregor, D. G., & Slovic, P. (2000). The bearable lightness of aging: Judgment and decision processes in older adults. In National Research Council, Committee on Future Directions for Cognitive Research on Aging, P. C. Stern & L. L. Carstensen (Eds.), *The aging mind: Opportunities in cognitive research* (Appendix C, pp. 144-165). Washington, DC: National Academies Press.

Peters, E., Slovic, P., Hibbard, J., Mertz, C.K., Tusler, M., & Schmidt, E. (2001). *Bringing meaning to numbers: Affective and deliberative processing of information display formats in the decisions of younger and older adults* (Report No. 01-04). Eugene, OR: Decision Research.

Salthouse, T. A. (1990). Cognitive competence and expertise in the aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (3rd ed., pp. 310-319). New York: Academic Press.

## Elke U. Weber, Columbia University

### Neuroeconomics and Aging: Opportunities and Challenges of a Multidisciplinary Approach

Mental and physical health outcomes are at least partially dependent upon the quality of the choices people make. Good choices support good health and promote a sense of mastery over one's world; bad choices compromise well-being and leave one feeling helpless when confronted with life's challenges. This is true for decision makers of all ages, including the elderly, who must continue to make important financial and health-related decisions in their lives, often in the face of increased cognitive deficits. The psychological obstacles facing the elderly, coupled with the increasingly complex decision-making problems posed to them by the institutions of a participatory democracy, make it important to understand the processes underlying their preferences and choice behavior. A better understanding of the causal mechanisms behind decision deficits can promote the development of decision aides that can be offered in cases where their decision processes are most likely to be compromised.

Studying decision making developmentally is a recent phenomenon in a relatively young discipline: the origins of behavioral decision research go back only 50 years and the field has only reached critical mass over the last 20 years. Behavioral decision research, an interdisciplinary enterprise that involves psychologists, statisticians, and behavioral economists, developed as a way to examine decision and choice descriptively, using empirical observation to build theories that model not just the outcomes of decisions, but often also related process variables (e.g., response times, confidence levels). The neuroscience of decision making is of even more recent origin, but has grown quite rapidly over the last 5 years or so, proportional to researchers' access to brain imaging technologies such as fMRI and related methodologies.

Many of the contributions that a neuroscience approach can bring to a multidisciplinary investigation of human decision processes, and strategic and market behavior have already been spelled out (Camerer, 2003; Glimcher, 2003; Glimcher & Rustichini, 2004). For the purposes of this discussion paper, it is worth pointing to the following three: (i) The neuroscience perspective has revived an interest in learning (rather than just asymptotic, steady-state performance) and, as a result, in mental representation. (ii) Because of its dependent measures (e.g., time series of activation levels of different brain regions in imaging studies), it focuses attention more than other disciplinary approaches on the actual (rather than "as-if") processes underlying a specific task. It is this feature that allows neuroscience data to distinguish between theories or models that are isomorphic at the outcome level, but pose different constructs as intervening variables (e.g., expected utility vs. risk—return decompositions of risky choice). (iii) Brain localization and neural representation appear to legitimize in the eyes of positivistic social scientists hypothetical constructs that do not correspond to any observable behavior (e.g., level of "trust" or "perceived risk").

Making best use of the promising range of neuroscience methodologies and technologies to better understand human decision processes (including life-cycle changes in decision processes) requires sophisticated theory development and careful empirical work. The result that activation levels of one or more brain regions differ as the result of some task variable or individual difference variable typically have a huge number of possible alternative interpretations, ranging

from the theoretically interesting to the trivial, which need to be unpacked. Given the large amounts of data collected, there also are serious problems with data mining and the reporting and interpreting of chance results. These problems argue that research hypotheses and study designs ought to be based on existing and tested theory about the cognitive and affective processes that are being studied. While behavioral economists may, on average, be more interested in the phenomena under study in the area of neuroeconomics, it is experimental psychology that has had a longstanding interest and expertise in decision processes and the mental representations on which these processes operate. It would be unfortunate if the perhaps too narrowly-conceived label neuroeconomics led the emerging field to ignore a large existing body of knowledge about human learning, memory, categorization, and motivational processes that psychology has provided. This is doubly true as we become interested in developmental changes in decision processes and decision quality, from those of children and teenagers to young and middle-aged adults and the elderly. Here well-established results from developmental psychology should be used to guide the theory-building and testing of decision researchers. This will require an active attempt to counteract the tendency to draw only from research within one's discipline, be it behavioral economics or computer science.

### **What do we know about changes in preference and choice over the life-span?**

It has only been in the past several years that research has begun to explore the effects of aging on decision-making and preferences, with reviews as late as 2000 revealing a surprising lack of research on the topic (Peters et al., 2000; Yates et al., 1999). The greatest progress has been made in the domain of discounting and intertemporal choice (Read et al., 2004; Sozou et al., 2003; Trostel et al., 2001), with some additional work exploring the effects of aging on risk preferences (Deakin et al., 2004), susceptibility to gain-versus-loss frames in risky choice (Mayhorn, Fisk, & Whittle, 2002; Ronnlund, Karlsson, Lagnas, Larsson, & Lindstrom, 2005), and the sensitivity of preferences to the number of alternatives available in choice sets (Kim & Hasher, 2005; Tentori, Osherson, Hasher, & May, 2001). Even this research, though, has left important questions unanswered by focusing on the effects of aging on the outcomes of decisions, rather than on the processes by which the observed changes in choice are mediated. As a result, it is unclear what kinds of interventions might help older adults improve their decision-making, nor is it easy to predict what other decisions or choices might be different for older than younger adults.

People's preferences change as they get older. For instance, older adults require more to delay the consumption of a good than do younger adults (Read & Read, 2004; Trostel & Taylor, 2001), are more averse to risk than are younger adults (Deakin, Aitken, Robbins, & Sahakian, 2004), and are more likely to prefer delegating decisions to other agents than are younger adults (Curley, Eraker, & Yates, 1984). Some of these changes are arguably quite functional and adaptive (Read et al., 2004; Sozou & Seymour, 2003; Trostel et al., 2001); others, however, may lead to decision-making patterns that leave the elderly open to suboptimal or dangerous outcomes (e.g., the preference to defer decisions to "experts", which may make older people more susceptible to frauds – Yates & Patalano, 1999). Indeed, one of the lessons that has emerged from the literature on everyday problem-solving and decision-making is that, while there are some domains in which decision-making quality remains stable or even increases over the lifespan (for instance, in the realm of social decision-making – Thornton & Dumke, 2005),

the quality of people's decisions generally do decline as people move from early to late adulthood (see Thornton et al, 2005, for a recent meta-analytic review).

### **What can a multi-level neurobehavioral decision science approach contribute?**

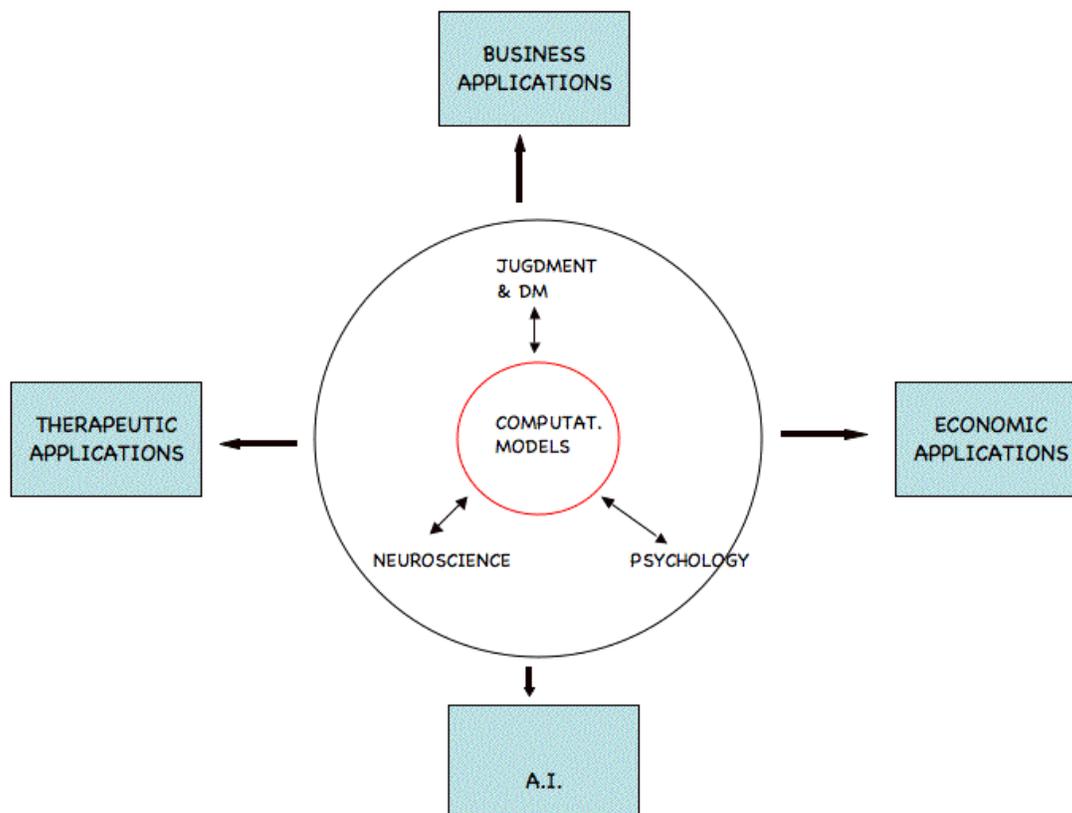
Because I am most familiar with it, I will use the “preferences as memory” research program in my own lab as an illustration of what a fruitful, integrative, multi-level, and cross-disciplinary investigation of human decision making across the lifespan might look like. The preferences-as-memory paradigm (Weber & Johnson, 2005) makes use of what is known about memory processes and the structure of memory representation to understand the effects of choice tasks, situations, and individual difference variables (including age) on decisions and preferences. Rather than conceive of decisions as the optimization of outcomes as they are evaluated along some well-defined utility function, we see them as a product of the same memory retrieval processes that underlie performance in many other non-decision-making domains. Ongoing research shows that the same, simple theoretical framework can account for a broad range of observed phenomena in the behavioral decision-making literature that have important real-world implications: loss aversion, or the tendency for people to put a higher value on an object they possess than on an object with which they are not already endowed (Kahneman, Knetsch, & Thaler, 1990); asymmetric intertemporal discounting, or the tendency for people to discount the future more when they are asked to delay consumption than when they are asked to accelerate it (Loewenstein, 1988); default effects, or the tendency for people to prefer an option more when it is the assumed or default choice than when it is not (Johnson et al., 2003); and anchoring, or the tendency for valuations to be influenced by the presence of arbitrary and irrelevant numerical values (Chapman & Johnson, 1999).

The fundamental assumption of the preferences-as-memory-framework is that preferences are constructed and that decision-makers construct their preferences by (implicitly) querying their memory for information about aspects of the decision or choice. The choice task or context is assumed to influence the types of queries and the order in which they are posed, which in turn affects available evidence and thus preference. Two retrieval phenomena are particularly relevant to the PAM model are (a) the dynamic effects of initial queries on the probability of successfully retrieving other subsequent information from memory and (b) the structure of mental representations on the effective retrieval of information from those representations. Since there are documented age effects on memory interference and task switching processes (Hedden & Park, 2001; Spieler, Balota, & Faust, 1996) and since there are known changes in the hierarchical structure of mental representation as the result of expertise (which is often correlated with age), we are currently starting to test the predictions that our preferences-as-memory framework makes for the interactions between decision task and the age as well as expertise of the decision maker on decision processes and outcomes. Given that many of the processes hypothesized to underlie performance in these tasks have known brain localizations, fMRI investigations with both younger and older adults should be able to provide additional evidence about the neuropsychological plausibility of our framework.

## Antonio Rangel, Stanford University

### Research Directions in Neuroeconomics and Aging

**I. A Brief Summary of Neuroeconomics.** The following figure provides an overview of the field of neuroeconomics.



At the core of the field are computational models of how the brain makes different types of decisions. These models combine tools from computational neuroscience, economics, and mathematical psychology. Surrounding this core are experimental methods in behavioral and cognitive neuroscience, cognitive and social psychology, and economics. These experiments provide vehicles for testing the computational models and for generating data that inform and motivate the development of better models.

Surrounding the core there are several types of applications: (1) economics (e.g., savings, labors supply, and health behaviors), (2) tools and therapies designed to improve the quality of decision-making (DM) of normal individuals, (3) health (e.g., developing diagnosis and treatment tools for diseases such as addiction, risky behaviors, or compulsive shopping), (4) business applications (e.g., neuromarketing), and (5) artificial intelligence.

**II. Neuroeconomics & the NIA.** It is well understood that the well-being of the elderly is greatly affected by their ability to make good decisions, not only in old age, but throughout the life-cycle. Early decisions are critical since they affect asset accumulation, which determine

wealth in retirement, and health and social behaviors, which affect morbidity and well-being later in life. With longer life spans the importance of quality DM in retirement has also increased.

Unfortunately, a growing body of evidence shows that the quality of DM in much of the population is far from ideal. This gives rise to a question that, in my view, is the key reason why the NIA should care about Neuroeconomics: **How do we help individuals make better decisions at all stages in life while maintaining the individual freedoms that our society holds dear?**

There are two non-exclusive approaches to this question. The first one is to attack directly the issue of how to improve DM, most likely through an educated process of trial and error. The second approach is to develop a deep understanding of how the brain makes decisions, and then to use this knowledge to “engineer” DM aids. I urge the NIA to take the second approach. The payoffs will be delayed a bit, but conceivable applications justify the cost. Consider a couple of examples:

- We will be able to use a combination of carefully designed psychological tasks and brain imaging techniques to diagnose early on in life shortcomings in brain structures/processes that play a crucial role in good DM later in life. This early diagnosis will be used to develop individually tailored behavioral therapies to address these problems.
- In the not too far future we will be able to have real time measures of the state of physiological and brain processes. These measurements, combined with carefully designed A.I. will aid DM by reminding individuals of potential mistakes that they might be about to make. Ex: “You might want to postpone that decision, your cortisol levels and amygdala activity suggest that you are not weighting your choices properly”

The development of such technologies is not feasible with our current understanding of how the brain makes decisions. For this reason, the priority on the short-run is to invest in the development of the basic science of neuroeconomics.

I conclude with some thoughts about some research directions that might be especially valuable in accomplishing this goal:

*Computational neuroscience models of DM.* Computational models of how the brain solves different types of decision problems are the core of the field. They provide a common language for neuroscience, psychology, and economics; they give a framework for comparing experimental findings and designing new tests; and they are a starting point for the type of applications described above. Unfortunately, the early days of neuroeconomics have not seen enough of this type of work.

*Decision-making in very simple situations.* One of the most challenging aspects of neuroeconomics is that the brain probably addresses seemingly similar decision problems in different ways. Consider, the difference between actually making a choice or “going on

automatic”, or the impact of “framing” on behavior. It is also likely that more complex decision tasks recruit more basic processes. This suggest that it might be useful to build the field from the ground up, starting with very simple decision tasks before moving on to savings, investing, etc.

*Measurement of non-behavioral variables.* Non-behavioral variables, such as different emotional states, play a crucial role in computational models of DM. We need to improve our ability to develop reliable operational measures of these variables. Our ability to measure them is critical to the applications listed above.

*DM diagnostic tests.* Can we use diagnostic tests (behavioral, psychophysiological, brain imaging, genetic ... ) to predict people’s decision making tendencies?

**Brian Knutson, Stanford University  
&  
George Loewenstein, Carnegie Mellon University**

**Aging and the Interplay of Emotion and Deliberation in Risk-Taking and Self-Control: Promising Avenues for Aging Research**

We suggest two promising avenues for research on decision-making and aging, one focusing on risk-taking and the other on self-control. Although these are typically treated as distinct topics when it comes to research and theorizing, we believe they share important commonalities.

First, and most significantly, decision making in both domains involves a tension between emotional impulses and reflective considerations -- deliberation. In the case of risk-taking, people often experience emotional reactions to risks, both positive and negative, and these emotional reactions often drive them to behave in ways that conflict with more reflective deliberations about costs and benefits and associated probabilities. In the case of self-control, people often experience emotions that impel them to make impulsive decisions, but also often deliberate in a more even-handed fashion about immediate and delayed costs and benefits. In both domains emotion and deliberation sometimes complement one-another but at other times produce competing motivations.

Second, both domains of decision making present interesting paradoxes when it comes to patterns of decision making with age. For risk, the paradox is that, although a prevalent stereotype views older people as highly risk-averse, there is evidence that older Americans are gambling at high rates and may be especially vulnerable to scams. When it comes to self-control the paradox is that the reflective capacity that has been viewed as playing a critical role in self-control seems to be diminished in older adults, perhaps as a result of diminished prefrontal cortical function, yet aside from those suffering from dementia, there is little evidence of extreme impulsivity in the elderly. Older people often seem less concerned about how other people perceive them (when it comes to what they say and personal hygiene), yet overall, the elderly do not necessarily show greater impulsivity than younger adults.

Below, we discuss these issues in greater detail and argue that integrated methods from behavioral and neuroscience can help to address both paradoxes and to more generally shed light on the interplay between emotion and deliberation and its changes with age.

**Emotion, aging and decision making**

To understand the role of emotion in decision making, it is useful to draw a distinction between two types of emotions: immediate (or anticipatory) emotions and expected emotions.

Immediate emotions are experienced at the time of decision making, and often impel behavior in specific directions with minimal reflection. In the domain of risk, negative aroused emotions like fear may promote risk-aversion when they are experienced at the moment of decision making, whereas positive aroused emotions like excitement may promote risk-taking. When it comes to self-control, immediate emotions, such as anger, as well as drive states such as hunger, typically

impel short-sighted, impulsive behavior, although some other types of emotions, such as fear, can sometimes have the opposite effect.

Expected emotions are emotions that people expect to experience as a result of the outcomes of the decisions they make. When people deliberate about the consequences of decisions they face, they are typically thinking about the expected emotional consequences of those decisions. Thus, as Isen and colleagues have found, people who are in a good mood sometimes avoid risks because they don't want to spoil their mood, and people who are in a negative mood sometimes take risks in an effort to shake themselves free of the negative affect. Note that both of these effects are opposite of the effects of immediate emotions on risk-taking. When it comes to self-control, a similar pattern can be seen. Whereas immediate positive emotions often induce people to behave in an impulsive fashion, people also sometimes delay gratification in the prospect of experiencing positive emotions in the future.

Studies of ongoing emotion in older adults presents a rather complex, and still paint a quite preliminary picture. Existing research suggest that low arousal positive emotions increase with age, whereas both low and high arousal negative emotions tend to decrease (e.g., Carstensen and colleagues). However, other research points to a decline in high arousal positive emotions across the lifespan, which may be associated with decreased dopamine activity (e.g., Volkow and colleagues), suggesting that even if older people may experience more positive emotions on average, they tend to be of a low arousal variety. These findings – especially those relating to high arousal emotions – are, however, still quite tentative. More research could productively examine how positive and negative emotions change with age, drawing a distinction between high arousal and low arousal emotions that occur during and after decision-making. These findings raise the question of how changes in emotions related to aging influence risk-taking and self-control across the lifespan.

### **Risk-taking**

Turning first to risk-taking, on one hand, one might expect that high arousal immediate emotions (e.g., excitement) would have the greatest influence on risk-seeking. To the degree that these emotions decline, therefore, one might anticipate a decline in risk-taking. However, another effect is also possible. If older people experience fewer high arousal positive emotions, and they miss experiencing these emotions, then it is possible that they might take greater risks in order to feel the emotions that they miss. Perhaps this is what is going on with the apparent increase in gambling, which is an ideal source of excitement for people with frail bodies.

When it comes to negative emotions, to the degree that older people do in fact experience fewer high arousal negative emotions, given the role that negative emotions are thought to play in risk-aversion, we might expect a decline in risk aversion. Indeed, this may be what is responsible for older persons' vulnerability to scams. Perhaps the decrement in high arousal negative emotions robs older people of emotional clues that promote vigilance.

Other questions concerning risk, emotions and aging that we think it would be productive to pursue include:

- Does risk-taking in general change or do domain-specific types of risk-taking change over the lifespan? What is the relationship between general and domain-specific risk preferences? Do individual differences in risk-taking become more or less pronounced with age?
- How do factors that affect the relative influence of emotional and reflective processes influence impact of emotion on risk-taking? How does this change with aging?
- What is the relationship between physiological changes in brain function and observed changes in emotional experience and risk-taking?
- Do laboratory assessments of risk-taking predict real-world behavior?

### **Self-control**

Although older adults have less reflective capacity, they also seem to experience less high arousal emotion, as discussed above. For instance, loss of self-control in the case of road rage often occurs when emotions are aroused too rapidly for self-control strategies to take effect. If diminution of highly aroused emotions occurs more rapidly than diminution of reflection, this could potentially explain why older people do not show greater impulsiveness. Because positive aroused emotion has been associated with subcortical activation in regions such as the ventral striatum (cf. Knutson et al., 2005), while reflective capacity has been associated with cortical activation in prefrontal regions (cf. McClure et al., 2004), modern neuroscience techniques such as fMRI could be used to deconstruct neural activation during intertemporal choice in order to understand which components might be related to changes in delay of gratification across the lifespan.

These considerations raise a number of questions:

- To what extent do aroused emotions and motivations, especially those associated with impulsive behavior (e.g., anger, hunger), decline with age?
- To what extent does reflective capacity decline with age?
- How does intertemporal choice change across the lifespan, and does it do so in a general or domain-specific manner? Do individual differences become more pronounced with aging?
- Can neural indices of emotional and reflective capacity be used to predict intertemporal choices? Are there parallel changes in neural function and tradeoffs across the lifespan?
- Do laboratory assessments of intertemporal choice predict real-world behavior?

Long-standing theoretical perspectives in psychology, and a plethora of new work in behavioral economics, mutually reinforces the idea that human decision making, and more broadly behavior, reflects the interplay of emotion and deliberation. Yet scientists still know very little about how emotion and deliberation change with age, let alone about any changes in the nature of the interplay between them. Due to improved nutrition and health care, more Americans are

living longer than ever before. These aged citizens must make increasingly complex decisions about retirement, finances, medication, and health care, and these decisions will inevitably call forth a combination of emotion and deliberation. A better understanding of the interplay between emotion and deliberation in decision making and of the effects of aging on the interplay between these processes might eventually help both younger and older adults make better decisions about how to allocate resources over the lifespan.

## David Laibson, Harvard University

### Research Priorities in the Neuroscience of Decision-making

#### Major questions:

**Childhood Development:** Different brain systems develop at different rates during childhood and young adulthood. Specifically, limbic and para-limbic systems evolve much more quickly than many cortical systems. What consequences does this have for the development of decision-making skills? Can we measure cortical development with paper and pencil tasks and/or neuroimaging methods? What does this research have to say about the sophistication and validity of decision-making among young adults? Are there biological markers for “complete” cortical development?

**Individual differences:** Different people have different cognitive styles and cognitive abilities. What are these key cognitive personality differences? What personality variables and personality scales robustly predict cross-domain variation in behavior? Can we improve our measurement of these cognitive differences using neuroimaging methods or molecular genetics methods?

**Cognitive recruitment:** Different tasks recruit different brain systems. We know very little about such recruitment for lifecycle decision-making tasks. What brain systems do people use when they make asset allocation decisions, savings decisions, health care decisions, and other lifecycle choices?

**Cognitive development in older adults:** Cognitive ability changes as people age. Some skills improve — e.g., experience-based knowledge and wisdom — and some skills decline as people age. Can we study the sources of these age-based trends using neuroimaging methods? Are these changes in brain systems associated with changes in behavior and decision-making?

**Markers for dementia:** What are the fMRI markers for different types of dementia? Would it be possible to improve our diagnostic toolbox for dementia by including neuroimaging data? Can we also use this neuroimaging data to explain behavioral changes for patients with early-stage dementia? Can we better understand dementia itself by integrating behavioral data and neuroimaging data in the study of dementia?

**Database development:** Many surveys are starting to include biological measures in current and future waves. Some integrative work should be done to determine best practices. For example, what tasks should be observed in fMRI (discounting, risk aversion, loss aversion, ambiguity aversion, spatial reasoning, etc...)? What cognitive genes should be genotyped? What cognitive tasks should be used to measure cognitive ability and ongoing cognitive function among older adults? What personality scales should be implemented?

## **Kevin A. McCabe, George Mason University**

Economists have long been aware of the effects of a person's life cycle on their economic behavior. This life cycle hypothesis is thought to affect behavior by acting as a change in the goals and resource constraints of the participant. An example is the life cycle savings model that accounts for the different resource needs and planning concerns of an aging person. However, economists assume that people can solve this temporal planning problem efficiently. This leads to conclusions like, people should be able to plan for and take care of their own retirement. This assumption takes on more meaning as the population in the United States and other developed countries continues to age.

However, research in cognitive neuroscience challenges this assumption. First, goal directed behavior seems to be more influenced by immediate opportunity costs and not so much by future opportunity costs. Second, cognition does seem to change over time using both behavioral and neuronal measures with continued improvement in neural connections at an early age, and later decline in both the number of neurons and the number of neural connections as they get older. Goal directed behavior is modeled in terms of the actor-critic model with the actor implemented by dorsal striatum and prefrontal ensembles of neurons and the critic implemented by neuronal ensembles in the ventral striatum. One important question is how the relative strength of these two roles changes in the aging brain. Another important question is how the external environment serves to compensate for the changes in actor-critic computations in the aging brain.

Another interesting set of question comes from the fact that humans are one of the few species to have developed a three generational system involving the direct participation of grandparents in wealth production. As is often the case for other evolutionary pressures we might expect there to be an accounting for this adaptation in the human brain. In particular what constitutes the grandfather or grandmother brain, and what changes in computation or morphology take place to accommodate these roles? One speculative, but very interesting research question is whether or not the grandparent brain is designed to take on more of an advisory and less of an action oriented role in the social unit. Another interesting research question is whether or not the grandparent brain is designed to become less receptive to the forming of new social relationships but instead maintaining the ones it has.

## Colin Camerer, Caltech

### NIA Neuroeconomics Conference Call Thoughts

From Lis Nielsen statement: “We are particularly interested in areas of research that address multi-level interactions among psychological, physiological, social and economic factors that influence how older adults negotiate important life decisions related to retirement, Medicare, and healthcare management.”

Background: I am a “behavioral economist” who is interested in bringing psychological ideas into economics in a disciplined way. We use experimental economics to carefully separate alternative explanations and establish regularity. More recently in neuroeconomics the types of data are from fMRI, lesion behavior, eyetracking and pupil dilation (more psych than neuro), and animals, and the explanations are at the level of neural circuitry. Disclaimer: I know very little about the empirical evidence on Medicare, retirement etc. So ideas below are very speculative, and many of them relate to ongoing work by others whose ideas you have solicited.

#### Wisdom and metacognition

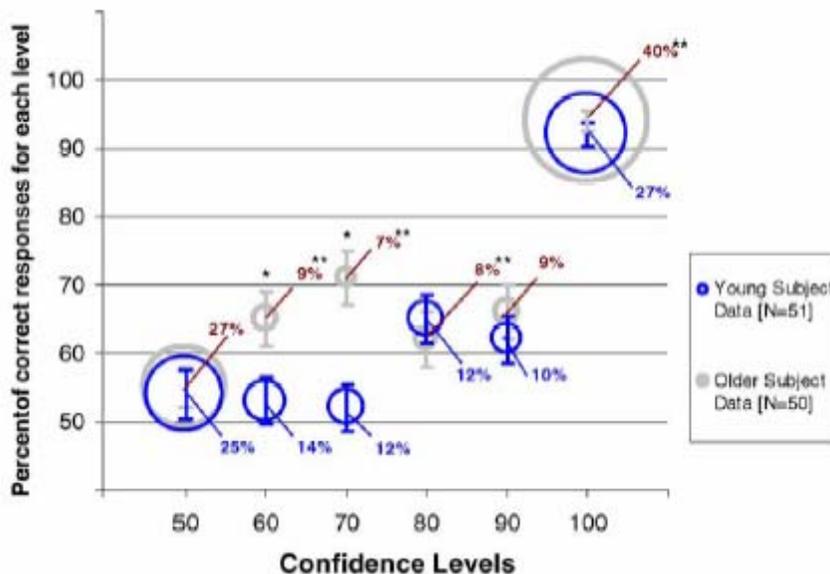
Judgment has two parts which are conceptually different: What you know, and what you know about how much you know (meta-cognition). For example, a person may be an expert on fine wines but thinks, incorrectly, that she knows very little. Or a stock market investor may know very little compared to experts, but think overconfidently that she knows a lot.

Metacognition is important in an economic system because it drives how much information people seek. An important component of metacognition is “overconfidence”—when people think they know more than they do (or perhaps, when they think they know more than others do). And metacognition concerns not only knowledge, but also physical capacity, likely longevity, and other components of aging.

Metacognition about knowledge can be measured by asking people to guess the answer to a question, and then to state their confidence that they are right. You then compare the stated confidence level to the actual percentage of times people are correct (averaging across all the questions with identical stated confidence). Figure 1 below shows one such study (Kovalchik et al, JEcBehavOrg 2004). The blue circles are data from young (20 yrs) student subjects; the grey circles are data from older subjects (average age 80) who are high-functioning spouses of Alzheimer’s and Parkinson’s patients.

If people have “well-calibrated” metacognition, then the circles should lie on a 45-degree line. For example, out of all the items in which people state they are 80% confident (on the x-axis), they should be right about 4 out of 5 times (the y-axis) But the students (blue circles) are generally *overconfident*: Their stated confidence is generally higher than their accuracy. Furthermore, the older subjects are generally less overconfident than the students—indeed, except for 80-90% confidence, their confidence and accuracy are very closely matched.

The size of the circles in the Figure also represents the number of confidence ratings in each category, from 50 to 100%. The older subjects also are more likely to give 100% sure ratings (40% versus 27%) than students are.



This simple experiment suggests that older people might generally know more (not surprisingly) *and* they know more about what they know. This result could be replicated and linked to behavior like searching for financial and health advice. There is also some evidence that men are more overconfident than women (e.g., men trade more aggressively in stocks). It may be that aging men are less likely to seek advice, and hence make more poor decisions, than women do.

### Trust, gullibility and aging

Trust is the willingness to put yourself in a vulnerable position for the joint benefit of yourself and another person, essentially betting that another person will feel morally obliged to repay your trust. Economists have created a simple game to measure trust and trustworthiness. In this game, one player can invest up to \$10, and the amount invested triples in size. A “trustee” then decides how much to repay. In the basic version of the game, the players are strangers who only play once and cannot communicate or make a binding agreement. In experiments with students, people typically invest about \$5 out of \$10 on average, and receive back about \$5 of the \$15 that is created by tripling the investment. But there is wide variation in behavior.

One concern often expressed about economics and aging is the possibility that older people become more gullible and trust the wrong people. Tools like this trust game could be used to calibrate whether young and old populations trust correctly. It is conceivable, for example, that there is a bifurcation as people age (related to gradual decay in social judgment), in which some become too trusting, and others become too paranoid and untrusting.

## The “emotional immune system” and post-retirement consumption

A topic psychologists have studied a lot is “projection bias” (Loewenstein, O’Donoghue, Rabin, QJE 2001) or “affective forecasting”. Dan Gilbert and others argue that people actually have a resilient “emotional immune system” which protects them from plunging into unhappiness, and that people underestimate the power of this system. For example, professors who say they would be crushed if they don’t get tenure, interviewed afterwards (upon being denied tenure), say that life isn’t so bad.

Affective forecasting raises some interesting questions about aging. If people become wiser as they age (improved metacognition, as above), perhaps they also become wiser about their emotional control and reactions, and learn to forecast their affective reactions more accurately. For example, anecdotal evidence suggests women in their 20’s and 30’s imagine that life will be much less pleasant when they turn, say 50. But older women often report being very happy. Despite changes in health and appearance, these women seem to find compensation in other activities and sources of pleasure—and these compensations surprise them (in the sense that they would not have anticipated being so happy in their 50s).

Empirically, it is typically observed in the US that people do not save enough for retirement, in the sense that consumption drops steeply upon retirement. (Under the ideal “life-cycle” model people who prefer to have a steady amount of consumption every year would save enough that no such drop would take place when they retire; so the drop is surprising to standard theory and of interest to behavioral economists.) Our presumption in behavioral economics has been that the drop in consumption is bad because people like having a steady amount of consumption, and they are unpleasantly surprised when they can no longer afford their pre-retirement lifestyle. But the emotional immune system may protect them. Indeed, an opposite problem to the typical pattern in the data is the cheapskate who saves “too much” and retires with a large nest egg. Rational spending dictates that these people should start to “dissave” out of this nest egg to maintain a pleasant lifestyle comparable to their earlier lifestyle, but they often have a hard time doing so.

## Andrew W. Lo, MIT Sloan School of Management

### New Research Directions in Neuroeconomics and Decisionmaking

One of the most controversial issues at the intersection of psychology and economics is the modeling of human risk perception and risk processing. Although much of the debate has centered in academic circles, these issues have far-reaching social consequences for the general population. In the wake of the bursting of the technology bubble in the U.S. stock market, the retirement funds of many households have been hit hard, and the typical reaction has been to withdraw assets from the stock market and switch them to safer investments. Unfortunately, this all-too-common behavior of ‘selling at the low’ and ‘buying at the high’ may have dire implications for the retirement wealth of a significant portion of the US population. Moreover, the current trend of employers shifting the responsibility of investment decisions onto employees through defined-contribution and 401(k) pension plans, and the recent proposal to privatize Social Security, only underscores the importance of a deeper understanding of the connection between brain, mind and behavior in the context of financial risk perception and risk preferences.

The standard economic paradigm assumes that individuals are highly rational, making decisions based on mathematical probabilities weighted by the ‘utility’ of outcomes, where utility functions are assumed to satisfy certain mathematical properties. In the specific context of financial markets, such a paradigm has led to the well-known ‘Efficient Markets Hypothesis’ in which the collective behavior of rational agents yields securities prices that ‘fully reflect all available information’ and are statistically unforecastable. Unable to curtail their greed, a host of investors aggressively pounce on even the smallest informational advantages at their disposal, and in doing so, they incorporate their information into market prices and quickly eliminate the profit opportunities that gave rise to their actions. If this occurs instantaneously, which it must in an idealized world of ‘frictionless’ markets and costless trading, then prices must always fully reflect all available information and no profits can be garnered from information-based trading (because such profits have already been captured).

However, psychologists and experimental economists have documented a number of contradictory behavioral biases that seem to characterize human decision-making under uncertainty, many of which lead to undesirable outcomes for an individual’s economic welfare, e.g., overconfidence, overreaction, loss aversion, herding, psychological accounting, miscalibration of probabilities, and regret. These critics of the Efficient Markets Hypothesis argue that investors are often-if not always-irrational, exhibiting predictable and financially ruinous behavior. The sources of these irrationalities are often attributed to psychological factors fear, greed, and other emotional responses to price fluctuations and dramatic changes in an investor’s wealth. But recent research in the cognitive sciences and financial economics suggest an important link between rationality in decision-making and emotion. Contrary to the common belief that emotions have no place in rational financial decision-making processes, there is now preliminary evidence that physiological variables associated with the autonomic nervous system—indicators of emotional responses—are highly significant for even the most experienced professional securities traders during the course of their trading activities.

This emerging literature—now known as *neuroeconomics*—has created several areas for fruitful collaboration between economists and neuroscientists, especially in the naturally

interdisciplinary set of issues surrounding financial decisionmaking. In particular, there are at least four new research directions that the National Institute on Aging might consider in evaluating its mission to investigate ‘multi-level interactions among psychological, physiological, social and economic factors that influence how older adults negotiate important life decisions related to retirement, Medicare, and healthcare management’:

**1. Asset Allocation Behavior in Theory and Practice.** The economics and finance literature is replete with theoretical models of optimal asset allocation. However, these models are often at odds with reality, as many behavioral economists have observed. But few behavioral studies have attempted to model the ultimate sources of such behavior. A potentially promising alternative is to construct a more realistic representation of individual risk preferences using recently developed models of the brain and cognition, and then calibrating such representations to the data to yield more accurate implications for retirement plans and aggregate savings behavior. For example, McLean’s *triune model* of the brain implies that emotional stimulus can sometimes supersede deliberations by the neocortex, which has specific implications for financial decisionmaking. In particular, this framework implies important asymmetries in the individual’s response to losses versus gains, above and beyond those captured by extant theories such as loss aversion and prospect theory. Moreover, the implications for aggregate savings behavior and the viability of public and private pension plans over various market cycles have yet to be explored in the literature.

**2. Integrated Survey Study of Savings Behavior.** Although many studies of savings behavior in individual retirement accounts have been published, few have systematically incorporated non-economic characteristics of the individual in modeling such behavior. Two sets of characteristics are especially relevant: psychological profiles that capture personality attributes as well as emotional state, and an individual’s medical history and health status. There is growing evidence that risk preferences are not stable over time or circumstances, but are highly context-dependent and influenced by a number of factors including personality, affect, and financial and medical history. A broad longitudinal study of participants in major pension plans that includes these characteristics would yield significant insights into the interactions between economic, psychological, and physiological conditions for retirement savings behavior. Potential participants in such an initiative include institutions such as TIAA-CREF, Charles Schwab, Fidelity, Merrill Lynch, and Blue Cross/Blue Shield.

**3. Psychophysiology of Financial Risk Processing.** Recent research suggests that professional securities traders exhibit distinct psychophysiological profiles from control subjects in short-term financial decisionmaking contexts. These differences suggest the possibility of identifying specific physiological characteristics that are beneficial and counterproductive for rational responses to financial risks. A more detailed study, including a broader cross-section of individuals—both professional investors as well as control subjects—and augmented by additional psychological survey instruments, may shed further light on how individuals process financial risks from a deeper, neurophysiological perspective. Using recently developed wireless physiological sensors, it is possible to conduct these studies *in vivo* as well as in the laboratory, which increases the likelihood of obtaining practically relevant findings that can be verified by more expensive methods such as fMRI studies. Moreover, there is a significant possibility of developing self-assessment protocols and therapies through psychophysiological experiments. In much the same way that biofeedback is now used by patients suffering from chronic pain,

hypertension, and asthma, psychophysiological measurements can help individuals identify and modify their mental state to suit specific financial decisionmaking contexts.

**4. Geriatric Financial Risk Processing.** One of the most significant issues facing retirees today is the overwhelming number of investment alternatives to which they can allocate their wealth. These decisions become even more challenging as an individual ages, yet there has been little or no attention paid to the savings behavior of elderly retirees. A combination of legal, economic, social, and medical issues make this topic extremely sensitive. For example, the onset of dementia and senility is often diagnosed only with a lag, thereby creating a significant window of ‘mis-opportunity’ for individuals to damage their financial wealth through inappropriate investment choices, thanks in part to certain unscrupulous financial advisors and brokers. However, the most obvious alternative—delegating investment decisions to the next generation or other family members—creates legal liabilities and ethical dilemmas that are not easily resolvable. A focused study on geriatric financial decisionmaking may yield a number of insights, including the impact of age and age-related cognitive impairments on risk processing abilities, the prevalence of geriatric biases in investment choices, and the potential pitfalls that current retirement plan pose for the elderly.