Decision Making and Aging

Bethesda, Maryland
August 16–17, 2006

WORK GROUP MEETING SUMMARY

National Institute on Aging
Behavioral and Social Research Program

For Administrative Use
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List of Acronyms

AI	anterior insula
BIAS	Behavioral Investment Allocation Strategy
BSR	Behavioral and Social Research
DD	delay discounting
DMC	decision-making competence
EV	expected value
fMRI	functional magnetic resonance imaging
GT	gambling task
NAcc	nucleus accumbens
NIA	National Institute on Aging
NIH	National Institutes of Health
PAM	Preference as Memory
PD	probability discounting
QT	Query Theory
SCR	skin conductance response
SMH	somatic marker hypothesis
WAIS	Wechsler Adult Intelligence Scale
WM	working memory

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Executive Summary

Older adults face challenging economic decisions, including those about retirement, pension savings, health care and pharmaceuticals, and end-of-life care, at a time when their cognitive abilities are perceived to be declining. Yet, some older adults continue to make good decisions, suggesting that mechanisms other than cognition play a role in decision making. An understanding of the factors that influence decision making among older adults will become especially useful as more baby boomers reach retirement age, particularly in the design of interventions that can aid those less able to make decisions.

Since 2004, the National Institute on Aging (NIA) Behavioral and Social Research Program has undertaken a research agenda to explore these factors, including a series of meetings, some held in collaboration with the National Academy of Sciences, to assess the state of the science in judgment and decision-making research and to generate ideas for future research. These meetings have brought together psychologists and economists and have led to the recent release of a request for applications focused on neuroeconomics and aging. On August 16–17, 2006, the NIA Behavioral and Social Research Program held a work group meeting on decision making and aging. This work group, chaired by Dr. Jeff Elias, included researchers from similar fields but different approaches and focused more on the cognitive aspects of decision making and aging.

The agenda was structured to allow work group participants to present their research. Invited perspectives began with exploration of the intersections between decision maker and decision-making context, including task and environment, and concluded with a provocative proposal to study the effects of aging on all components of a decision-making construct, as opposed to studying one component in an experimental vacuum. Other work group participants presented theories to address intertemporal choice, endowment effects, and loss aversion; the motivation of older adults in their decision making; and the use of heuristics in decision making. Some presenters focused on cognitive functions such as working memory and numeracy, as well as imaging studies that suggest ways to predict financial choices. The most prominent themes that emerged during the discussions that followed each presentation were:

- ***Study populations and methods***. Populations can be drawn from health plans, such as those of Kaiser Permanente, and from nontraditional sources such as the American Association of Retired People and the U.S. Federal Bureau of Investigation's lists of scam victims. Several work group participants had used online survey methods, which can prove useful in future studies assessing cognitive function. Imaging studies also will prove useful in decomposing the components of good decision making.
- ***The need for longitudinal studies***. Populations gathered from health plans can be followed longitudinally to tease out possible cohort effects.

- ***The role of knowledge***. Several studies have shown that knowledge or expertise can compensate for cognitive decline, but the role of knowledge has not been fully explored, and some studies have not considered or controlled for knowledge.

Invited perspectives were followed by discussions in which meeting participants generated ideas for future research. The NIA is eager to support areas of practical importance in which innovative approaches can push basic science forward. Work group participants were encouraged to begin thinking about possible applications.

Ideas for Future Research

- ***Identifying the need and extent of the problem***. It is not clear whether older adults who make poor decisions tend to make poor decisions overall or only in specific contexts or domains. It is possible that older adults do not make poor decisions but have some difficulty or take more time in their decision making. Some data have been published on older individuals' inability to comprehend critical components of a decision-making process, and other studies have shown that older people are more susceptible to scams.
- ***Defining a good decision***. Establishing a set of standards to define a good decision is key. These definitions might be implicit, but they are not necessarily obvious. Standards might include some measure of consistency, rationality, outcomes, and satisfaction or regret. Each criterion for good decision-making may have a broad range of characteristics. In addition, objective and normative criteria for good decision making should be distinguished from subjective and descriptive criteria.
- ***Developing interventions to prevent suboptimal choices***. While efforts are under way to define criteria for good decisions, interventions should be designed to prevent poor ones, such as participation in a scam. Susceptibility to scams is poorly understood. A program project that accesses existing lists of scam victims and tests potential interventions among these populations was suggested. Other suggestions included designing standard labels (like food labels with nutrition information) to facilitate comparisons among health care plans or mutual funds.
- ***Exploring intersections between decision maker, task, and context***. Future research should continue to explore the characteristics of the individual, such as anxiety and familiarity, as well as the task and environmental variables that could improve decision making overall. Decisions by older adults often are influenced by the social networks to which they belong.
- ***Understanding age differences in decision making***. It is important to distinguish unique age effects affecting decision making. The cognitive processes and components involved in decisions concerning wills, family arrangements, savings, and consumption are measurable and should be examined.
- ***Using new technologies to aid measurement***. New technologies are making it increasingly possible and cost-effective to bring the laboratory to the field, such as Web-based methods or handheld mobile devices like personal digital assistants for data collection and simple cognitive testing and magnetic resonance imaging caps to measure brain activity. These technologies should be integrated with the development of interest in aging and decision making so that the multiple components of decision making can be measured concurrently.

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SUMMARY OF PROCEEDINGS

Introduction

The National Institute on Aging's (NIA) Behavioral and Social Research (BSR) Program has undertaken a research agenda to investigate factors that influence the way older adults make important life decisions, including those related to retirement and health care management. BSR efforts began with a meeting in July 2004, in which seven experts discussed lessons from the past, opportunities for research advances, and ways to realize research goals in decision making and aging. The workshop highlighted the importance of affect and motivation on judgments, probability perception, and decision making. Discussion surrounding perceptual biases underscored the need to consider behavioral elements and the potential contributions that behavioral scientists can make to improve the measurement of utility and cognitive functioning in large population surveys.

In November 2005, the NIA/BSR, in collaboration with the National Academy of Sciences, held a workshop on the decision-making needs of older adults. Participants at this workshop discussed the neural basis of decision making, the design of health decision aids, the role of affect and emotion in decision making, the effects of age and social context, and aging and decision-making competence (DMC). On the basis of this and the July 2004 workshop, economics became an important focus, and the NIA sought to build upon ongoing efforts at the intersection of economics and the neurosciences. NIA staff organized a series of teleconferences on neuroeconomics and aging that culminated in a 2-day exploratory meeting in spring 2006 that included researchers from the fields of social, cognitive, and personality psychology; cognitive and affective neuroscience; decision making; and health and retirement economics. Informed in part by discussions at this workshop, on July 31, 2006, the NIA released a Request for Applications for new exploratory and developmental research in neuroeconomics and aging with an application deadline of November 27, 2006. Other important areas of interest to the BSR include decisions in terms of lifestyle and risk, specific medical decisions, motivated decision making, and corporate or group decision making, as well as the irrational, noncognitive components of decision making, which are not addressed by cognitive psychology or economics.

On August 16–17, 2006, the BSR held a working group meeting on decision making and aging at the NIA offices in Bethesda, MD. The agenda for this meeting, which brought together researchers from similar fields but with different approaches, returned attention to the cognitive aspects of decision making (see appendix 1, agenda and appendix 2, list of participants). Before the meeting, participants were given suggested background readings to aid in their discussions (see appendices 3 and 4).

Dr. Jeff Elias began the meeting by briefly outlining BSR efforts in the area of decision making and aging and providing an overview of the meeting goals. Work group participants then presented their research agendas and discussed emerging themes and future research directions. NIA staff members plan to incorporate the ideas from the meeting into a program announcement focused on aging, cognitive intervention, and decision making.

Invited Perspectives

Measuring Decision-making Competence in Older Adulthood
Melissa L. Finucane, Ph.D., Kaiser Permanente Hawaii

Research on the DMC of older adults is motivated by theoretical, methodological, and practical concerns. Longer lifespans and the rapid aging of the world's population[1] demand a better understanding of older adults' ability to make god decisions. As people age, their opportunities to recover from or compensate for poor-quality decisions diminish. The impact of age-related changes is magnified further by recent social trends (e.g., emphasis on independence and geographical dispersion of families) that create a need for maintaining strong decision-making capabilities for longer periods. Even though decision-making competence (DMC) tends to be questioned more often as individuals age, very little research has directly examined older adults' decision skills. There are relatively few studies that document the decision making skills of older adults, provide criteria for competent decision making in older adulthood, or describe how individual, task, and context characteristics may act independently or interactively to influence DMC. One reason for the neglect is that we have few reliable and valid tools for performance-based DMC assessments, even though such tools are critical for modeling and assisting successful aging. Dr. Finucane and her colleagues are exploring ways to apply existing theories and methods from research in younger adults to assess and improve decision making among older adults. Research underway attempts to answer questions such as:

- Are real-world decision skills maintained in older adulthood?
- Are decision skills related to or independent of traditionally measured cognition?
- Are measures of DMC useful predictors of real-world functioning and adaptation in older adulthood?

Traditional methods for assessing DMC are imperfect Self-reported data can be unreliable. Clinical judgments also may be subject to individual clinician competence and are constrained by the performance-based evidence gathered over a short period of time. Family judgments of older adult competence also are subject to questionable reliability and validity, despite the longer exposure to behavior. Structural interview instruments generally tap into specific medical competencies, such as the ability to sign consent forms, and the reliability and validity of these instruments have not been examined thoroughly.

A sound theoretical framework for DMC should describe underlying processes, explain effective performance on decision-making tasks, and predict how decision making or task characteristics constrain the quality of a decision. Models developed thus far have not satisfied these criteria. Normative models postulate axioms that an individual must follow to make the most optimal choice, but people do not conform to these axioms and these models do not describe the processes that people use in their decision making accurately.[2-6] Descriptive models attempt to

define competence in terms of component skills. This is advantageous because these models allow researchers to treat competence as a broad concept and accept that no single component is sufficiently broad enough to identify all individuals whose decision-making skills are impaired.[7-13] However, descriptive models are limited because their focus on the decision process ignores the characteristics of the decision maker or the task.

DMC is a multidimensional concept consisting of decision structuring, comprehension, insight, information integration, and affective fluency. One way of assessing these dimensions is via performance-based behavioral decision measures, which permit us to tap into multiple skills and to examine systematically the effects of decision maker and task characteristics simultaneously. Performance-based competence measures based on real-world decisions are often complex and may require the simultaneous use of several skills. The Person-Task Fit Framework of DMC[14] explores how the individual decision maker, the task, and context characteristics may interact to influence specific skills. In this framework, age-related declines should be interpreted with respect to developmental changes in decision making and the effect of those changes on the ability to meet the demands of the decision environment.

Dr. Finucane described cross-sectional studies that assess the following dimensions of DMC:

- Comprehension, the ability to understand the decision options available and how each option rates on one or more attributes. A particular example is document literacy, including the ability to read and understand medication labels and legal documents.
- Insight, which includes the ability to appreciate the personal relevance of information, the consequences of options, the limits to knowledge, and the limits of the decision process. For example, insight is involved in the ability to understand nutritional consequences, when to exercise, and when to seek the advice of a specialist.
- Information integration, a complex construct involving the ability to select an appropriate decision strategy effectively and to weigh attributes in an internally consistent manner.

In short, results showed that compared with younger adults, older adults displayed poorer comprehension and insight and greater inconsistency across a range of tasks related to health, nutrition, and financial decisions. Higher levels of comprehension, insight, and consistency were associated with better performance on tests of basic cognitive abilities (vocabulary, memory, processing speed), greater self-rated motivation and experience, and a more “rational” decision style. Furthermore, higher levels of performance on indices of DMC were related to fewer physician visits, suggesting that the indices may capture some aspect of individuals’ behavior in everyday life.

A manuscript describing the work Dr. Finucane presented is in preparation. Future research goals include developing models to distinguish cohort effects from developmental changes, determining the relative contributions of basic abilities versus experience, exploring the validity of behavioral measures in assessing DMC among older adults, assessing whether decision skills transfer across domains, and determining how contextual variables (mood states, stereotypes) affect DMC assessments. This research will have further implications for policy, for example, by developing ways to capitalize on strengths and minimize weaknesses of older adults’ decision

making processes or by developing educational programs to raise older adults' awareness of their strengths and limitations.

Discussion

Dr. Richard Suzman observed that decision-making issues could be built into longitudinal studies conducted through health plans such as Kaiser Permanente, as has been done with Medicare Part D. Participants agreed that standard tests could be adapted to the Internet but were not certain how much the Internet has been used to assess basic cognitive functions. Dr. Suzman suggested this as an area ripe for Small Business Innovation Research funding.

One meeting participant mentioned studies in which older adults were more inclined to believe familiar but false health-related statements, and children were found to believe false statements about their own behavior. In addition, people seem to believe the content in advertisements immediately, even though they may change their minds upon further thought. In response to a question about whether older adults are more prone to believe false statements, Dr. Finucane cited research showing that mere exposure to something increases familiarity, which results in more favorable ratings.[15,16] Older adults may tend to forget important message details, relying instead on how they feel about the message to determine their evaluations and choices. The affect coming from the positive feelings of familiarity created by mere exposure to the message is less relevant information than the content of the message. As a result, older adults might fall prey to marketers using affective appeals or repetitive, misleading information.[17,18]
Participants also discussed work that separates the components of memory and suggests reliable age differences in the ability to retain the gist of information, rather than a detailed memory of it, as well as the degree of confidence or trust in one's memory.

Dr. Timothy Salthouse questioned whether the dimensions Dr. Finucane discussed could be considered components of DMC. He argued that these were cognitive components that were more complex than basic cognitive skills; assessing these would not allow investigators to determine whether someone was competent to make decisions. Dr. Salthouse suggested that Dr. Finucane's research actually focuses on a few components having to do with capability in a narrow sense but not with DMC. Dr. Finucane pointed out that she and her colleagues had begun deconstructing the concept of DMC because individuals might be judged incompetent when actually incompetent in only one aspect. Thus, rather than addressing a person's decision-making ability globally, interventions could support individuals with respect to specific skills to facilitate the making of informed, appropriate decisions. Dr. Finucane acknowledged, however, that deconstructing DMC does take away from it—all of these components must be integrated in the real world—and that there are benefits to approaching DMC in both ways. She also noted the difficulty in identifying large enough samples that permit robust measures of expertise.

Other participants asked whether competence within a larger context should be considered. Yet others observed that what makes a decision good is not always clear; it might depend on the perspective. Dr. Finucane responded that the Person-Task Fit Framework is useful in addressing perspective and the environment because it claims that competent decision making occurs when an individual's cognitive abilities and other characteristics adequately match the demands of the decision task or context. She agreed that longitudinal studies would be useful because age-related changes in DMC need to be interpreted with reference to how developmental changes in

decision-maker characteristics influence the ability to adequately meet the demands of various decision tasks and contexts.

Work group participants also discussed consistency, which could be used as a standard to determine whether a decision is good. However, this could be problematic, as some individuals might arrive consistently at poor decisions. Dr. Finucane noted the complexity of consistency as a construct, the pros and cons of focusing on it, and the different ways of measuring it. Other participants suggested that consistency in context is most important and that how context is measured might influence decision making by triggering different processes.

Intertemporal Choice Across the Life Span: A Query Theory Account
Elke U. Weber, Ph.D., Columbia University

Dr. Weber and her colleagues have drawn on insights about the functions and operations of memory provided by cognitive psychology and social cognition to show that memory plays a crucial role in preference and choice. She discussed the Preference as Memory (PAM) framework and Query Theory (QT), which were designed to explain a broad range of judgment and choice phenomena not explained by economic theory by applying what is known about memory processes such as accessibility, reactivity, and interference and inhibition. The PAM framework requires investigators to think about decision making in a different way. It provides for a theory-based approach for making better predictions about individual and lifespan differences in decision performance and uncovering relationships between performance on *different* judgment and decision tasks that may share processes, though not surface similarities. Dr. Weber focused her discussion on interference and inhibition and how they influence decision making.

QT assumes that an individual implicitly generates and recalls several classes of evidence or aspects when making a decision (queries), that normatively inconsequential variations in elicitation procedure or judgment/choice context influence the order of queries, and that different query order results in different recall success for different classes of aspects as the result of memory interference or inhibition. The inhibition of remaining or subsequent items once an initial query is retrieved is of particular relevance to the PAM model.[19-24] These phenomena occur due to a retrieval-induced forgetting effect[19,20,25,26] in which the successful retrieval of a subset of items *requires* the inhibition of remaining items, and on a part-set cuing effect,[27,28] in which heightened accessibility of initially retrieved items increases the probability of their intrusion during attempts to retrieve remaining items.

The structure of memory representation also affects retrieval in the PAM framework. Hierarchically organized information is easier to retrieve than poorly organized information.[29-32] The fan effect illustrates how learning a larger set of facts about a category increases the amount of time to verify whether any fact is true.[33-35] The fan effect is reduced when learned facts are organized into subcategories,[32] and this type of organization is found in the expert knowledge of a domain.[36] Dr. Weber and her colleagues attempt to map external constructs onto internal processes for which individuals may not always have conscious awareness by having them think out loud and generate questions in some type of order.

Older adults are less able to avoid interference on short-term memory and Stroop tasks,[37,38] engage in directed forgetting,[39] and ignore irrelevant information on reading tasks.[40] Older adults also are more susceptible to part-set cuing effects.[41] That is, the presentation of study list items as cues at retrieval impairs recall for the remaining items of the study list. Potentially, study list items with higher retrieval strength block access to study list items with weaker retrieval strength. Both younger and older adults show these effects in recall when the ratio of cues to the number of items in a total recall set is large (e.g., six cues in a nine-item set). However, older adults show part-set cuing effects even when that ratio is small (e.g., one cue in a nine-item set). The reduced ability to control inhibitory processes is responsible for some memory deficits in older adults, but greater expertise associated with aging can compensate for deficits in some cognitive functions.

QT can be used to explain aspects of judgment and decision-making phenomena, including loss aversion, framing effects, and intertemporal choice discounting, and discount asymmetries. Dr. Weber focused her presentation on intertemporal choice, which often involves a tradeoff between money and time and is based on an assumption that deferral of consumption should be compensated. The ability to predict deliberative outcomes of intertemporal tradeoffs has important consequences for pension savings, smoking and eating behaviors, health and medical decisions, and decisions with long-term environmental consequences. The way shipping options are presented is one real-world example: A consumer can choose between standard delivery and faster delivery at a higher cost. The compensation for delay is lower cost. Cost structure and time choices including consumer lock-in on Web sites[42] and the choice to use environmentally suboptimal electrical appliances are other examples. "Save more tomorrow" schemes for pension savings[43] are yet other examples.

Two factors are important in intertemporal choice: (1) People tend to be impatient, especially disliking delays that prevent immediate consumption, and (2) people tend to discount less for acceleration than for delay decisions. For example, if someone is presented with a choice between a $50 gift certificate today versus a gift certificate worth much more 3 months from now, that person typically will demand twice as much compensation to delay immediate receipt than s/he is willing to pay to speed up later receipt, contrary to standard economic theory. Loewenstein and colleagues explained this asymmetric discounting in terms of loss aversion[44] in which losses are viewed as more painful than gains of the same magnitude. Yet, existing models are silent on the psychological processes giving rise to loss aversion, and increased understanding of these processes might inform the design of decision-making interventions. Dr. Weber and her colleagues have defined a dependent measure, which is discount factor d, in terms of the amount x_1 at time 1 (t_1) versus amount x_2 at time 2 (t_2), where t_1 is less than t_2. No discounting is assigned an index of 1; smaller discount factors ($d < 1$) indicate more impatience or $x_2 > x_1$.

QT is a working hypothesis that assumes the following about discounting:

- Decomposition of valuation. In response to valuation questions, people decompose valuation into queries to memory or external sources and execute component queries *sequentially*.
- Task-dependent query order. Different valuation questions lead to different query orders. Status quo is considered first in which case the focus is on the foregone.[45] In decisions to

delay, an individual queries the benefits of immediate consumption first, then the benefits of delayed consumption. In acceleration decisions, the individual queries in the reverse order.

- Order-dependent evidence generation. Earlier queries produce a richer set of responses. Although this could arise for multiple reasons, Dr. Weber and her colleagues assume memory interference. Delay decisions involve more thoughts favoring the benefits of immediate consumption, whereas acceleration decisions involve more thoughts favoring delayed consumption.
- Balance of evidence determines discounting. Valuation judgment reflects a relative balance of support. A greater balance of aspects favoring immediate consumption versus delayed consumption leads to greater discounting in a delay decision.

Dr. Weber described three experiments that her group conducted. In the first, 176 Web users were presented with an Amazon.com gift certificate scenario; they had the choice of receiving the gift certificate now or 3 months from now. The dependent variable was the difference in the denomination of the gift certificate considered acceptable, and the independent variable was the acceleration versus the delay frame. Respondents were asked to list everything that went through their minds as they made their decisions. The aspects listed by respondents were both self-coded (at the end of the study) and coded by two independent and blind coders as favoring immediate or delayed receipt, both, or neither. Results from this experiment replicated previously observed asymmetries and showed that query order differs between conditions and affects the balance of support, that the balance of support mediates asymmetry in discounting and predicts the degree of discounting, and that older adults exhibit stronger asymmetry.

In the second experiment, 112 Web users were presented with the same Amazon.com gift certificate scenario. In this experiment, the dependent variable was also the discount factor, and the independent variables were the acceleration versus delay conditions as well as natural or unnatural aspect listing order. For example, for delay decisions, web users in the natural order condition were explicitly asked to list arguments for either immediate or delayed consumption in the order found in the first experiment. Queries of the benefits of immediate consumption came first, followed by queries of the benefits of delay. In the unnatural order condition, the two queries were explicitly solicited in the reverse order. “Unnatural” order of aspect generation changed the balance of support and eliminated the discounting asymmetry between acceleration and delay. Process-level explanations for these results provide a recipe for interventions that would reduce impatience in intertemporal choice.

In the third experiment, Dr. Weber and her colleagues addressed concerns that aspect listing might interfere with the normal way in which discounting decisions are made or that aspect listing might provide justification, rather than cause, for discounting. If acceleration vs. delay decisions affect query order and query order affects the accessibility of different aspects in different ways, then reaction times should be faster for more accessible aspects when an individual performs a post-decision, speeded aspect categorization task. Ninety-six Web users were asked to make acceleration or delay decisions about Amazon.com gift certificates. They then noted whether an aspect had been generated by another participant who made a decision about the certificates or some other decision. This experiment provided an implicit measure of memory accessibility and showed that the task condition and the resulting query order result in differential accessibility of different types of aspects.

Discussion

Dr. Weber commented that the order in which aspects are retrieved and the proportion of impatient to patient thoughts both matter, are correlated, and are both significant predictors of discounting in regression analysis. However, the number of aspects had a greater weight. While in general early generated aspects had greater weight (primacy), there also was a small recency factor, but it played a minor role. When numeracy was entered into regression analyses on discount factors, a small recency factor remained.

Work group participants expressed concern about prompting study participants for too many aspects and cited work by Schwarz on fluency. Dr. Weber and her colleagues were careful not to provide blanks in their response interface so as not to cue subjects for a particular number of aspects. Dr. Eric Johnson noted that the work presented distinguishes accessibility from amount but that this dissociation is rare in the real world.

In response to a question about age effects, Dr. Weber stated that the reason there was only an effect of older adults showing greater aspect listing interference than other groups and no spread in performance between younger and middle ages is not clear. There are plans to replicate these experiments with a larger sample. This group also is considering work to measure and distinguish memory interference or inhibition as the underlying cause for the effects and age differences from other possible mechanisms, like task switching. Participants speculated that the relationship between age and memory interference paradigms might not be very consistent.

Query Theory and Memory-based Choice
Eric Johnson, Ph.D., Columbia University

Dr. Johnson continued the discussion of QT but focused his presentation on a laboratory study of the endowment effect and a field study of loss aversion. Simply put, loss aversion means that "pain hurts more than gain feels good." This affects consumer choice in several ways.[46] For example, grocery stores are hurt more by price increases than by price decreases,[47-49] investors do not sell losing stocks, and some cab drivers stop work at a certain income on a rainy day even when they stand to make even more money by working longer. Other examples include status quo biases in housing choice and health care, the choice of conservative stock investments, and increased choice of defaults by consumers.[50] Loss aversion is distinct from risk aversion. Risk aversion is another label for choice or a statement about a utility function. Loss aversion, however, involves the ***predicted experience*** of gains and losses.

As Dr. Weber discussed earlier, people decompose valuation queries into components. This is done serially; different valuation questions suggest different orders of query, and the first query produces richer representation because of inhibition of other, potentially relevant information. In laboratory studies on endowment effects, Dr. Johnson and his colleagues provided half of the study subjects with a mug. They then asked subjects who did not have mugs how much they would pay for one (buyers) and asked those with mugs how much they would accept to part with one (sellers). In combining experimental economics and psychology for this study, Dr. Johnson established ground rules taken from both disciplines. The study involved real transactions, Becker-Degroot-Marschack procedures for eliciting reservation prices,[51] tests for comprehension, and no deception. The study also included aspect listings and self-coding, both

in laboratory studies and on the Internet. Subjects were allowed to list as many aspects as possible. Examples of positive or value-increasing aspects were "a nice memento of this experiment" (buyers) and "I am a starving student and need money" (sellers). Negative or value-decreasing aspects included "The mug is ugly" (buyers) or "I could not buy that much with the money" (sellers). Usually, those with mugs demanded twice what others were willing to pay for them.

In the first of these studies, subjects endowed with mugs showed no difference in the number of positive versus negative aspects Non-endowed subjects, however, listed more negative aspects. In the second of these studies, Dr. Johnson and colleagues assessed whether the natural order of queries could be reversed, whether reversal would produce differences in the number and kinds of aspects, and whether reversal would produce differences in prices. Non-endowed subjects were asked to think about positive aspects first, whereas endowed subjects were asked to think about negative aspects first. When the order of queries was reversed, the endowment effect disappeared, and the types of aspects changed. These results indicated that the endowment state influences the order of generated aspects and that aspects predict price. In a third study, Dr. Johnson and his colleagues assessed whether query order alone, independent of possession, could create an endowment effect. Subjects were asked to make a choice between a mug and an amount of money. If they were asked to list positive aspects first, as if they were endowed with the mug, there was no difference between the number of positive aspects and the number of negative aspects. If subjects were asked to list negative aspects first, as if they were non-endowed, they listed more negative aspects than positive ones. A latent semantic analysis showed that sellers thought more about the uses of the mug, whereas buyers considered what they would have to do to get the mug. "Neutral" data from the first and second studies showed that positive versus negative aspects predicted prices, differed between buyers and sellers, and mediated endowment. Results from these studies also provided direct evidence of output interference:[52] Sellers demonstrated better recall of positive aspects, whereas buyers had a better recall of negative aspects.

It is not yet clear whether QT accounts for loss aversion in other domains, such as default effects, framing effects, context effects in choice, and intertemporal choice. QT predicts that loss aversion will increase with age because older adults are more affected by fan effects and less able to avoid memory interference,[37,38,53,54] demonstrate less ability in directed forgetting tasks,[39] and show worse part-list cuing effects.[41] In addition, the frontal cortex, which is the speculated center for executive functions, diminishes with age, and fluid intelligence appears to deteriorate more quickly than crystallized or knowledge-based intelligence.

There are a number of possible views of loss aversion:

- A constant. Hastie and Dawes (2001) have reported that "Most empirical estimates conclude that losses are about twice as painful as gains are pleasurable."[55] How typical this is remains an open question.
- A trait. As with risk aversion, individuals may differ in loss aversion. If so, representative consumer "types" could be modeled to predict behavior.
- A function of the attribute. Loss aversion might apply to some attributes but not to others, as shown by several studies.[56-59] Differences between the willingness to accept and the willingness to pay fall into a wide range.[60] Less loss aversion is shown with utilitarian

attributes than with hedonistic ones;[61] more loss aversion is shown with important attributes.[62]

- A result of the construction process. Different characteristics can change the value construction. QT predicts that expertise should diminish loss aversion because experts' memories are better organized[63,64] and because better organization results in less interference.[32,34] This has been shown with traders in sports memorabilia, cab drivers in New York, and real estate sellers.[47,65-67] However, there are some skeptics.[68]

Dr. Johnson turned next to discussing moderators of loss aversion in the field. He described a field study conducted in collaboration with a German automaker. This study involved 347 owners of a popular car model and relied on online methods, which were advantageous because a broad range of demographics was represented, and the technology allowed the use of fairly sophisticated techniques in collecting information about reaction times, priming, and aspect listing. Data were collected in three waves. The first wave involved a personal interview; subjects were presented with two cars that were identical in every attribute except for fuel efficiency and then asked which rebates would make them choose one car over the other. Low, medium, and high levels of each attribute were used as a robustness check, and random coefficient models were used to analyze the data. In the second wave, car owners participated in Fehr-Götte gambles[69] and then looked at a model car and stated how much they would pay for the car and how much they would ask for the car. In the third wave, 60 subjects used a MouseLab-like environment to make choices.

Results from these studies showed that loss aversion was not a constant or a trait but was attribute specific. However, the data were highly heterogeneous. In terms of characteristics, loss aversion was high among subjects with little knowledge of an attribute but low among those with more knowledge of that attribute. The largest drivers of loss aversion were knowledge, importance, and age. A significant tendency toward more loss aversion among older subjects was observed. Other demographics, such as education, income, and blue-collar versus white-collar employment, also affected loss aversion. A more recent analysis shows that affect, or anticipated regret, plays a role but is largely independent. Understanding loss aversion and its moderators can inform optimal product design and market segmentation. Previous work has attempted to assess loss aversion in the wrong demographic: Most studies have used college students who are usually well off and more educated. Future research should replicate loss aversion studies across other samples and explore "the importance of importance" and the relationship between loss aversion, other individual difference variables known to affect memory, and other QT effects.

Default effects, which determine revealed choices, are fundamentally important. Studies have examined default choices in auto insurance,[70] pension savings,[71] Internet privacy,[72] and organ donation. In the field study collaboration with the German automaker, Dr. Johnson and his colleagues looked at the effects of configurators used online. Subjects could choose attributes and prices of the model cars, which were updated as they made their choices. Once the entire car was configured, subjects were asked about their satisfaction and confidence. Prices paid could shift based on the placement of each attribute without affecting satisfaction.

PAM and QT provide a memory-based explanation for preference construction that captures the endowment effect and intertemporal choice phenomena. This explanation predicts systematic individual differences in loss aversion and suggests causes and cures.

Discussion

Work group participants discussed the continuing confusion between loss aversion and risk aversion. The concept of loss aversion has been around since the 1970s, but early papers discussed risk aversion and loss aversion as if they were interchangeable. The difference between the two became clearer in the 1980s, and the first paper describing loss aversion alone was published in the 1990s. Dr. Johnson emphasized the distinction between risk aversion and loss aversion and pointed out that loss aversion can apply when no risk is present. One also could think of risk aversion as a way to make choices. Studies should examine how loss aversion plays out in a risk scenario. Work group participants suggested that future publications should begin to address the confusion in terminology more explicitly.

In response to a question about loss aversion in children and the existence of a developmental curve, Dr. Johnson cited one study showing loss aversion in 4- and 5-year-olds as well as a 1994 study showing that framing effects do not appear among children but become apparent in older individuals. Reflection effects are seen in subjects as young as preschoolers. It is not known whether this is memory based or an example of task switching.

It also was noted that confidence and self-efficacy could be part of what Dr. Johnson and his colleagues have observed. Dr. Johnson and his colleagues have not conducted longitudinal experiments in which subjects might benefit from knowledge obtained previously.

Studies by Dr. Laura Carstensen and her colleagues have shown a positivity bias among older individuals and more choice supportiveness among older individuals Work group participants suggested repeating some of these positivity studies (see below) in younger people. Loss aversion might increase among older individuals because they have more to lose. Dr. Ellen Peters also discussed studies with lottery tickets in which stronger endowment effects were observed among individuals who reported liking their tickets more. This was specific to younger adults. Participants suggested studies to examine whether importance ratings differ by age.

Work group participants also pointed out the important distinction and tension between judgment and choice. A large amount of literature exists on the strategies people use for choice.

Working Memory and Individual Decision Making
John M. Hinson, Ph.D., Washington State University

Working memory (WM) is a function associated with the quality of many forms of performance.[73] Many models of WM exist,[74,75] and component functions include robust maintenance, updating, and selection of information.[76-80] Dr. Hinson described his research with Dr. Paul Whitney exploring individual differences in WM function, [81,82] situational factors taxing WM,[81,83-85] and the extent to which WM constraints contribute to suboptimal decision making. Although this work began with an interest in cold (i.e., nonsocial and nonemotional) cognitive factors, it quickly evolved into an examination of the contributions of both cold and hot cognition. Dorsal and ventral frontal systems supporting cold and hot cognition have been well

established,[86,87] but the interactions between these systems are not well characterized,[88-90] and the extent to which these systems are fully dissociated is a subject of debate.[87,91,92]

Individual differences in frontal lobe function are responsible for variability in WM,[93,94] including differences in normal development,[95] aging,[96] frontal lobe pathology,[97] and basal ganglia pathology.[98,99] An approach focused on individual differences requires accurate measurement of the functioning of WM components. Existing measures imperfectly capture these components,[82] a single WM score may misrepresent important differences in the functioning of individual WM components,[100] and different aspects of WM are related in complex ways to different subtypes of decision-making problems, such as impulsiveness.[81] Studies of situational factors taxing WM primarily use secondary task methodology.[75,101-103] Dr. Hinson's research uses an experimental approach involving well-defined, individual decision-making tasks, including the Iowa gambling task (GT)[104] and delay discounting (DD)[105] or probability discounting (PD) tasks.[106]

The GT (http://en.wikipedia.org/wiki/Iowa_gambling_task) is a simple form of decision making with face validity.[104] It has clearly defined outcomes and normative performance with an essential role for learning. Poor performance on the GT is predictive of frontal lobe pathology,[107-109] and decision-making results from the GT are a primary source of evidence for the somatic marker hypothesis (SMH).[107-111] Although the GT is used widely as a general purpose test of decision making and executive functioning from which far-reaching conclusions have been drawn,[112,113] there is still considerable debate about the finer points of what the GT is measuring and the status of the SMH.[112,114-116] Dr. Hinson presented results from a three-choice variant of the original four-choice GT,[84] which provides good, bad, and neutral options rather than pairs of good and bad options; allows the use of differential anticipatory skin conductance response (SCR) as an index of somatic reactions; and clarifies the interpretation of SCR measures.[116-118] The three-choice variant also uses embedded secondary tasks that do not necessarily require executive control resources or tasks that employ stimuli with affective valence.

For a cold WM load, subjects underwent a digit load, were offered the three choices, received reports of their choices with feedback, and then answered questions about the digit load. SCR measurement commenced while subjects were preparing for the task and ended once they made their choices. Secondary tasks that required executive control resources, such as random number generation or digit string maintenance, disrupted GT performance and somatic markers associated with it, and resulted in slower progress of learning and inferior asymptotic performance. The absence of a differential SCR to good and poor choices was predictive of poor GT performance. Somatic markers did not become more prominent causal factors as WM load increased, contrary to the original version of the SMH. Secondary tasks that did not require executive control resources had no effect on GT performance. These results indicated that cold WM load could interfere with decision making that previously had been associated with hot cognitive processes.

To examine the influence of hot cognitive processes,[81] Dr. Hinson loaded WM with words differing in affective value while equating for other properties such as familiarity and general arousal, as done by Bradley and Lang.[119] These WM load procedures are a form of affective

priming,[120] but they are not strictly equivalent to mood manipulation.[89] No changes in mood were observed or self-reported, although the words did produce measurable physiological effects. Two procedures were used. In affective loading, words with either a positive or negative load appeared more frequently during each choice trial but did not signal choice outcomes. At the end of the task, the participant was asked to say the word. In affective biasing, affective words were used to load WM in a sense, but they were redundant signals for each choice. Congruent bias used positive words to signal good choices and negative words to signal poor choices, whereas incongruent bias did the opposite, using positive words to signal poor choices and negative words to signal good choices. In this procedure, subjects were asked to remember their words during the trial. For both procedures, SCR was measured from the beginning to the time the choice was made.

Negative affective loading produced poor initial GT performance and continuing difficulties throughout the task, whereas positive affective loading produced good initial GT performance that was maintained throughout the task. Subjects showed no insight into the affective nature of the secondary task. The effects of affective biasing were even more profound. Incongruent affective biasing produced poor initial GT performance with continuing difficulty throughout the task, whereas congruent affective biasing produced good initial GT performance that was maintained throughout the task. Again, subjects showed no insight into the affective nature of the biasing procedure. Differential, anticipatory SCR to good and poor choices was associated with good overall GT performance. The priority of onset for somatic markers and good GT performance was identified by regression analyses in which good GT choices in each trial block were predicted based on differential SCR in that block. These analyses indicated that somatic markers represented by differential SCR are lagging indicators of GT performance. Thus, cold cognitive loads were generally deleterious, whereas hot cognitive loads could be beneficial or detrimental.

Dr. Hinson described his work with colleagues to understand linkages between explicit knowledge and affect[116] through examination of a combination of measures taken in the context of WM load manipulations: Actual GT choice performance; explicit knowledge of GT contingencies and outcomes, including an evaluation of the overall quality of and estimation of the gains and losses from each option; and differential SCR measurement of somatic markers. Affective biasing and loading conditions of comparable valence produced similar results with some minor exceptions. Over the course of the task, estimates of gains and losses for each option rapidly approached the true values, and these estimates did not differ markedly between conditions despite the impact of valence on overall choice performance. Global evaluations of the quality of each option were consistent with actual choice performance and reflective of the impact of affective loading and affective biasing. In a regression analysis in which good GT choices were predicted by explicit knowledge and affective markers, subjects' global evaluations of how good things were was clearly the best predictor of overall performance. Cold cognitive load interfered with subjects' ability to evaluate gains and losses and assess value, thereby impairing GT performance. Hot cognitive loads did not interfere with the evaluation of gains and losses, but they did alter the global assessment of value, thereby impairing or improving GT performance. Contrary to the SMH as originally conceived, the mechanism of the hot cognitive load's impact on choice is not the somatic marker.

Temporal discounting is associated most strongly with measures of trait impulsiveness.[121] The DD task involves repeated choices for immediate versus delayed hypothetical gains or losses,[81,85] and an analysis of DD performance is based on the hyperbolic discounting model.[106] DD is related closely to problems in the real world, such as drug abuse,[122-124] and the DD task has been used widely.[105,125] There is a weak relation between DD and GT,[126] but the functional properties of DD of these tasks differ considerably. DD does not involve learning or explicit corrective feedback, and normative performance in DD is not defined simply.

One form of WM load required the comparison of multiple options, whereas another load manipulation involved secondary tasks embedded in the primary decision-making task, as used with the GT. Under cold WM load conditions, temporal discounting was increased, and this increase was comparable to differences in impulsive decision making. Under these conditions, temporal discounting appeared to result from interference that built during the task. For conditions that are inherently difficult, such as comparing multiple options, increased temporal discounting appeared from the outset and did not change systematically across decision trials.

To assess the effects of hot WM loads and temporal discounting, Dr. Hinson and his colleagues used an affective loading procedure similar to the one employed with the GT task. Affective biasing procedures could not be used. Temporal discounting was assessed directly by asking for the value of the delayed option that just exceeded the immediate option, or indirectly by determining the hyperbolic discounting parameter based on preference between immediate and delayed choices. Again, affective loading did not produce a measurable change in self-reported mood. Affective loading increased temporal discounting compared with a no-load control. Negative affective loading produced the greatest degree of temporal discounting, but the effects of positive affective load were comparable with those of digit maintenance. This pattern of load effects was observed with both choice and indifference point measures of temporal discounting.

In summary, both hot and cold factors affecting the WM system influenced decision making. Challenges to the WM based on cold cognition produced more impulsive decision making and could interfere with the contributions of hot cognition to decision making. Challenges to the WM system based on hot cognition impacted the quality of decision making based on affective valence, and they were not limited to effects mediated by changes in mood. Overall, cold and hot cognitive factors appeared to be interdependent rather than fully dissociable. These findings have several implications for aging and decision making. Age-related reductions in the efficiency of top-down, dorsolateral prefrontal cortex circuits are connected most strongly to cold WM functions,[96,127,128] and these changes are exaggerated in mild cognitive impairment and cortical dementias.[129] Age-related reductions in the efficiency of striatal circuits contribute to both cold WM function and reward processing.[130,131] These changes are exaggerated in Parkinson's disease and related disorders.[37] Several lines of evidence suggest that affective processing in a variety of domains is well preserved in normal aging.[132-134]

In healthy, older adults, decision making in the above tasks is generally adequate when WM challenges are limited. GT performance is more deliberate, but not inferior to younger adults,[96,135] and DD performance shows a general trend away from delay aversion and impulsive decision making.[136,137] Decision making becomes more seriously impaired in older adults under conditions of higher WM load. Simple WM measures might underestimate the potential impact

of WM challenges.[127] Under the appropriate circumstances, older people can make optimal decisions when the environment is structured so that these individuals can derive maximum benefit from affective processes that are still intact.[138,139] Compensatory neural processes are observed in older adults that are not apparent in younger adults.[140] Mood might be important, but it is not an exclusive contributor to decision making. Task-irrelevant positive mood is likely to contribute to good decision making,[141,142] whereas negative mood might interfere with it.[89]

Discussion

Work group participants remarked that the lack of insight into the affective biasing procedure was surprising. In other studies, subjects' moods are observed to improve when they perform better. Dr. Hinson reported that some subjects were surprised by their poor performances, but investigators saw nothing to indicate that these subjects' moods had changed.

As Dr. Hinson presented the results of affective biasing and loading on the GT task, some work group participants noted that the rate of learning appeared to be the same throughout the first block. Although there was apparent improvement over time for incongruent biasing, subjects who experienced incongruent biasing never recovered after the first few trials. Work group participants suggested that study subjects had chosen the good words more frequently and that their choices interfered with the GT. Dr. Hinson responded that some subjects had chosen good words immediately and ignored everything else. He reiterated the result that these subjects reached asymptotic performance more quickly.

In response to questions about incentives, Dr. Hinson noted that on occasion, study subjects were paid, but no material differences appeared. However, what subjects were paid was not contingent on performance. Work group participants suggested another experiment with an additional condition in which payment is contingent on performance.

Discussion also centered on the need for better independent measures of affect. Dr. Hinson acknowledged that SCR does not allow a definitive conclusion that the effects observed were truly effects on affect. However, by the standard definition of affect, the effects observed in these studies were affective.

Dr. Weber attempted to relate Dr. Hinson's results to QT and suggested that there may be a hierarchy of processes in response to WM load. She reported that in studies conducted with Dr. Johnson, subjects generated more positive aspects than negative ones. It may be that hot affective priming might be more damaging than cold affective priming.

Another participant noted that the interaction of two independent systems with memory was somewhat telling. Dr. Valerie Reyna pointed to studies that found that "gist" predicted independent effects on WM, whereas accurate verbatim memory did not. In combination with Dr. Weber's proposal, this model might prove intriguing. Dr. Salthouse has studied concept formation, where subjects were asked to state their hypotheses right before they received feedback, and suggested that something similar could be done with studies of the evaluation of gains and losses and then subjects' choices in the next trial. Dr. Salthouse found that older adults were less likely to employ new information. Dr. Hinson agreed that this was a possible avenue to pursue with his subjects.

Neural Antecedents of Financial Decision Making
Brian Knutson, Ph.D., Stanford University

Dr. Knutson discussed studies that he and his colleagues have conducted using event-related functional magnetic resonance imaging (fMRI) to see whether anticipatory neural activity predicts optimal and suboptimal choices in a financial decision-making task. His work focuses primarily on affect, rather than cognition, but the two most likely are related.

Dr. Knutson began by defining the expected value (EV) of a gamble as the product of the value of the gamble and the probability that an individual will gain from that gamble.[55] EV is influential in game theory,[143] self-efficacy,[144] and expectancy value theory.[145,146] Assuming that EV occurs before the behavior, it is likely that an area of the brain correlates with the behavior and that activation of that area can be used to predict the behavior. Several brain stimulation studies have been done. Mesolimbic dopamine projections are likely areas for eliciting self-stimulatory behavior when an individual expects a reward.[147] These areas are activated before learning in response to a reward or after learning in response to cues or delay. If no reward is present, activity ceases. This was shown by Pavlov in dogs and has been observed in monkeys and humans.

In previous imaging studies, Dr. Knutson's group focused on mesolimbic dopamine projections and affect, which is defined by good or bad valence and high or low arousal. Specifically, these studies moved subjects along the axis of positive arousal and assessed what happened when they anticipated rewards. A Monetary Incentive Delay task,[148] which manipulates gain or loss anticipation, gain outcomes, and non-loss outcomes, was used. Aspects of the cue were changed to symbolize increments, gains, or losses, among other things, and the group examined both what happened when subjects had seen the cue and were waiting to respond and when subjects learned the outcome. Gain anticipation activated the nucleus accumbens (NAcc) with activation proportional to the anticipated magnitude of the gain.[149] Further study showed that NAcc activation correlated with positive arousal[150] and that gain outcomes activated the medial prefrontal cortex contingent on anticipated gain[151] In addition, other studies showed that the anterior insula (AI) was activated during nonmonetary loss and in anticipation of aversive stimulation. On the basis of these studies, Dr. Knutson's group hypothesized that activation of specific circuits could predict a person's choice.

Dr. Knutson next discussed whether investing could be elicited in the context of fMRI, whether activation in anticipatory areas precedes risk-seeking versus risk-averse choices, and whether these phenomena extend to both rational and irrational choices. His working hypotheses predicted that NAcc activation would precede risk-seeking choices, that AI activation would precede risk-averse choices, and that these areas of activation would be observed with both rational and irrational choices. Nineteen Stanford University doctoral students, about half in finance and the rest in the humanities, underwent fMRI while performing a Behavioral Investment Allocation Strategy (BIAS) task. In this task, subjects were asked to choose one of two stocks or a bond, once for each trial, with the goal of maximizing their earnings. Their pay was 10 percent of their earnings, plus $20 per hour. Subjects went through 20 blocks of 10 trials, and the two stocks were shuffled at each block. Subjects knew one stock was better (assigned randomly at the outset), but they did not know which. The investigators analyzed localization, including the outcome and the market, as well as prediction based on anticipation.

The BIAS task is advantageous in that results from the task can predict the behavior of an optimal trader. Dr. Knutson's definition of rationality assumes that a risk-neutral, rational agent will choose stock if he or she believes that the probability of gaining from that stock exceeds 0.7. Otherwise, the agent will choose the bond. BIAS variables included risk-seeking (stock) or risk-averse (bond) choices and risk-seeking (stock when bond is optimal) or risk-averse (bond when stock is optimal) mistakes.

Dr. Knutson and his colleagues found that activation in distinct neural circuits preceded switches in financial choice strategies. NAcc activation preceded risk seeking on the next choice, whereas AI activation preceded risk avoidance. These distinct areas of activation were observed with rational and irrational decisions and were most pronounced when a participant made a sudden change in behavior. All correlations exceeded 0.7 except for confusion mistakes, which occurred rarely. In addition, subjects behaved like the rational agent 70 percent of the time. Thus, activation in distinct neural circuits precedes switches in financial choice consistent with a simple model.[152] These phenomena apply to rational choices but even more to mistakes.

Dr. Knutson concluded that neural markers exist for EV and that affect influences choice and optimization behavior varies among individuals. There are several applications for the lifespan. Practically, these studies imply that predictions can be made and anomalies accounted for. Theoretically, good is not necessarily the opposite of bad, and anticipation is not the same as outcome. More probes of the influence of affect are needed. Studies of older versus younger community members are under way.

Discussion

Dr. Johnson commented that an economist examining risk aversion would want to know more about these study subjects' financial situations, which might affect how they perform on the BIAS task. He also observed that although Dr. Knutson used the term "risk aversion," it was actually loss aversion or loss-seeking behaviors that were assessed in these studies. Dr. Knutson agreed but noted that he and his colleagues wanted to define what subjects are doing behaviorally in a way that the neurosciences field would find acceptable. Dr. Carstensen added that when subjects become totally involved in this task, they might see just cues and making choices without considering outside factors. One participant noted that subjects essentially are pulled through the BIAS task and that a load might therefore be induced.

Another participant referred to a study in which the response among extroverts was greater than among introverts. Dr. Peters added that extroversion was predictive on the Iowa Gambling Task but that this effect disappears in older adults. Dr. Knutson reported that these types of traits have not been assessed in the imaging-BIAS studies. Work group participants speculated that these measures could be linked. Individual differences in brain activity could be predictive of personality traits.

Numeracy, Affect, and Decision Making
Ellen Peters, Ph.D., Decision Research

Dr. Peters' research focuses on the interaction between affect and deliberation in decision making. This research follows two directions. Studies on numeracy and secondary affect (affect produced through deliberative thought processes) include basic decision-making studies, applied

studies that will generate methods to help less able individuals make better decisions in health and financial domains, and studies of the relationships between numeracy and cognitive performance. Dr. Peters' group also studies direct affect and decisions by experience.

A combination of theory, empirical data, and real-life phenomena supports the existence of two parallel and interacting modes of information processing.[153,154] The experiential system, or System 1, relies primarily on affective feelings and is intuitive and holistic, fast, and less than conscious. The deliberative system, or System 2, is slower, analytical, conscious, and logical, has a fairly recent evolutionary history, and allows individuals to monitor the quality of information processing. Traditional views of decision making hold that it is based primarily on deliberation. However, individuals have a limited capacity to represent, process, and manipulate information, and deliberative efficiency declines with age. Yet, age-related, deliberative decline might be too simple an explanation for declines in decision making among older adults. These individuals appear to use their deliberative capacity selectively, and the amount of experience they have accumulated compensates for this decline. An affective/experiential view might prove useful in addressing declines in decision making. Affect guides decisions and perceptions of information,[118,155-157] and affect acts as a source of information. Without affect, information is meaningless. Direct affect is familiar or learned through experiences,[158] among other things, and secondary affect often involves a comparison of options or attributes and may depend on number ability, or numeracy.[159]

Numeracy is the ability to understand and use basic probability and mathematical concepts. It is estimated that half of Americans lack the minimal math skills needed to use numbers embedded in printed materials.[160] A typical numeracy item might ask, "Which of the following numbers represents the biggest risk of getting a disease, 1 in 100, 1 in 1,000, or 1 in 10"?[161] Most respondents answer this question correctly, but the proportion declines with age and education status. Another question might be, "The chance of getting a viral infection is 0.0005. Out of 10,000 people, about how many are expected to get infected?" The proportion of respondents answering this question correctly is lower, but again, that proportion declines with age. Higher vocabulary scores, but not WM or speed, are associated with higher numeracy. Male gender also is associated with high numeracy. In addition, individuals who report better health have higher numeracy, but when data are controlled for other variables, the correlation between health and numeracy becomes negative.

Lower numeracy is linked with lower comprehension, greater framing effects in decisions, less meaning drawn from numbers, and greater influences by direct and irrelevant sources of affect and emotion in decisions.[159,162] In a study of the effect of numeracy on attribute framing,[159] Dr. Peters and colleagues described a college student in a positive frame ("Emily got 74 percent correct on her exam") or negative frame ("Emily got 26 percent incorrect on her exam") and then asked college students to rate the quality of this fictitious student's work. Low-numerate subjects showed larger effects of the given frame than did high-numerate subjects. The impact of frames seems to be due to reliance on information in the form it was given. It may be that people who have greater number ability are more likely and/or more able to transform numbers from one format to another in which case they will show less of a framing effect.

Dr. Peters and her colleagues evaluated the ability of subjects to draw meaning from numbers by asking study subjects to rate the attractiveness of a bet.[163] Group 1 subjects were told that the bet would give them 7/36 chances to win $9, and Group 2 subjects were told that the bet would give them 7/36 chances to win $9 and 29/36 chances to lose 5 cents. Surprisingly, subjects in Group 2 rated their bets as more attractive and showed a stronger positivity effect. In the context of the 5-cent loss, subjects compared those numbers and drew affective meaning from it. Group 1 tended to rate the $9-incentive as neutral, whereas Group 2 rated the $9-incentive more positively. Surprisingly, only the high-numerate (and not low-numerate) subjects found the objectively worse bet more attractive, which seems to be driven by affective feelings generated through a comparison of the numbers (so-called secondary affect). Older adults showed similar but weaker effects.

To examine the influence of less relevant, direct affect, Dr. Peters and her colleagues gave subjects a task in which they had to choose between a bowl with lots of jellybeans that had a 9-percent chance of selecting a winning jellybean (e.g., 9 out of 100) and a bowl with only a few jellybeans and a 10-percent chance of selecting the winning jellybean (e.g., 1 out of 10). A sizeable proportion of subjects chose the bowl with more winning jellybeans, even though their chances of selecting a winning jellybean were worse. This was true for 33 percent of low-numerate subjects compared with 5 percent of high-numerate subjects. When subjects were asked how the 9 percent made them feel, everyone knew that the 9-percent probability was less favorable, but these feelings were more precise among high-numerate subjects.

Dr. Peters and her colleagues tested these findings in a real-world setting. In a conceptual replication of the jellybean task (Peters E, Dieckmann N, Västfjäll D, Mertz CK, Slovic P, Hibbard J (manuscript in review). Bringing meaning to numbers: the functions of affect in choice), community subjects were asked to rate the attractiveness of a hospital based on three quality indicators. Subjects received only numbers, and each quality indicator was low, medium, or high. Just before the subjects' decisions, their moods were measured. High-numerate subjects were able to use the numbers they were given significantly, and mood had no effect on them. Low-numerate subjects were not able to use the provided numeric information; they depended on their moods to rate the hospital; they misattributed these irrelevant mood states as feelings about the hospital instead of using the numbers. To determine whether judgments could be improved, Dr. Peters and her colleagues had subjects perform the same hospital-rating task, but they made the information easier to evaluate. In this case, low-numerate subjects depended less on mood and relied more on important indicators. In another set of studies,[164] the investigators assessed the effect of numeracy on comprehension of hospital quality. When numbers were used in a direction contrary to the number line (i.e., lower means better), less numerate subjects were less able to comprehend them. However, when numbers were used in a direction consistent with the number line, comprehension improved among both low- and high-numerate subjects.

Dr. Peters also discussed intuitive number sense and comparison speed. Intuitive number sense, which has been linked with teaching math ability in acalculic children, is a way to evaluate how individuals mentally represent the number line.[165] Two systems of numbers account for basic numerical intuitions. One system represents large, approximate numerical magnitudes for integers. A second system precisely represents very small integers. Measures of intuitive number sense include the distance effect paradigm and magnitude estimates. If individuals see two

numbers, one of which is larger in type size, and are asked which one is greater, those individuals take longer to respond if the distance between the two numbers is larger in size (i.e., 5 and 8, versus 5 and 6). This might depend on affective representations, cognitive representations, education, interest, or numeracy. In a study examining the standard distance effect among younger adults, Dr. Peters found that high-numerate subjects responded faster and with less steep slopes, suggesting faster and more precise representation. The same was true for a modified distance effect in which subjects were asked whether a given number was larger or smaller than 50 percent. The speed of comparisons added a significant and independent contribution to numeracy scores. When comparison speed was incorporated into the bet attractiveness studies, the objectively worse bet appeared more attractive among subjects with high comparison speeds. In another example, Science for Life, subjects were asked to rank three institutions' worthiness to receive funding based on reductions in the number of deaths. One institution X saved the fewest number but the greater proportion of lives whereas another institution Z saved the greatest number of lives but the smallest proportion. Overall, numeracy had no effect on the selection of the best institution to receive money, but comparison speed made a significant difference.

Thus, numeracy affects the cognitive representation and comprehension of numbers, as well as the approximate affective representation of numbers, all of which can affect decision making. Affect from other sources, number sense, and comparison speed also can affect choice. To further examine numeracy and aging, the investigators will have to consider an intersection of theories. Information processing in decisions appears to change and develop throughout the life course, and age-related change might lead to different decisions and reliance on different processes. Thus, older adults might require different decision aids than those designed for younger adults.

Discussion

Dr. Suzman mentioned connections between low numeracy and indecisiveness and ambivalence. Dr. Peters and her group have talked about exploring the idea of indecision as a lack of emotional response. If low-numerate people draw less affective meaning from numbers, then they might be indecisive simply because they do not have clear guidance through complex choices.

Several work group participants observed that in the Science for Life example, two mathematical strategies could be used: Subtraction or ratio. Subjects might be better at one strategy versus the other. Values are also a concern. In the real world, individuals would consider other factors such as which problem is more prevalent or who has more money. Individuals also could apply a scaling factor and intuitively think in comparative terms. Thus, there might be room in this task for misunderstanding.

In response to questions about brain areas associated with numeracy, Dr. Peters mentioned studies showing that the processing of numbers comparisons appeared to be located in the parietal areas and that number sense involved a bilateral activation. One participant questioned whether high-numerate individuals had more intuitive number sense and used System 1, whereas low-numerate individuals used the more deliberative system. Another participant was reminded of mental rotation, which is parietal. Dr. Peters reminded everyone that numeracy is not dissociated from affective quality; in the decision-making tasks her group employed, an

interaction was associated with the source of affect. It is not clear whether comparison speeds limited the ability to draw affective meaning from numbers in older adults. Other participants wondered whether the positivity effect was related to the experienced effect.

Studies in the literature have shown that for affective stimuli, people tend to be insensitive to probabilities in the middle range. Other studies have shown that low-numerate individuals are less sensitive to differences in probability.

Dr. Johnson noted the public policy applications of these studies, particularly in designing ratings or food labels. How numbers are presented might shift an individual from one processing system to another.

The Role of Motivation in Decision Making
Laura L. Carstensen, Ph.D., Stanford University

Motivation affects decisions, preferences, and emotional experiences. If motivation changes with age, then one would expect to see systematic differences and changes in what a person sees, hears, and remembers. The Socioemotional Selectivity Theory holds that humans monitor time in their lifetimes and set goals in a temporal context.[166,167] Because chronological age is associated with time left in life, goals change across the lifespan. When temporal horizons are long, humans are motivated to collect information in preparation for a long-term future. They collect information broadly because even if it is not relevant to the present it could become useful later in life. Younger people experience chronically activated goals to expand horizons, acquire knowledge, meet new people, and take chances. When time horizons are more constrained, however, goals shift. In older people, emotional goals are chronically activated. They are less likely to collect irrelevant information and more likely to regulate emotional states and focus on the present. They live in the moment, know what is important to them, invest in sure things, deepen relationships, and savor life. Dr. Carstensen outlined the following theoretical postulates:

- Perceived constraints on time motivate people to pursue emotionally meaningful goals.
- Motivation to pursue emotionally meaningful goals directs cognitive resources to emotional information.
- Focusing on emotionally meaningful goals is good for well-being.

Dr. Carstensen's group has conducted several studies in which subjects are presented with choices representing different types of goals and time horizons that are manipulated. In these studies, preferences change systematically. The preferences of younger people resemble those of older people when time horizons are shortened, and the preferences of older people when time horizons are expanded resemble those of younger persons.[168-170] When events such as personal illnesses, epidemics, political upheavals, or terrorism prime endings, young people's preferences again resemble those of older people.[169-171] Studies have shown good mental health overall among older people. The distribution of depression by sex and age generally declines with age for both sexes,[172] and the percentage of older individuals reporting psychological distress is lower than that of younger or middle-aged persons.[173,174] The frequency of negative emotions in day-to-day life also declines among older individuals.[175] These findings are consistent with the Socioemotional Selectivity Theory.

The Socioemotional Selectivity Theory was rooted initially in an interest in social isolation and reductions in social networks among the elderly. Now, Dr. Carstensen's group is interested in the effects of shifting motivation on cognitive processes. Focusing her presentation on doctoral work done by Dr. Helene Fung, Dr. Carstensen showed how older individuals were more likely to remember slogans and products when they were represented in an emotional context.[176] When subjects were asked to consider a time-expanding situation, however, the preference for emotional advertisements disappeared.[176] This work led to the consideration of differences in the type of emotional information remembered. In one study, three age groups were shown positive, negative, and neutral images.[177] All groups were more likely to remember the emotional images than the neutral ones, but by middle age, positive images were preferred. Dr. Carstensen and her colleagues replicated this study and added imaging to assess areas in the brain that were activated at the time subjects viewed the images.[178] Again, recall proportions showed that older subjects remembered more positive images than negative or neutral ones. Younger subjects showed an increase in amygdala activation in response to positive and negative images, but the amygdala in older persons activated only in response to positive images. A subsequent study presented subjects with two faces on a screen: One neutral and one emotional. In the next screen, a dot appeared behind one of the faces, and subjects were asked to record where the dot appeared, behind the right or left face. Accuracy was high, but the question was how fast the answers were recorded. Older participants tended to look toward the positive image or the neutral image if it was paired with a negative one.[179]

Affective WM is a process that maintains a representation of an emotion in the absence of the immediate elicitors for the service of goal-directed behavior. In studies by Mikels and colleagues,[133,180] subjects viewed an image and, after a delay, viewed a second image and stated whether this image was more negative than the first. As a control, subjects performed a brightness WM task. Although brightness WM was lower in older subjects, there was no difference in affective WM between younger and older study subjects. There were differences by valence, however. Older subjects performed better with positive images, whereas younger subjects performed better with negative images, suggesting that older people invest more cognitive resources into positive tasks.

Studies also were done to assess the positivity effect in autobiographical memory. In 1987, the School Sisters of St. Francis completed a 26-page questionnaire about their physical, social, and emotional lives. In 2002, in a quasi-experimental design, the nuns were recontacted and asked to complete the questionnaire again.[181] Some nuns were asked to focus on accuracy, whereas others were asked to focus on how they felt. Older subjects remembered their autobiographical pasts more positively than did younger subjects. This effect was eliminated if subjects were primed to focus on accuracy. Thus, decision aids may be able to overcome the effects of motivation.

Studies by Löckenhoff and Carstensen applied these concepts to a real-world example by asking subjects to review information about different health care choices.[182] The information was covered by different shades of gray to indicate positive, negative, or neutral. The control group received no instruction, whereas another group was asked to focus on the facts and details of the information. Again, older subjects focused more on the positive information, but this effect disappeared when they were asked to focus on the facts and details. Studies assessing the

implications of these findings for decisions about health care, as well the effects of age on gain or loss anticipation are under way.

Discussion

Work group participants considered whether preference could be separated from emotion and suggested experimental designs that could answer those questions. Dr. Carstensen observed that when people are asked to make a choice, they are asked to be emotional because it is difficult to make a choice without stating a preference. Dr. Suzman cited a large study examining health plan choices made and individuals and noted that it would be interesting to see what cognitive dissociations led to a revision of choice. Dr. Peters suggested an experiment in which subjects are asked what they think about something rather than how they feel about it. Gist, which does not have to be emotional, and WM also were discussed.

One of the benefits of old age is being relieved or liberated from having to plan for the future, thus freeing up cognitive resources. Dr. John Haaga was struck by the number of attributes presented as descriptive in Dr. Carstensen's work that are presented as prescriptive in self-help books aimed toward people in their 30s and 40s. In effect, these books appear to advise readers to behave like older people. Dr. Carstensen thought of the change in behavior as more of an adaptive process with individuals operating within a biological, physiological, and cognitive niche appropriate for their age or subjective sense of time remaining.

Aging-related Influences on Judgments: Mediators of Heuristic Processing
Thomas M. Hess, Ph.D., North Carolina State University

Dr. Hess' research originated with a simple approach to the relationship between age and the use of heuristics. Previous research had suggested that memory in older adults was based more on schema and that these adults made simpler decisions and thought more simply. Further study showed this question to be more complex and illustrated a need to account for multiple factors.

Heuristic processing involves judgment rules, often considered shortcuts, that are based on easily processed cues and minimal demands and are stored in memory.[183] Examples include "length is strength" and "consensus opinions are correct." This contrasts with systematic or "bottom-up" processing, which is comprehensive and analytic. Heuristic processing is associated with availability, accessibility, applicability, task demands, available capacity, and motivation. Aging has been associated with several of these factors. Life experience and knowledge are related to availability. Cognitive capacity, including processing, resources, and executive functions, interacts with task demands and influences accessibility and applicability. Thus, older adults would be expected to resort more to heuristics, and age differences would be expected to be large. In the most demanding tasks, cognitive capacity could help a person inhibit inappropriate schemes for processing information. However, cues in a situation might activate heuristics, and these cues might be applied inappropriately because of problems with WM and executive function. Age-related developmental goals and personal relevance also might influence heuristic processing.

Dr. Hess's research focuses on how relevant a situation is to an individual. More specifically, his research addresses:

- Age differences in judgment processes, for example, associations between aging and increased use of shortcuts in processing
- Factors, such as motivation and capacity, associated with such processes
- The interpretation of effects and whether they are based on cognitive decline, expertise, or adaptation (e.g., selectivity)

Several priming studies have been done to determine the extent of differential susceptibility to priming judgments across the lifespan. In one study, Dr. Hess and his colleagues used a procedure similar to one used by Murphy and Zajonc:[164] 149 subjects aged 20 to 81 years were presented with a Japanese character and asked to state how they liked it. In a typical trial of priming effects, subjects first saw an asterisk, then a positive, neutral, negative valenced priming word, and then the Japanese character.[17] Subjects were either in the suboptimal condition, in which the prime word was flashed below the person's awareness, or in the optimal condition, where the prime word was presented long enough for the person to become aware of it. Among younger adults in the suboptimal condition, judgment assimilated toward the valence of the primes; they thought that they liked or disliked the Japanese character in a manner that was consistent with the valence of the prime. Older subjects behaved similarly. In the optimal condition, younger adults behaved similarly to subjects in previous priming studies, exhibiting no impact of prime valence on judgments, but older adults behaved similarly to those in the suboptimal condition. These results suggest that even though older adults were aware of the prime, they were unable to separate the feeling elicited by the prime from the decision context. Further study revealed a motivational aspect in the need for structure, suggesting that in later life, the interaction between the need for structure and the extent to which people are affected by primes is influenced by the likelihood of them holding on to affective information associated with the prime. Why this does not happen in middle-aged or younger adults is not clear. When need for structure is correlated with other ability measures, there is a significant but negative correlation with WM capacity and comparison speed. Need for structure also is correlated inversely with physical health with all of these effects increasing in strength with age. Thus, resources impact motivation, which in turn, influences how people use information. This suggests that cognitive constraints are important but that increased use of heuristics among older individuals is not a simple translation of cognitive ability.

Studies have been done to extend these findings in a realistic context. In one, subjects rated the likability of a sample of proposed legislation.[184] They first read information about the person proposing the legislation and rated the likability of the source, and then they read a description of the legislation, rated the personal relevance of the legislation, evaluated the legislation, and listed their thoughts. The study included four conditions in which the personal relevance of the legislation was crossed with the likability of the source. When the relevance of the legislation was low, results were similar to those observed in the optimal condition described above. Younger subjects' opinions were not affected by the likability of the legislator, but older adults' opinions of the legislation were affected significantly by how much they liked the legislator. The effect diminished when the relevance of the legislation was high; older adults separated the likability of the legislator from the value of the legislation and made decisions based upon their own evaluation of the legislation. Dr. Hess observed that in typical laboratory studies, older adults might do what is expected based upon data relating to declines in basic cognitive skills,

but in situations where decisions are meaningful, they do well, suggesting they selectively engage resources based upon importance.

Dr. Hess also presented studies on the impact of trait-diagnostic information on social judgments.[185] These studies involve an impression formation task in which subjects read a description of two positive and two negative behaviors relating to the honesty or intelligence of a person and then rated the competence and trustworthiness of the person. Negative behaviors were diagnostic in the morality domain (honesty), but positive behaviors were diagnostic in the competence domain (intelligence). Older subjects were more likely than younger subjects to pay attention to the diagnostic value of behaviors. To assess whether this represented a type of social expertise, Dr. Hess and his colleagues had participants fill out a variety of scales relating to personality, cognitive complexity, social activity, and intrinsic motivation. Factor analyses on these measures revealed four general relating to need for structure, sociability, complexity of social reasoning, and social activity. Only social activity was found to moderate the strength of these effects, as well as interactions involving age. For example, younger adults high in social activity performed more like older adults than did those individuals low in activity. This suggests that social expertise based in age-related cumulative social activity may account for the general finding that age is positively associated with attention to the diagnostic value of information in this particular context.

On the basis of these studies, Dr. Hess concluded that aging-related cognitive constraints result in the increased use of heuristics, which is moderated partially by goal-based processes such as selectivity. The use of heuristics is an adaptive function based in growth- and loss-based processes such as conservation of limited resources. Cognitive constraints also may limit flexibility in processing. Heuristics also may be based in age-related experience, including the development of expertise, and they may be adaptive in terms of general functioning within the culture and accommodating to declines in cognitive resources. This has several implications for decision making and aging, including the need to consider multiple developmental functions such as cognitive resources, motivation, and knowledge, as well as the context of the problem.

Discussion

Results from the legislation study appeared to conflict with the positivity effect findings presented by Dr. Carstensen. Dr. Hess suggested that differences might arise because his work has focused more on situational goals, whereas Dr. Carstensen's work focuses on chronic goals. Work group participants speculated on what would happen if people were given a task where chronic goals were not relevant.

Another participant remarked that results from the diagnosticity study showed that the diagnosticity effect was strongest among middle-aged adults and then declined with age. This trend could be consistent with other research showing a more linear effect. Dr. Hess reported that his data were compatible with a tendency among older people to skew information. However, his results also point to an adaptive process in which expertise allows one to see what is important and make an accurate judgment. Another participant sought to connect these data to childhood studies in which processing becomes more general with advanced childhood development and processes rely more on gist and less on quantitation and verbatim information. Dr. Salthouse suggested that Dr. Hess and his colleagues develop a diagnosticity index by correlating relevance with diagnosticity.

Dr. Carstensen expressed surprise that subjects could self-report the need for structure, and she noted that this might be related to tolerance for ambiguity. Dr. Hess responded that in his studies, need for structure had impacted older adults consistently. Resources may map more strongly onto this motivational construct later in life. Participants then discussed sample items on the assessment of need for structure.

Aging and Reasoning
Timothy A. Salthouse, Ph.D., University of Virginia

Reasoning is similar to decision making in that it requires the integration of different pieces of information and the satisfaction of multiple constraints. However, reasoning is dissimilar from decision making because *an objectively correct answer is not clear, and reasoning may not be influenced as much by affect*. Dr. Salthouse and his colleagues have administered a wide range of cognitive tests and found a decline in reasoning associated with increased age. They observed the same results when they administered standardized test batteries to stratified samples.

In a search for causes of these age-related differences, Dr. Salthouse and his colleagues first conducted studies based on an integrative reasoning task.[186] In one condition, all information was relevant, and subjects had to integrate it; in the other condition, only one piece of information was relevant, and no integration was required. Declines in reasoning were observed among older subjects regardless of the number of relevant pieces of information. Studies based on matrix reasoning also were conducted.[187] Both simultaneous and sequential presentations were used. Younger adults were more accurate at recognizing content that they had seen earlier, while older adults frequently made redundant inquiries. These results suggest that younger adults can maintain relevant information long enough to make a decision, whereas older adults may lose some early information because of redundant inquiries, which hinders their ability to make a decision. Similar results were observed when subjects performed a spatial reasoning task.[186,188,189] Thus, age-related declines in reasoning most likely result from an inability to maintain relevant information rather than an inability to integrate information.

Recently, Dr. Salthouse's research has focused on componential analyses, which are similar to the approach described in Dr. Finucane's presentation. Componential analyses assume that several components contribute to the performance of a criterion task. To assess the effects of age on the ability to perform that task, plausible components are identified, tasks are selected to assess those components, the relation of those components are examined, and age differences on both the components and the criterion are investigated. These analyses are limited because of the unknown validity of components. The analyses often rely heavily on a single variable, assume that the variable exclusively and conclusively represents a construct, and assume that all variants are reliable. To solve this problem, an investigator can have different reflections of a construct, each with different influences, and identify what is common to those reflections. The investigator can examine different indicators for each component. Thus, each component should have a strong relation with observed variables but not with other components.

Dr. Salthouse attempted to apply this componential approach to the matrix reasoning task. Hypothesized components included rule identification in which relations among cells are inferred, rule application in which the inferred relationship is applied to other rows and columns, and information integration in which rules are combined for rows and columns. Subjects

performed two different tasks for each component. Attempts to apply a componential approach to the matrix reasoning task were not successful. Because all components were highly correlated with one another, Dr. Salthouse and his colleagues were unable to establish that these components were distinct. The same pattern of results was observed with analytical reasoning tasks. Significant age differences were observed in the variables representative of each component, and there was no evidence for the construct validity of these components. Correlations across components were as large as those within components. Dr. Salthouse emphasized the need to administer tasks correctly, and he noted that components could correlate in cohorts or as they decline over the lifespan. These challenges should be considered in future decision-making research.

Most reasoning tasks are designed to minimize reliance on knowledge, yet knowledge is important. Dr. Salthouse described a study where individuals completed a questionnaire that asked them to rate how often they had trouble making decisions and planning for the future. Memory judgments increased dramatically with increases in age. Among subjects with approximately 16 years of education, none self-reported problems with decision making or with planning for the future. It is possible that subjects did not self-report declines in decision making or differences in reasoning because their knowledge overwhelms their processing determinants. Study results, particularly age trends, could look different if tasks require an extensive reliance on knowledge. Dr. Salthouse described studies that compared an analytical reasoning task and crossword puzzles.[190] Both of these tasks required reasoning while satisfying multiple constraints. In four separate studies, each with approximately 200 subjects, analytical reasoning declined with increasing age. When knowledge was parceled out of the crossword group, older adults showed similar declines, consistent with the idea that knowledge overwhelms processing.

To determine whether subjects of different ages are comparable and whether a study sample is representative of a population, Dr. Salthouse and his colleagues took advantage of standardized tests from commercial test companies and compared scores with those from a nationally representative, normative sample. The Wechsler Adult Intelligence Scale (WAIS), for example, showed that this sample had higher functioning than the general population. For the WAIS vocabulary scale, scores were much higher among older groups in Dr. Salthouse's sample. For the WAIS digit symbol scale, scores were higher overall in Dr. Salthouse's sample, but they declined with increasing age in a manner similar to the general population.

It has been established that cognitive variables are not independent of one another; thus age-related variables are not independent of one another. Therefore, Dr. Salthouse proposed that new variables should be interpreted in the context of an existing structure or context that includes related variables even though these other variables might not be of interest. Reference abilities can be organized, and relationships between these abilities and between these abilities and age can be examined. Target variables thus could be said to represent one construct more than another. This approach can help determine what effects are unique. Dr. Salthouse and his colleagues tried this approach with three tests of executive functioning and found age differences, but these differences were mediated through known effects. They found that the Wisconsin Card Sorting Test primarily measured reasoning, the Stroop Test primarily measured speed, and the Keep Track Test primarily measured reasoning (rather than memory). Decision-

making researchers can use multiple measures to test their intuitions objectively and develop procedures by choosing the best variables involved in decision making.

Dr. Salthouse cited several implications for decision-making research. Because most cognitive variables are interrelated, decision making should not be considered in isolation. It is important to determine the extent to which age-related effects on decision making are unique and statistically independent of age-related effects on other cognitive variables. In addition, the representation and comparability of samples in age-comparative research should be assessed, and attempts to investigate components of decision making should evaluate the construct validity of the hypothesized components. Finally, studies of decision making should consider the role of relevant knowledge in the performance of a task.

Discussion

In response to a question about moderators and areas where knowledge breaks down, Dr. Salthouse stated that his crossword studies specifically looked at a demanding activity to see if it moderated age trends. Again, no moderation was observed. In response to questions about cohort differences, Dr. Salthouse noted that the time frames for the studies he described were too narrow and that no systematic cohort effects were observed. He speculated that cohort effects do exist and most likely are more detrimental to longitudinal comparisons than cross-sectionally. Some participants expressed concern that the approaches Dr. Salthouse described might be too rigid and deterministic. Dr. Salthouse responded that he did not want this approach to become too rigid and that he is looking for moderators because of his view that researchers tend to overrate one component.

Dr. Salthouse noted that in some domains it is hard to see how all assessments measure a single construct. He noted for example that in the executive function domain the Wisconsin Card sort seemed to contain several components of cognitive functioning, but it was the "gold standard" for executive functioning. Participants noted that the gold standard for testing executive functioning was a matter of debate. Dr. Elias pointed out that the Wisconsin Card Sorting Test is no longer considered the gold standard for executive function as investigators have become aware that the task involves several cognitive constructs. Dr. Elias commented that in general it was a good idea to evaluate cognitive measures for the constructs they represent and agreed with Dr. Salthouse that seemingly similar measures can sometimes contain very different constructs. By example, he noted that the tachistoscopic presentation Stroop Test was a more pure measure of conflict and congruency, but the reading Stroop Test now includes several executive components in addition to congruent or conflictual information. The tachistoscopic Stroop essentially "pulls" the participant into the task a single presentation at a time. The reading Stroop allows participants to provide the motivation to keep reading quickly, to monitor their own speed and accuracy of performance, and to have other thoughts be a part of, or conflictual with, the list-reading task. A researcher might assume that a single measure of inhibitory function was represented in the outcome variable, but the other executive components present in the task should be kept in mind. Dr. Salthouse responded that the approach he described would be helpful in this case because it could provide a way to validate hypotheses. Relevant to the discussion of variables related to decision making, Dr. Elias noted that the Wisconsin Card Sort task had definite components of winning (correct sort) and losing (wrong sort) and a change of sorting strategy involved aspects of affect, matching and mismatching of expectations, and loss avoidance as well as reasoning. Given our increasing knowledge of the importance of inherent

responses to success, failure, and expectations, it was suggested that cognitive tasks should be examined for these components to better understand how such inherent value processing affected cognitive performance.

A work group participant pointed out that to understand aging and decision making and to identify prescriptive ways to alleviate problems that older adults might have, underlying mechanisms must be understood. Dr. Salthouse noted that if a determinant of DMC or effectiveness is related to factors that generally decline, one must be careful about the interventions proposed. A researcher also could state an interest in a particular type of decision making and then examine knowledge and heuristics that are relevant to that type. For example, specific training might be useful for relevant situations, but more general interventions might be needed for general deficits.

Industrial psychology's emphasis on knowledge, skills, ability, and other factors recognizes the separate components for determining functioning in the workplace. It is possible that knowledge and skills increase with age but that ability might decline. Thus, all interactions should be understood. Other participants also noted the need to draw more from studies using animal models, including *Drosophila* and rabbits, which also show age-related declines. Yet another participant noted the importance of examining what happens in the brain at the molecular level and thinking about that in terms of cognition. In this case, correlating age-related effects makes sense because these effects may depend on the biological effects of aging on the cells. Work group participants agreed, but they also noted other factors by which individuals vary. Some variables do not decline with age. All of these considerations are consistent with the model Dr. Salthouse has proposed. Social networks, decision environments, task characteristics, and types of decisions also should be examined.

General Discussion

As part of the general discussion, Dr. Elias asked Drs. Peters, Knutson, and Suzman to speak on specific issues.

Affect and Numeracy

Processes underlying decision by description differ from those underlying decision by experience. Experienced affect might become more important with age due to activation of chronic goals and associations with affective reativity,[118,191] or due to cognitive limitations causing a shift in processing. Decisions by description might activate more situational goals. Dr. Peters reported on a study that her group conducted on experiential decision making. This study used a simplified experiential choice task loosely based on the Iowa GT and manipulated conditions such that subjects made a simple choice or deliberated before they made their choices. The literature offers conflicting views on the effects of deliberation on decision making. Some studies have concluded that increased deliberation can result in greater satisfaction with decision aids, especially if important attributes are the focus of deliberation.[192] Other studies have concluded that increased deliberation can impair judgment and choice.[193] Dr. Peters and her colleagues hypothesized that increased deliberation might hinder access to more intuitive and affective components of decisions.

In the task, undergraduate students and older adults were randomly assigned to one of three conditions, simple choice without deliberation, a deliberative choice based on the numerical probability of winning, or a deliberative choice based on verbal probability. A series of cognitive measures were performed during the task, including vocabulary, speed of processing, WM, numeracy, and affective reactivity. In a hierarchical linear regression model, younger adults made better choices overall, but older adults explored more and chose more often. Both groups showed greater risk aversion after a win. Younger adults clearly made the best choices without deliberation. Although the effects of deliberation were not obvious among older adults, according to mean data, a transition did appear in which the older group performed better during deliberations, particularly those based on verbal probability. Among the cognitive measures, only WM (specifically with gain choices) significantly interacted with the effects of deliberation. Across conditions, older adults higher in WM showed improved learning of positive information. Among younger adults, there was a significant interaction between decision making and number ability. These results were consistent with studies presented by Dr. Carstensen and memory work done by Mather and Knight.[194] Dr. Peters noted the importance of considering decision-making tasks as different and activating different goals.

Dr. Peters had stated that younger adults had performed better when they simply chose as opposed to when they received help. Dr. Johnson pointed out, however, that the deliberation conditions might not help them; rather, they might focus the younger adults on winning. He suggested a reverse study in which the groups are asked about the probability of losing. Dr. Peters responded that she had considered that experiment but had not done it because of sample size limitations.

The work group discussed the effects of numeracy on motivational shifts from chronic goals. Dr. Peters reiterated that younger subjects tended to rely on numeracy and have a negativity bias. Numeracy only related to choices from the loss decks. Dr. Peters speculated that high-numerate people are more geared to probabilistic information even in the experiential choice task.

One participant suggested that what Dr. Peters has observed has to do with cognitive functioning overall rather than on numeracy alone. Dr. Peters noted that among younger adults, those with high numeracy appeared to be better off cognitively. Among older adults, those with high WM appeared to be better off cognitively, but they showed the positivity bias predicted by Carstensen's theory. This is consistent with a motivational explanation; younger people in the learning mode would attend more closely to negative information. Thus far, Dr. Peters has controlled for other variables and focused on numeracy but has not examined how various cognitive constructs fit together.

Considerations in Neuroimaging

Neuorimaging is expensive but can be useful in decomposing components involved in complex processes like decision making. Pointing to the componential approaches proposed by Dr. Salthouse, Dr. Knutson noted that neuroimaging could be used to validate conceptual measures. Neuroimaging also will become useful in testing or validating predictions about different areas of decision making as a function of different areas of the brain. Dr. Knutson cited cross-validation, logistic prediction of choices, time, and space as examples.

Another application would involve showing study subjects movies or images, gathering information, and entering that information into regression models. Several statistical and mathematical models exist for large arrays of data, and there are several ways of predicting choices based on brain activation. Participants highlighted research by Sanfey, which used a dictator game, and McClure, who has examined parietal activation. Dr. Knutson commented that these studies were correlative and had not examined when activation occurred relative to choice. There is more room for precision and the ability to predict on a trial-by-trial basis.

General Issues

The work group discussed the distinctions between decisions by experience and decisions by description. One participant pointed out, for example, that decision by description does not use short-term memory.

Dr. Suzman mentioned gerontological studies that examine the texture of every day life, including activities of daily living and instrumental activities of daily living. These activities are used to measure disability in functioning, but more varied and fine-grained approaches are needed, including in the context of decision making. Dr. Suzman suggested an area of research that will involve remeasuring areas of competence without relying on self-report. Other participants suggested studies examining the degree of anxiety in financial decision making. For example, in the Medicare Part D studies, various types of negative emotion were observed consistent with other studies reporting stress associated with hypothetical choices. When individuals are faced with emotionally difficult tradeoffs and more negative emotion, they might use more simplifying decision-making strategies such as the status quo. The work group also discussed libertarian paternalism as a cost of default decisions and the need for ethical considerations in these defaults. Examples include the use of air bags in cars, which could kill people of small stature. The work group agreed that defaults should be customized and that policymakers should make an extra effort to provide ethical default options. Participants also remarked on the immediate impact of affective priming when decision makers are faced with a win-lose situation.

Funding Considerations

Dr. Suzman commented that in discussing the National Academy of Sciences report on behavioral, cognitive, and sensory sciences, many had raised the issue of difficulties in getting subject pools for these types of research. The NIA is considering ways to develop subject pools around centers of psychological research. Dr. Suzman also noted that in the last Health and Retirement Study, there was a great deal of discussion about bringing the laboratory and survey worlds closer together so that the depth of the laboratory could be paired with survey information about differences and the total population.

In terms of review, Dr. Suzman cautioned the work group that the field of decision making and aging might run into difficulties with traditional review sections, especially if applications incorporate different approaches that have not been well represented on the review committee. Applicants should send a letter to the NIH with their recommendations for reviewers, potential conflicts, and special issues. This letter can be forwarded to study sections to alert them to the types of applications that they will see. The field of decision making and aging also might be a

good area for small program projects, which can be used effectively to combine disciplines and approaches to data collection. This topic is in the core for the Roybal Centers for Applied Gerontology, which also seeks to push basic science forward through a combination of basic and applied science.

Ideas for Future Research

The NIA is keen to support areas of practical importance, in which innovative approaches can push basic science forward, as well as practical applications. Work group participants were encouraged to begin thinking about possible applications. The work group discussed a number of ideas for future research in decision making and aging, including the following:

- ***Identifying the need and extent of the problem***. It is not clear whether older adults who make poor decisions tend to make poor decisions overall or only in specific contexts or domains. It is possible that older adults do not make poor decisions but have some difficulty or take more time in their decision making. It is also possible that older individuals must make more complex decisions than other age groups. Some data have been published on older individuals' inability to comprehend critical components of a decision-making process, and other studies have shown that older people are more susceptible to scams.

- ***Defining a good decision***. Establishing a set of standards to define a good decision is of the utmost importance. These definitions might be implicit, but they are not necessarily obvious. Consistency, rationality, and outcomes have been suggested as standards, but work group participants pointed out that although inconsistency might be evidence of a poor decision, consistency was not necessarily evidence of a good one. Some participants suggested dominance as a gold standard. If someone chooses an option that is better than all others, then that person is making a good decision. Weights and domains also should be considered.

  The work group also cited studies suggesting regret as evidence of a poor decision. The brain mechanisms in good decision making also should be studied, and molecular cognitive issues should be incorporated into criteria. Most animal studies have been based more on reward than motivation, and although some neuroimaging studies have been done in humans, few have focused specifically on decision making in a reductionist way. Participants cited studies in drug addicts where activation of certain areas of the brain predicted who would relapse, studies in which subjects are given statements and their reaction times are measured, and foraging studies exploring optimization versus probability matching and mechanisms for encoding incentives. Decision making also could be analyzed along a genetic spectrum.

  Dr. Elias added to the discussion by suggesting three goals: (1) Development of clear normative criteria for evaluation of decisions, (2) exploration of the relation between decision making and quality of life, and (3) noting the affective and motivational components of decisions such as satisfaction, and/or winning and losing. Work group participants cautioned that regret might be too narrow a criterion to solely judge the good or bad aspects of a decision because someone might make a risky decision that leads to a poor outcome but not be unhappy about the decision that was made. Others cautioned that criteria might be specified but could include a broad range of characteristics. Distinctions also should be made

between objectively and normatively good decisions and subjectively and descriptively good decisions.

- ***Developing interventions to prevent suboptimal choices***. One participant suggested that while efforts are under way to define criteria for good decisions, interventions should be designed to prevent poor ones. This type of work would not require the optimal decision to be defined; it would simply help individuals not to make poor choices. Dr. Carstensen discussed her meetings with the American Association of Retired People and the U.S. Federal Bureau of Investigation, who are working together to limit scam susceptibility. So far, efforts have proved unsuccessful. These organizations have lists of scam victims, including chronic victims. Dr. Carstensen suggested a program project that accesses these lists and tests potential interventions among these populations. The work group also agreed that susceptibility to scams is an area where expertise or knowledge is limited. One potential intervention involves changing the questions individuals ask themselves before they make a purchase or choice. Dr. Finucane also mentioned classes at Kaiser that explain things older individuals can do to avoid scams. However, these programs have not been evaluated for effectiveness.

- ***Exploring intersections between decision maker, task, and context***. Dr. Finucane suggested that decision aids should provide an environment that does not require the decision maker to seek additional information elsewhere. Future research should explore the characteristics of the individual or the task as well as the environmental variables that could improve decisions overall. Anxiety is one characteristic of the individual. Throughout the meeting, the work group cited work by Luce[195] that showed that individuals might make what is considered to be a poor choice because the status quo makes them feel better. Another individual characteristic, response to feelings of familiarity, has been characterized carefully in memory studies where the context of the original information has been lost, but has been applied to decision-making research on only a limited basis. It is possible that unfamiliarity results in a requirement for more information and might serve as a precursor to emotional effects. Familiarity versus novelty also changes the processes underlying the decision. For example, imaging studies have shown a large amount of ventral striatal activation in people learning cues in a reward task. As people over learn the context and cues for the task, activation moves to the dorsal stratum. Yet, familiarity might be somewhat difficult to incorporate into the componential approach proposed by Dr. Salthouse.

- ***Understanding age differences in decision making***. It is important to distinguish unique age effects affecting decision making. The cognitive processes and components involved in decisions concerning wills, family arrangements, savings, and consumption are measurable and should be examined.

- ***Using new technologies to aid measurement***. New technologies are making it increasingly possible and cost-effective to bring the laboratory to the field, such as Web-based methods or handheld mobile devices like personal digital assistants for data collection and simple cognitive testing and magnetic resonance imaging caps to measure brain activity. These technologies should be integrated with the development of interest in aging and decision making so that the multiple components of decision making can be measured concurrently.

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Appendix 1

National Institute on Aging
Decision Making and Aging Work Group Meeting
Gateway Building 5th Floor Conference Room
7201 Wisconsin Avenue • Bethesda, Maryland
August 16-17, 2006

Agenda
(Rev. 8-15-06)

August 16 (Wednesday)

8:00 am Continental Breakfast

8:30 am Welcome and Introductory Remarks
Jeff Elias, National Institute on Aging

Invited Perspectives
Each speaker will have 40 minutes to present their research agenda in the area of decision making and aging, and should anticipate about 20 minutes for discussion.

8:45 am Measuring Decision Making Competence in Older Adulthood
Melissa L. Finucane, Senior Research Investigator
Center for Health Research, Kaiser Permanente Hawai'i

9:25 am Discussion

9:45 am Intertemporal Choice across the Life Span: A Query Theory Account
Elke U. Weber, Jerome A. Chazen Professor of International Business and Professor of Psychology and Management
Department of Psychology, Columbia University

10:25 am Discussion

10:45 am Break

11:00 am Query Theory and Memory Based Choice
Eric Johnson, Norman Eig Professor of Business
Columbia Business School, Columbia University

11:40 am Discussion

12:00 pm Lunch

12:30 pm	Working Memory and Individual Decision Making ***John Hinson***, Professor and Chair Department of Psychology, Washington State University
1:10 pm	Discussion
1:30 pm	Neural Antecedents of Financial Decision Making ***Brian Knutson***, Assistant Professor of Psychology and Neuroscience Department of Psychology, Stanford University
2:10 pm	Discussion
2:30 pm	Break
2:45 pm	Numeracy, Affect, and Decision Making ***Ellen Peters,*** Research Scientist Decision Research
3:25 pm	Discussion
3:45 pm	The Role of Motivation in Decision Making ***Laura Carstensen,*** Professor and Chair Department of Psychology, Stanford University
4:25 am	Discussion
4:45 pm	Adjourn
6:30 pm	Group Dinner **Rock Creek Restaurant** (Private Dining Room) 4917 Elm Street, Bethesda, Maryland (301-907-7625)

August 17 (Thursday)

8:00 am Continental Breakfast

Invited Perspectives—Continued

8:30 am Aging-related Influences on Judgments: Mediators of Heuristic Processing
Thomas Hess, Professor
Department of Psychology, North Carolina State University

9:10 am Discussion

9:30 am Aging and Reasoning
Timothy Salthouse, Brown-Forman Professor of Psychology
Department of Psychology, University of Virginia

10:10 am Discussion

10:30 am Break

10:45 am **General Discussion**
—Emerging themes in decision making, cognition, and aging

11:45 am Lunch

12:15 pm **General Discussion—Continued**

1:15 pm **Next Steps and Wrap Up**
Jeff Elias, NIA

1:45 pm Adjourn

Appendix 2

National Institute on Aging
Behavioral and Social Research Program
DECISION MAKING AND AGING WORK GROUP MEETING
August 16-17, 2006

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Rev. 08/17/2006

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Appendix 3

National Institute on Aging
Behavioral and Social Research Program
DECISION MAKING AND AGING WORK GROUP MEETING
August 16–17, 2006

SUGGESTED BACKGROUND READINGS
Rev. 08/23/06

Laura Carstensen:

Carstensen, L.L. The influence of a sense of time on human development. *Science*, 312: 1913–1915, June 30, 2006.

Jeff Elias:

Charness, Neil. Intelligent design for older adults. Division 20 Presidential Address, American Psychological Association, August 12, 2006. *(Slides show how mode of presentation affects responses by older adults. Slides 30-34 show how presentation affects recognition of emotional expressions.)*

Coan, J.A. & Allen, J.B. (Eds.) The Handbook of Emotion Elicitation and Assessment. Oxford University Press Series in Affective Science. In press.
Detailed Prospectus: http://apsychoserver.psych.arizona.edu/EmotionBook/prospectus.html

Reyna, V.F. & Farley, F. Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological Science in the Public Interest*, 7 (1): 1-44, 2006.

Reyna, V.F. & Lloyd, F.J. Physician decision making and cardiac risk: Effects of knowledge, risk perception, risk tolerance, and fuzzy processing. *Journal of Experimental Psychology: Applied*. In press.

Melissa Finucane:

Finucane, M.L. & Lees, N.B. Decision-making competence of older adults: Models and methods. Paper presented at the National Research Council Workshop on Decision Making by Older Adults, Washington, DC, November 29, 2005.

Finucane, M.L., Mertz, C.K., Slovic, P., & Schmidt, E.S. Task complexity and older adults' decision-making competence. *Psychology and Aging*, 20 (1): 71–84, 2005.

Thomas Hess:

Hess, T.M. Adaptive aspects of social cognitive functioning in adulthood: Age-related goal and knowledge influences. *Social Cognition*, 24 (3): 279-309, 2006.

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Hess, T.M., Osowski, N.L. & Leclerc, C.M. Age and experience influences on the complexity of social inferences. *Psychology and Aging*, 20 (3): 447-459, 2005.

Hess, T.M., Rosenberg, D.C. & Waters, S.J. Motivation and representational processes in adulthood: The effects of social accountability and information relevance. *Psychology and Aging*, 16 (4): 629-642, 2001.

John Hinson:

Hinson, J.M., Jameson, T.L., & Whitney, P. Somatic markers, working memory, and decision making. *Cognitive, Affective, & Behavioral Neuroscience*, 2 (4): 341–353, 2002.

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Whitney, P., Jameson, T.L., & Hinson, J.M. Impulsiveness and executive control of working memory. *Personality and Individual Differences*, 37: 417–428, 2004.

Eric Johnson and Elke Weber:

Johnson, E. J., Haeuble, G., & Keinan, A. Aspects of Endowment: A Query Theory of Loss Aversion. *Journal of Experimental Psychology-Learning Memory and Cognition* 33 (3), 461-474, 2007.

Weber, E. U. & Johnson, E. J. Constructing preferences from memory. In: Lichtenstein, S. & Slovic, P., (Eds.), *The Construction of Preference* (pp. 397-410). New York NY: Cambridge University Press, 2006.

Weber, E. U., Johnson, E. J., Milch, K., Chang, H., Brodscholl, J., & Goldstein, D., Asymmetric discounting in intertemporal choice: A query theory account. *Psychological Science*, 18, 516-523, 2007.

Brian Knutson:

Kuhnen, C.M. & Knutson, B. The neural basis of financial risk taking. *Neuron*, 47: 763–770, September 1, 2005.

Ellen Peters:

Peters, E., Hess, T.M., Väsfjäll, D. & Auman, C. Adult age differences in dual information processes and their influence on judgements and decisions: A review. Unpublished manuscript, 2006.

Peters, E., Väsfjäll, D., Slovic, P., Mertz, C.K., Mazzocco, K. & Dickert, S. Numeracy and decision making. *Psychological Science,* 17 (5): 407–413, 2006.

Timothy Salthouse:

Salthouse, T.A. Aging of Thought. In E. Bialystok & F.I.M. Craik, Eds. *Lifespan Cognition: Mechanisms of Change.* New York: Oxford University Press, 2006.

Appendix 4

National Institute on Aging
Behavioral and Social Research Program
DECISION MAKING AND AGING WORK GROUP MEETING
August 16-17, 2006

Background Documents: Prior NIA/BSR Activities

July 14-15, 2004 Decision Making and Aging Workshop Summary
NIA/BSR convened a small working group to share ideas in the area of decision making and aging. The presentations highlighted the importance of affect and motivation on judgments, probability perception, and decision making. Age differences in affective/experiential and deliberative processes have important theoretical implications for both theory and application. Some of the underlying themes of the discussion were: the need for greater cross-disciplinary understanding; the need to identify common problems of interest; the need for better models; and the need for better cognitive data.

November 29, 2005 Workshop on Decision Making by Older Adults
The Center for the Study of Behavior and Development, in the Division of Behavioral and Social Science, National Academies of Science, in conjunction with BSR, conducted this meeting. Topics discussed included the neural basis of decision making, the design of health decision aids, the role of affect and emotion in decision making, the effects of age and social context on decision making, and aging and decision making competence. The meeting was exploratory, to help develop directions for future NIA research in this area.

March 31-April 1, 2006 Neuroeconomics and Aging Meeting Summary
NIA/BSR convened an exploratory workshop to share ideas about neuroeconomics and aging around a set of defined workshop goals. Presentations from experts in aging research in areas of social, cognitive, and personality psychology; cognitive and affective neuroscience; decision-making; and health and retirement economics framed the discussion of how the neuroeconomics perspective can be applied most fruitfully to issues of relevance to aging. This workshop built on themes developed in two NIA teleconferences on Neuroeconomics of Aging held on August 12, 2005 and August 26, 2005. Participants' prepared statements of research opportunities in neuroeconomics of aging were circulated in advance of the teleconferences. A Request for Applications (RFA) in the Neuroeconomics of Aging (R21) was released on July 31, 2006 with an application deadline date of November 27, 2006.