NEUROECONOMICS OF DECISION-MAKING IN THE AGING BRAIN: THE EXAMPLE OF LONG-TERM CARE

Ming Hsu, Hung-Tai Lin and Paul E. McNamara

ABSTRACT

Purpose – *Long-term care (LTC) services assist people with limitations in the ability to perform activities of daily living (ADLs) as a result of chronic illness or disabilities. We discuss possible behavioral explanations for the under-purchasing of LTC insurance, as well as the current state of knowledge on the neural mechanisms behind these behavioral factors.*

Findings/approach – *Ideas from behavioral economics are discussed, including risk-seeking over losses, ambiguity-preferring over losses, hyperbolic discounting, and the effect of the aging process on the underlying neural mechanisms supporting these decisions. We further emphasize the role of age, as aging is a highly heterogeneous process. It is associated with changes in both brain tissue as well as cognitive abilities, and both are characterized by large individual differences. Therefore, understanding the neural mechanisms is vital to understanding this heterogeneity and identifying possible methods of interventions.*

Neuroeconomics
Advances in Health Economics and Health Services Research, Volume 20, 203–225

ISSN: 0731-2199/doi:10.1016/S0731-2199(08)20009-9

Research implications – *LTC financing and insurance is a looming issue in the next 10–20 years. It is important to understand the process by which people make decisions about LTC insurance, heterogeneity in decision processes across individuals, and how these decisions interact with changes in policy and private LTC insurance markets.*

Originality/value of the chapter – *By providing an overview of the current state of knowledge in behavioral economics of LTC insurance and the neuroscience of aging, this chapter provides some new directions in the emerging area of neuroeconomics of aging.*

INTRODUCTION

Long-term care (LTC) is a collection of services that assist people with limitations in the ability to perform activities of daily living (ADL) as a result of chronic illness or disabilities. The estimated lifetime risk of entering a nursing home ranges from 31 to 50%, with an average annual cost of nursing home care of $50,000 in 1998 dollars (Mulvey & Stucki, 1999). Total annual LTC expenditures in the United States total about $100 billion, approximately 10% of the entire US health expenditure.

LTC's burden on private and public finances is substantial. About 40% are paid for out-of-pocket (McNamara & Lee, 2004). The remaining percentage is borne by the taxpayer, primarily in the form of the Medicaid program (Congressional Budge Office, 2004). This, combined with the increasing life expectancy of population, is placing tremendous burden on the federal budget. LTC expenditure is estimated, in constant 2,000 dollars, to double by 2025 and increase five-fold by 2045 (American Association of Homes and Services for the Aging, 2006). Current estimates of the financial sustainability of the Medicaid program put the date of insolvency at around 20 years, in large part due to the high costs of LTC (Marron, 2006).

Under standard life-cycle models of saving, individuals smooth their consumption or expenditure to keep the marginal utility of money constant over time (Browning & Grossley, 2001). Thus, without any LTC financing plan, once individuals need LTC services at some point during their lifetime, their expected lifetime utility will fall since then.[1] The reason is that they have to modify their expected consumption bundle through relocating their consumption and savings to make up for the greater financial impact of needing LTC on their lifetime consumption plan. Contrary to the predictions of the standard model, and despite the substantial portion paid out-of-pocket, only about 10% of the elderly in the US have private LTC insurance (Congressional Budge Office, 2004). Such policies typically promise to pay up to a specified amount per day for nursing home and home health care services for policyholders who develop chronic impairments. Annual premiums average $1,000–2,000 if the policy is purchased at age 65, and considerably more if purchased later in life. Table 1 summarizes the cost of a typical LTC insurance plan (State Farm Insurance, 2006).

As is clear from the earlier example, to effectively plan for LTC insurance, the decision maker needs, at the least, to be able to trade off between present and future consumption. This requires taking into account risk attitude, time preference, and forecast income, and consumption before and during retirement. This is clearly a nontrivial task and perhaps it is unsurprising that individuals behave sub-optimally.

There are a variety of reasons why people do not purchase LTC insurance. The most commonly invoked explanation in the past has been that the elderly are misinformed (Task Force on Long Term Health Care Policies, 1987). This explanation is less relevant today than in previous decades. For example, the awareness of private LTC insurance as an option increased from 38% in 1995 to 63% in 1999 (American Association of Homes and Services for the Aging, 2006). Another explanation invokes the existence of Medicaid as a provider of service of last resort, which serves effectively to "crowd out" private LTC insurance (Marron, 2006). This is clearly an important factor. Preliminary figures estimate that Medicaid

Table 1. Benefits and Annual Premium of a State Farm Series #97059 Policy for the State of Illinois.

	Buy Today	Buy in 10 Years	Buy in 20 Years
		(Costs below Adjusted to Keep Pace with Inflation)	
	Age 55	65	75
Daily benefit	125	200	325
Annual premium	1,370	3,646	14,277
Daily benefit at age 85 with inflation protection	540	531	529
Total benefit dollars at age 85	985,943	968,454	966,138
Total premium to age 85	41,100	72,920	142,773

crowds out private insurance purchase for over half of households (Brown & Finkelstein, 2004b).

One explanation that has been convincingly ruled out as a primary cause of under-purchasing of LTC insurance is imperfection on the supply-side of the LTC insurance market. There are a number of causes for supply-side imperfection, including transactions costs, imperfect competition, and asymmetric information. Existence of such imperfection could lead to either higher than actuarially fair pricing or less than comprehensive coverage.[2] It was found, however, that supply-side imperfection explains a small share of the under-insurance. Using a dataset that included approximate two-thirds of industry-wide sales, Brown and Finkelstein found that, in contrast to limited coverage, there are widely available policies that will cover about 90% of the expected present value of expenditures for a 65-year-old (Brown & Finkelstein, 2004a). Moreover, they found the existence of *better* than actuarially fair prices for women;[3] yet insurance rate for elderly women is similarly low as men.

WEAK DEMAND FOR LTC INSURANCE: THREE BEHAVIORAL EXPLANATIONS

Given the considerable evidence that consumers violate predictions of the standard models, as well as the considerably difficult choices that consumers face, we turn to behavioral factors that may lie behind the departure from the standard models. Behavioral models have been influential in areas such as retirement planning and saving (Laibson, 1997; Thaler & Benartzi, 2004), insurance (Hogarth & Kunreuther, 1989), and more recently in the annuities market (Brown, Kling, Mullainathan, & Wrobel, 2008). Here we note three stylized facts that apply to LTCI: (i) outcomes are clearly stated in the loss domain, (ii) the probability of the disability is ambiguous,[4] and (iii) disability can occur many years in the future.

We will discuss each in turn, but first we will review some of the basic knowledge of cognitive and neural changes that are associated with aging. There are several reasons why an understanding of the neurobiological basis of decision-making is relevant here. Practically, age is associated with an inevitable reduction in brain tissue, as well as decline in various cognitive abilities (Fig. 1). As LTCI is a decision that impacts overwhelmingly those in late-middle age to old age, this may either ameliorate or exacerbate preexisting behavioral biases (as an example, the brochure in Table 1 gives

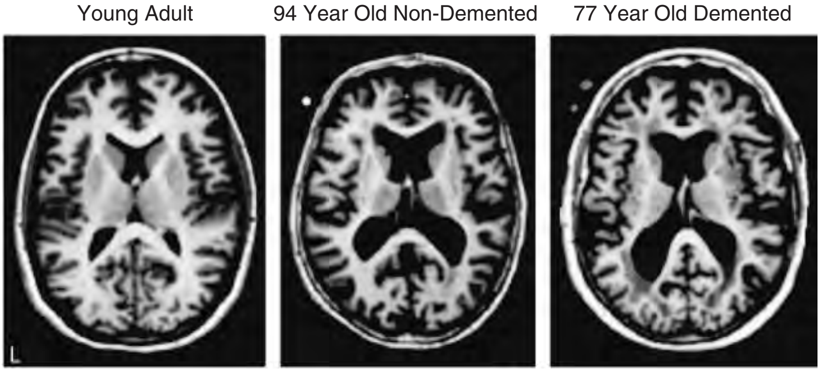

Fig. 1. Brain Differences between Young and Old, with and without Dementia (Adapted from Buckner et al., 2004). AU :1

examples of outcomes for 55-, 65-, and 75-years-old). More generally, using neuroscientific data may augment the predictive capabilities of standard economic models (Glimcher & Rustichini, 2004), as well as provide guidance for policy changes in investment for future generations (Heckman, 2007).

Age-Related Changes in the Brain

Perhaps the most striking feature of age-related changes is the heterogeneity of the aging process. This is a theme that will be repeated throughout the chapter. In terms of cognitive abilities or neural degeneration, there may be little difference between a low functioning 65-year-old and high functioning 85-year-old. That is, physical age can be a poor proxy of cognitive and neural aging. In general, aging is associated with both brain volume decrease and ventricular expansion (Raz, 2005). For example, in a review of five studies on older adults with mean ages 70–81, the median annual rate of expansion of the ventricles was 4.25% (2.90–5.56%). This is as compared to the rates of younger adults, which were an order of magnitude smaller (0.43%) (Raz, 2005). This includes reduction in gray matter in dopaminergic regions such as the striatum, as well as prefrontal cortices and the insula (Bäckman & Farde, 2005; Raz, 2004, 2005), regions that are critically involved in decision-making, as we shall see later in the chapter. However, there is substantial variability in effects of aging *within* the brain (Raz, 2005). That is, whereas there is comparatively minor decrease in gray matter

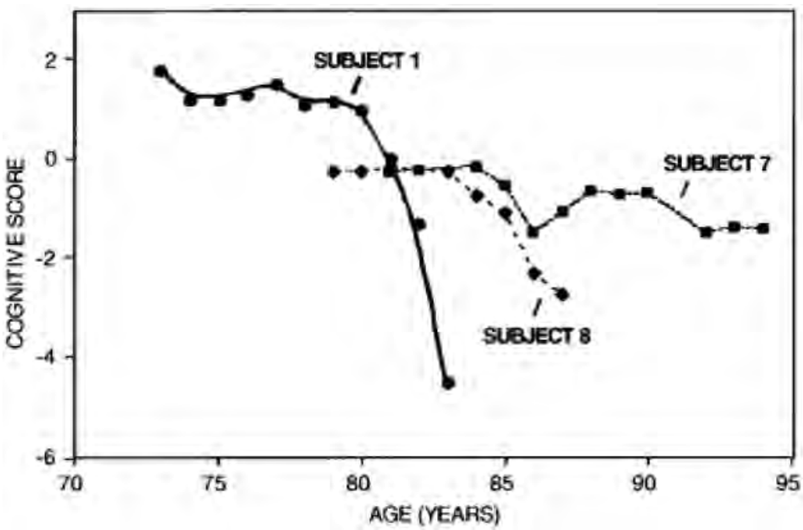

Fig. 2. Example of Longitudinal Cognitive Function in Three Individuals. *Note:* Dramatic Declines in Cognitive Functioning at Different Times for Subjects 1 and 8, and Intact Functioning in Subject 7 at an Extremely Advanced Age (Adapted from Buckner, 2004).

in the visual cortex, there is substantial degradation in prefrontal cortices (for survey, see Raz, 2005) (Fig. 2). AU :5

Given the known profound effects of aging on cognitive abilities, it is surprising that the search for aging-related changes in economic decision-making has so far found mixed results. One of the earlier studies by Kovalchik, Camerer, Grether, Plott, and Allman (2005) compared a group of healthy elderly individuals (ages 70–95) to a group of Caltech undergraduates. They found little difference between the two groups across a variety of different decision tasks in terms of (1) overconfidence, (2) Iowa Gambling Task (IGT), (3) endowment effect, and (4) strategic thinking (*p*-beauty contest). Other studies, however, find substantial differences. We shall return to this point further in later portions of the chapter.

Losses

Unlike savings and investments, LTC deals clearly with outcomes in the loss domain. It is well known in behavioral economics that decision-makers tend to be risk-seeking under losses – a finding that has underpinned the development of prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). This result has been confirmed in laboratory experiments (Cohen, Jaffray, & Said, 1985) and field data (Odean, 1998), with outcomes in health states (Verhoef, Dehaan, & Vandaal, 1994) and insurance contexts (Hogarth & Kunreuther, 1989).

Fig. 3 shows a hypothetic utility function in prospect theory. Note that the utility function is concave over gains and convex over losses. This corresponds to risk aversion for gains and risk-seeking for losses. Finally, losses have been found to be weighted more relative to gains, implying that the loss aversion coefficient $\lambda > 1$.

To see why risk-seeking behavior would result in under-insuring, note that an agent is risk-seeking if she prefers a gamble to the expected value of the gamble. That is, $\sum_{i \in S} p_i u(x_i) > u(\sum_{i \in S} p_i x_i)$, where p_i and x_i denote the probability and outcome in state i, respectively. For example, suppose that the agent will be healthy at age 80 with probability .75, but in need of LTC with probability of .25, which would cost her \$10,000. Since she is risk-seeking, she will reject an actuarially fair premium of (present value) \$2,500. Moreover, no insurance company can feasibly provide insurance to this agent, as it would generate negative profit in expectation.

In addition, there is good evidence that individuals exhibit patterns of preference in line with prospect theory when valuing health decisions and life durations (Verhoef et al., 1994; Bleichrodt & Pinto, 2005). Consistent with prospect theory, individuals' utility for living appears to be dependent on the reference point of the individual. Finally, there is much evidence that people behave inconsistently with expected utility theory in insurance markets. First, many people do not purchase insurance voluntarily

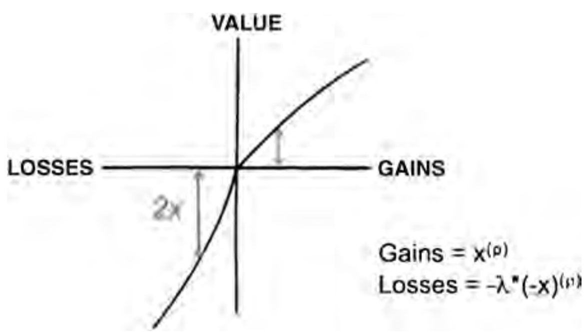

Fig. 3. A Utility Function under Prospect Theory.

(e.g., most states require mandatory automobile insurance). Second, econometric tests of field data rejects expected utility in favor of prospect theory, both in terms of non-nested model selection criterion and out-of-sample prediction (Marquis & Holmer, 1996). Finally, a crucial piece of evidence lies in the observation that people overwhelmingly reject what is called "probabilistic" insurance when it is offered to them at an actuarially fair price. This behavior violates expected utility theory, but can easily be explained by prospect theory (Camerer, 2001).

Recent neuroeconomic evidence shows that the amygdala is activated when choices are framed in terms of losses, as opposed to gains (De Martino, Kumaran, Seymour, & Dolan, 2006), suggesting a role for emotions in this overweighting. Failure to value gains and losses correctly has been found in patients with orbitofrontal and amygdala patients, mostly notably through the IGT (Bechara, Damasio, & Damasio, 2000; Bechara, Tranel, Damasio, & Damasio, 1996).

Furthermore, it is known that activity in the striatum and OFC is correlated with level of reward (Knutson, Adams, Fong, & Hommer, 2001; O'Doherty, Critchley, Deichmann, & Dolan, 2003), and the role of the insula in encoding for the valence of the stimulus (O'Doherty et al., 2003). It is now a widely accepted view that dopamine and dopaminergic regions – including the dorsal and ventral striatum, as well as the orbitofrontal cortex – are critical in different aspects of reward evaluation and reward (O'Doherty et al., 2004; Schultz, 2000, 2006). These regions undergo varying degrees of degeneration in aging humans. Parkinson's disease, for example, is characterized by the loss of pigmented dopaminergic cells in the substantia nigra. Understanding the neural mechanisms, therefore, is crucial given the prevalence and heterogeneity of such degeneration inherent in the aging process. Tom, Fox, Trepel, and Poldrack (2007) find that activation of the ventral striatum corresponds to both gains and losses. Whereas activation of the ventral striatum is positively correlated with the magnitude of the gains, it is negatively correlated with the magnitude of the losses (Fig. 4A). Importantly, differential response between gains and losses in the ventral striatum is highly correlated with behavioral measure of loss aversion (Fig. 4B).

Samanez-Larkin et al. (2007) conducted a rare study on age-related responses to gains and losses. In the study, 12 young and 12 older subjects were administrated the monetary incentive delay (MID) task. Unlike most behavioral economics studies, which focus on choice, the MID task is primarily focused on reward anticipation. In the MID task, subjects are given a cue that signals the amount of money one can gain or avoid to lose.

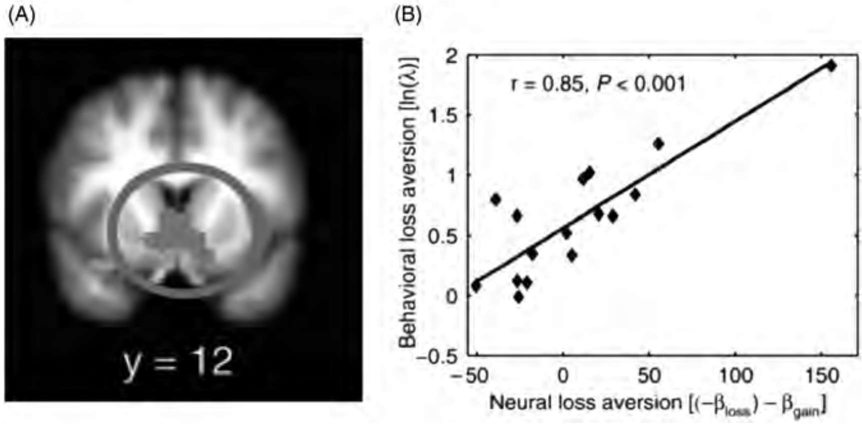

Fig. 4. (A) Conjunction Analysis of Ventral Striatum Activation with Respect to Response to Losses as well as Gains, (B) Differential Magnitude of Activation to Losses Minus Gains is Highly Correlated with Behavioral Loss Aversion (Adapted from Tom et al., 2007).

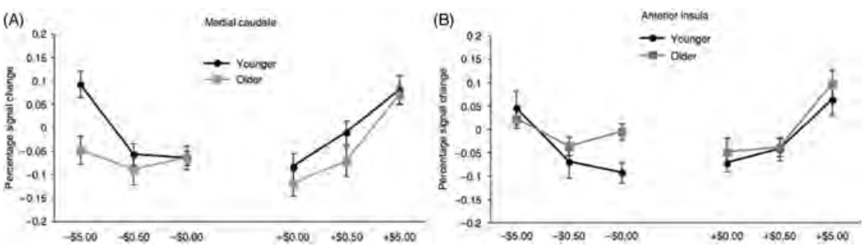

Fig. 5. BOLD Activation between Young and Old in (A) Medial Caudate and (B) Anterior Insula (Adapted from Samanez-Larkin et al., 2007).

Subjects win if they are able to press a button in reaction to a target quickly enough. Uncertainty is determined through calibration to the reaction time of the subject. This provides a straightforward method of assessing the neural correlates of reward anticipation in the absence of choice (Fig. 5).

Intriguingly, Samanez-Larkin et al. found a dissociation between neural responses to gain and loss in the caudate nucleus and the insula cortex. Whereas there were no differences between neural responses in the gain domain between young and older subjects, older subjects were found to have decreased activation in the loss domain relative to the young subjects. Due to the lack of a choice paradigm in the MID task, it is unclear how, or even whether, the neural changes will be reflected in choice behavior. Several intriguing possibilities exist. First, decreasing sensitivity to losses in these regions may lead to less risk-seeking behavior in the domain of losses. In addition, if the difference affects the relative weighting of losses to gains, this could also lead to lowered loss aversion. Finally, it is also possible that other regions may compensate for decreasing sensitivity in losses in these regions. Given the heterogeneity in the aging process, it will be important to include behavioral measures in future experiments to assess the impact of these neural changes on evaluation of losses.

Ambiguous Probabilities

In most real-life decisions, probabilities are vague and based on limited information. For example, a 65-year-old woman is unlikely to know the precise probability that she will need LTC at age 80. This is known in economics and decision theory as "ambiguity" (Ellsberg, 1961).

Fig. 6 illustrates the difference between risk and ambiguity. The deck on the left has a known proportion of red and black cards, and is said to be "risky"; the deck on the right has an unknown proportion of red and black cards, is said to be "ambiguous." Work in behavioral economics has shown that a substantial proportion of people are ambiguity-averse for gains and ambiguity-seeking for losses (for review, see Camerer & Weber, 1992).

Unlike risk-seeking behavior, which is modeled in expected utility theory as convexity of the utility function, ambiguity-seeking (averse) behavior is a violation of SEU (Ellsberg, 1961). A convenient form of representing

Fig. 6. The Deck on the Left is "Risky"; the Deck on the Right is "Ambiguous."

ambiguity attitudes is the α-maxmin model (Mukerji, 2003). In this model, agents are assumed to have set ordered priors over ambiguity, and take a linear combination of utilities under the best and worst case scenarios. For example, if an agent believes that the probability she will require LTC (cost \$10,000) is in the interval [0.25, 0.75], her α-maxmin expected utility would be $\alpha(0.25 \times 10,000) + (1 - \alpha)(0.75 \times 10,000)$. If the agent is perfectly ambiguity-seeking, $\alpha = 1$ and she will only buy actuarially fair insurance if the actual probability of requiring LTC were $p < 0.25$.

The application of ambiguous probability to insurance markets have been investigated by, among others, Hogarth and Kunreuther (1989). Hogarth and Kunreuther elicited willingness to pay from economically sophisticated subjects, including professional actuaries, under conditions of ambiguity and risk. They found that, except for small probabilities ($p = 0.01$), subjects were willing to pay *less* to insure against states with unknown probabilities (ambiguity), compared to those with known probabilities (risky) (see Table 2).

Work in neuroeconomics has elucidated the neural correlates and causal mechanisms of decision-making under ambiguity (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; Huettel, Stowe, Gordon, Warner, & Platt, 2006). This work has implicated the role of the amygdala, lateral OFC, and dorsal striatum in decision-making under ambiguity. Specifically, the amygdala and lateral OFC appear to signal ambiguity, while the dorsal striatum encodes a lower reward value for ambiguous gambles, compared to risky gambles (2005). AU :6

The role of the striatum is, therefore, a potentially important distinction between the behavioral effects of ambiguity versus those of loss framing. It suggests that while reward value is lowered for decisions under ambiguity, it is not under the loss frame. This is consistent with preliminary data suggesting that loss aversion can be reduced by cognitive regulation strategies (Sokol-Hessner, Hsu, Delgado, Camerer, & Phelps, in progress.); however, this has generally not been the case for ambiguity (Raiffa, 1961).

Table 2. Median Hypothetical Willingness to Pay to Insure Against a Possible Loss of \$100,000.

Probability Levels		Risk
.01	1,500	1,000
.35	35,000	35,000
.65	45,000	65,000
.90	60,000	82,500 AU :2

Source: Adapted from 17. AU :3

Finally, it was shown in (2005) that patients with OFC lesions were abnormally ambiguity-neutral as well as risk-neutral over gains. As all three regions are part of the dopaminergic pathway, this raises the counter-intuitive hypothesis that those with dopaminergic system degeneration may actually purchase *more* insurance, relative to healthy comparison subjects. AU :7

Subjects were given gambles with known or unknown probabilities, and chose between picking the gamble or a sure amount that carried no risk (see Fig. 7). The top-panel conditions are called ambiguous due to the fact that the subject is missing relevant information that is available in the risk conditions (bottom-panel).

In the Card-Deck treatment, ambiguity is not knowing the exact proportion of reds and blues in the deck, whereas risk is knowing the number of cards (indicated by numbers above each deck). In the Knowledge treatment, ambiguity is knowing less about the uncertain events (e.g., Tajikistan) relative to risk (e.g., New York City).

Subjects always choose between betting on one of the two options on the left side or taking the certain payoff on the right. The stakes in the gambles, certain payoff, and the ratio of red and blues (risk condition of Card-Deck

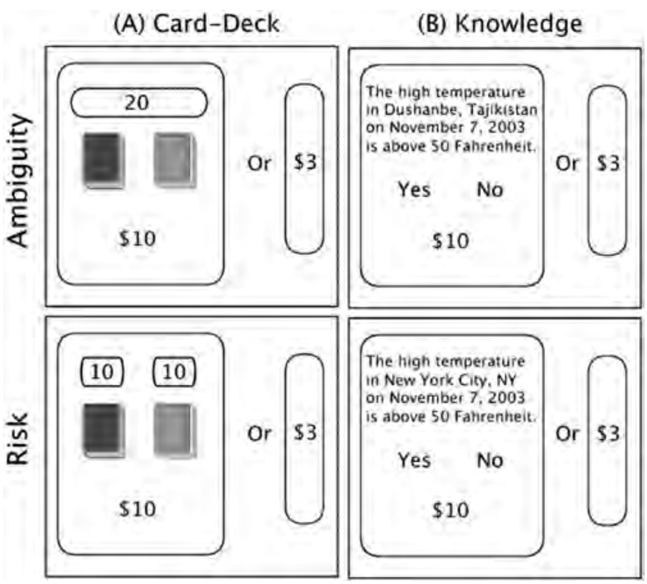

Fig. 7. Sample Screens from the Hsu et al. (A) Card-Deck Treatment, and (B) Knowledge Treatment.

treatment only) all varied during the course of the experiment. This enabled us to estimate subjects' risk and ambiguity attitudes from their choices.

The results of this imaging study implicated the role of the amygdala, lateral OFC, and dorsal striatum in decision-making under ambiguity. Specifically, it was hypothesized that the amygdala and lateral OFC signal ambiguity, while the dorsal striatum encodes a lower reward value for ambiguous gambles, compared to risky gambles (2005). AU :8

The latter is shown in Fig. 8. A random effects analysis strongly implicated the dorsal striatum as being more strongly activated during risk than ambiguity trials (Fig. 8A). This is consistent with the well-established finding that the dorsal striatum is involved in reward processing and anticipation (e.g., Schultz, Tremblay, & Hollerman, 2000; Knutson et al., 2001). This is further supported by results showing that the same dorsal striatal areas were significantly correlated with the expected value of the subjects' choices (Fig. 8C). In addition, the laterality of these activations is consistent with the fact that language processing tends to occur in the left brain, while more abstract mathematical processing tends to occur in the right brain.

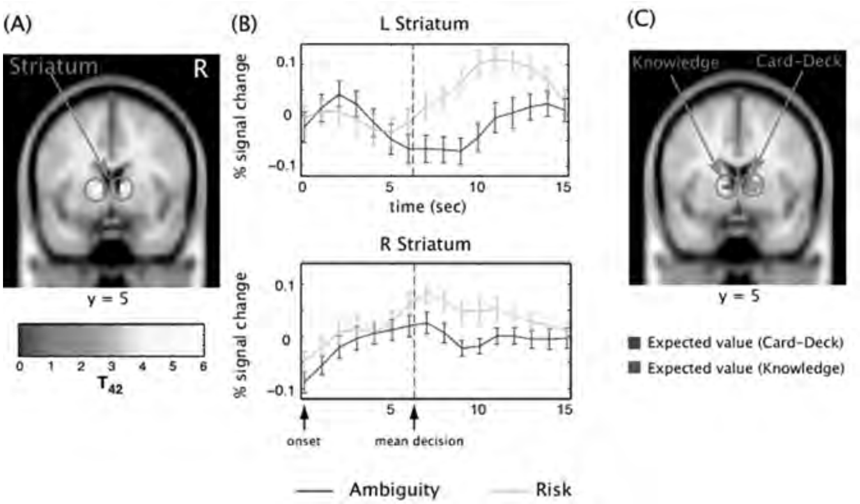

Fig. 8. (A) Greater Activation in Dorsal Striatum under Risk than Ambiguity ($p<0.001$, $k > 10$) and (B) Mean Time Courses (Time Synched to Trial Onset, Dashed Vertical Lines are Mean Decision Times; Error Bars are SEM; $n = 16$). (C) Activity in These Same Regions Also Show Correlation with Expected Value of Choices ($p<0.005$, $k > 10$).

To confirm the hypothesis that the lateral OFC is necessary for ambiguity aversion over gains, we, in collaboration with Daniel Tranel at the University of Iowa, conducted behavioral experiments similar to the Card-Deck task above using a lesion method. Twelve neurological subjects with focal brain lesions were partitioned into those whose lesions included the focus of OFC activation revealed in the fMRI study ($n = 5$) and a comparison group whose lesions in the temporal lobe did not overlap with any of our fMRI foci ($n = 7$). The two groups had equivalent IQ, mathematical ability, and performance on other background tasks as well as decision tasks. Parametric analysis using behavioral choice data from the patients confirmed the hypothesis that the lateral OFC is necessary for ambiguity aversion over gains. In particular, frontal patients are risk- and ambiguity-neutral. In contrast, the behavior of frontal patients was significantly averse to both risk and ambiguity.

To date, no known work has been done on the effects of aging on ambiguity attitude. There does exist tasks, however, that incorporate some aspects of ambiguity. These include in particular the IGT (Bechara et al., 2000; Bechara et al., 1996). In the standard IGT, subjects can choose from four decks of cards with varying schedules of gains and losses. Since the subjects do not know the distribution of gains and losses at the beginning of the experiment, the decks are *ambiguous* at the start and become *risky* towards the end of the experiment through learning.

Two studies have used the IGT to study decision-making and aging. As noted earlier, Kovalchik et al. (2005) compared a group of healthy elderly individuals (ages 70–95) to a group of Caltech undergraduates. The IGT was one of the tasks included in the paper. They find no significant differences between the two groups. On the other hand, a recent study by Denburg et al. (2007) did find significant differences between young and elderly subjects in the IGT. More importantly, they found the difference was driven mainly by an increase in the number of impaired individuals in the elderly group, rather than a global increase in the mean. Specifically, whereas only three participants out of 40 were significantly sub-optimal in the young subjects, 14 out of 40 were significantly sub-optimal in the elderly group (Fig. 9).

As is clear from our comparison of Kovalchik et al. and Denburg et al., behavioral effects of aging are not uniformly distributed in the elderly population. This underscores the point that aging itself is a heterogeneous process (Cabeza, Nyberg, & Park, 2005) and serves as an ideal illustration of the utility of combining different measures from a variety of disciplines. Imaging experiments can help elucidate this heterogeneity by looking at

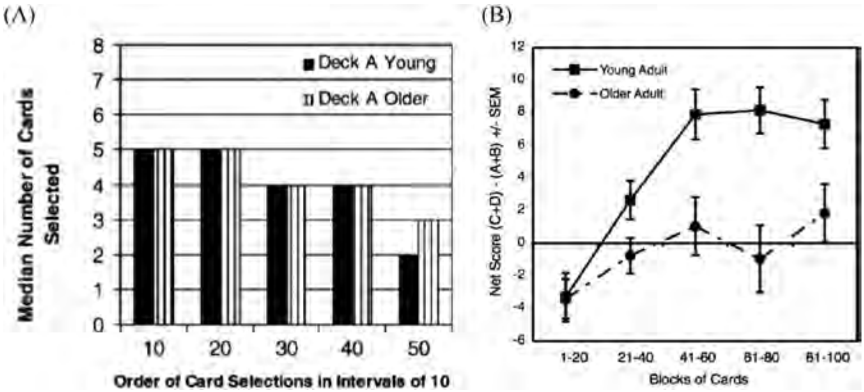

Fig. 9. Comparison of Two Studies on IGT Behavior in Aging Populations. (A) Kovalchik et al. Study Showing No Significant Difference between Young and Older Subjects. Abscissa is Median Number of Disadvantageous Cards Chosen. That is, Lower is Better. (B) Denburg et al. Study Showing Significant Difference between Young and Older Subjects. Abscissa is Difference between Advantageous and Disadvantageous Cards Chosen. That is, Higher is Better.

whether differential degeneration in regions such as the caudate and orbitofrontal cortex, implicated in Hsu et al., is driving individual differences found in Denburg et al. and Kovalchik et al.

Hyperbolic Discounting

The third stylized fact about long-term insurance is self-evident – the need for LTC can occur many years in the future. Moreover, insurance companies often require a period time, ranging from 30 to 90 days, before payment can begin (American Association of Homes and Services for the Aging, 2006). The perception and valuation of time, therefore, is critical to understanding behavior. Fortunately, time discounting has been extensively studied in both theory (Laibson, 1997) and experiments with both human (McClure, Laibson, Loewenstein, & Cohen, 2004) and non-human organisms (Mazur, 1987). This literature emphasizes the fact that organisms have a preference for immediate rewards. The theoretical literature has provided us with conveniently parameterized functional forms to capture the time inconsistencies (Laibson, 1997).

A comparison of the functional forms is given in Fig. 10: the standard time-consistent exponential discount function (assuming that $\delta = 0.97$), the

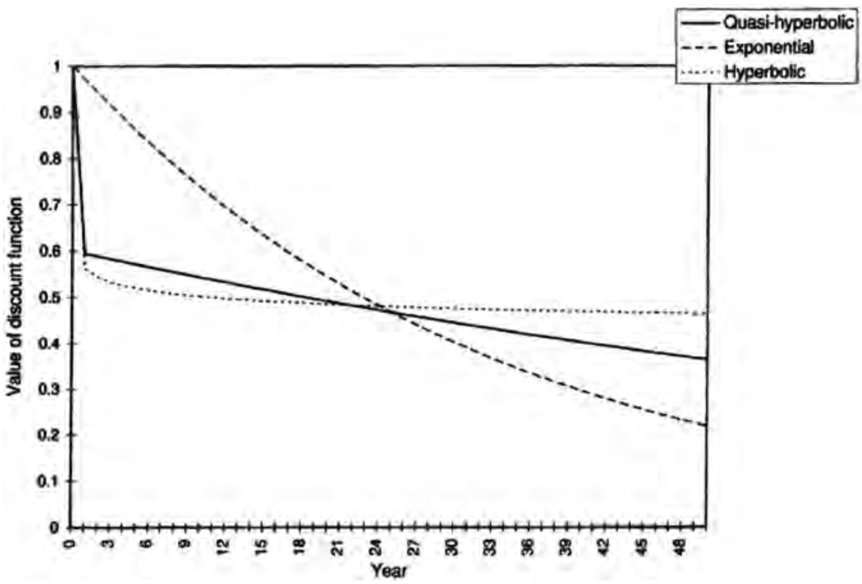

Fig. 10. Commonly Used Discount Functions [Adapted from 35].

generalized hyperbolic discount function (assuming that $\alpha = 10^5$ and $\gamma = 5 \times 10^3$), and the quasi-hyperbolic discount function (assuming that $\beta = 0.6$, $\delta = 0.99$). Note that both hyperbolic and quasi-hyperbolic discount functions underweight the immediate future much lower than does the exponential discount function.

To see how a quasi-hyperbolic agent will demand less insurance than that of a time-consistent (exponential) agent, note that the quasi-hyperbolic agent's utility function from present to future consumption is $u(c_t) + \beta\sum_{i=1}^{T-t}\delta^i u(c_{t+i})$ The exponential case can be treated as a special case with the constraint $\beta = 1$. A hyperbolic discounter would then value a loss of x dollars in t years as $\beta\delta^t u(c_t|x)$, whereas an exponential discounter would value this at $\delta^t u(c_t|x)$. Since $\beta < 1$ by assumption, the hyperbolic discounter will value the future consumption less in comparison, and hence will be willing to pay a lower premium to insure against the risks.[5]

Much work in economics, in particular, has focused on the distortionary effects of hyperbolic discounting on savings behavior as well as insurance (see Laibson, 1997). The results show considerable support for the hypothesis of hyperbolic discounting, and thus time inconsistency, in people's choices. In the case of financial choices, hyperbolic discounting results in over-consumption and under-saving (O'Donoghue & Rabin, 1999).

Applying neuroimaging to intertemporal decisions, McClure et al. found the ventral striatum to be differentially activated in immediate versus future rewards. Moreover, they hypothesized two competing systems involved in such decisions – a limbic system associated with immediate rewards, and a fronto-parietal system, including dorsolateral prefrontal and lateral intraparietal regions, with delayed rewards (McClure et al., 2004). They posited that the limbic region is associated with "immediacy-seeking," and the fronto-parietal system is a "rational" system (Fig. 11).

Although not viewed as directly involved in reward processing, dorsolateral prefrontal, temporal and parietal regions are known to be involved in working memory and executive function (Fabiani & Wee, 2001; Kramer, Fabiani, & Colcombe, 2006). Executive function, as it is commonly conceived, consists of two aspects: an evaluative aspect, related to forming, maintaining, and updating appropriate models of the environment

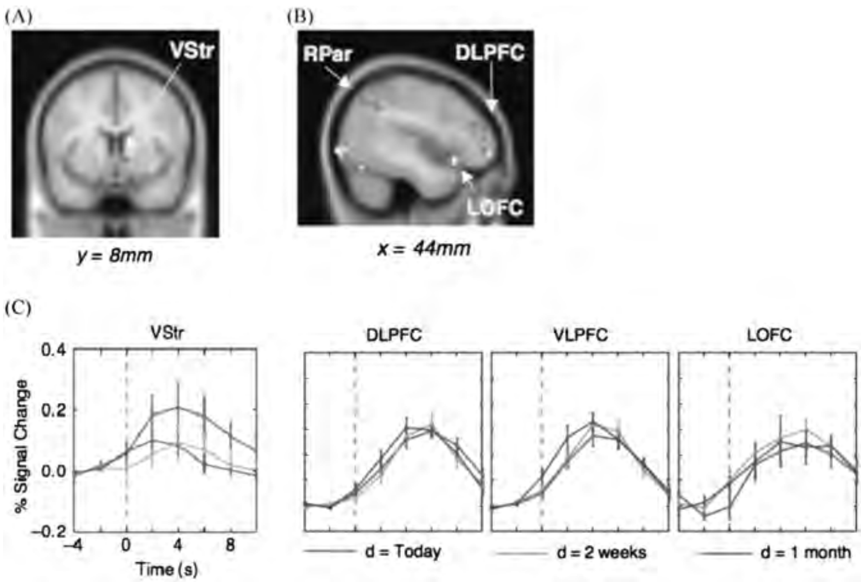

Fig. 11. (A) Ventral Striatum is Preferentially Activated for Choices when Money is Available Immediately, (B) Regions that are Activated by Choice but Independent of Delay Duration. (C) Hemodynamic Responses of Activations in (A) and (B) (Adapted from McClure et al., 2004)

(which may be carried out through various types of memory processes) and an action-oriented aspect, which is instead involved with the coordination of other cognitive functions, including perception, attention, and action. This coordination presumably takes place over time and is reflected in future behavior, so that when performed appropriately it can lead to successful adaptation to changing task demands (Fig. 12).

In general, there are also disproportionate changes across the adult lifespan in the brain structures subtending these functions. Further, these structural changes appear to parallel the age-specific declines in executive control and a subset of memory processes that are supported in large part by prefrontal, parietal, and temporal regions of the brain (Robbins et al., 1998; Schretlen et al., 2000) (Fig. 13).

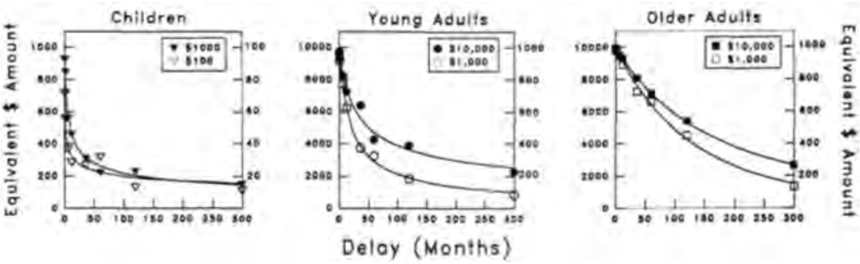

Fig. 12. Amount of Money Available Now (Top Right Corner of Graphs) and Equivalent Monetary Amounts by Delay Time (Adapted from Green et al., 1994).

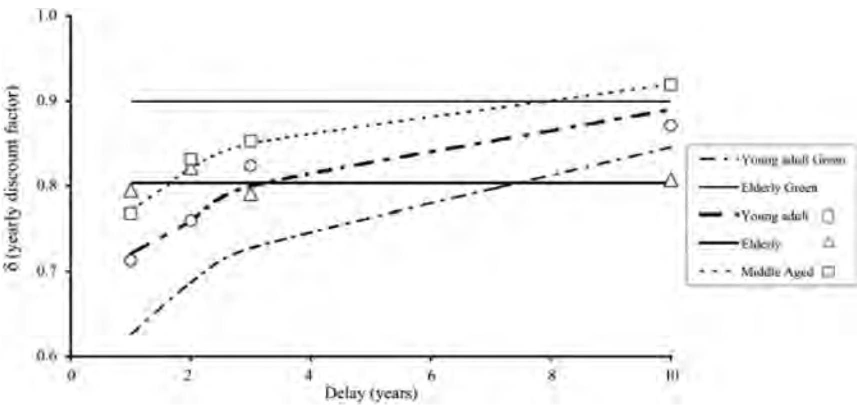

Fig. 13. Comparison of Discount Factor Across Time in Different Populations (Adapted from Read & Read, 2004).

Compared to the previous two topics mentioned, the effect of age on time discounting is relatively well informed by existing data. The seminal study of Greene et al. (1994) suggested that old adults discounted the future less steeply than children, who were the most steep, and young adults, who were intermediate. More recently, it was suggested that discounting has an inverse-U relationship with age, such that there is a tendency to discount more as one reaches extreme old age (Read & Read, 2004). However, it is unknown whether this is due to brain degeneration, possibly in regions involved in cognitive control such as the anterior cingulated, or to a rational response to end of life forecasts.

CONCLUSION

LTC financing and insurance is a looming issue in the next 10–20 years. It provides a concrete example of the type of decisions that neuroeconomics is seeking to understand by taking into account the role played by psychological and biological factors in observed behaviors. In addition, answers to these questions may yield insights that could help shape public policies regarding the regulation, organization and structure of LTC insurance markets and programs.

More broadly, on the demographic level, older people hold a substantial portion of society's wealth, owing to the fact that wealth tends to accumulate with age. Social and economic mobility, however, tends to decrease in age, as human capital accumulation is generally diminishing in age. These factors contribute to the importance of both individual planning and national policy towards issues of financial decision-making and planning in aging (Peters, Finucane, MacGregor, & Slovic, 2000). In addition, the demographic shift currently experienced by much of the developed world is turning many policy issues involving aging from "important" to "urgent."

Finally, structural and cognitive changes in the brain itself provide unique challenges but also valuable opportunities for studying decision-making, which so far has overwhelmingly focused on samples of healthy young adults. Studying neural contributions to aging introduces issues that are not present, or at least not as pronounced, in current studies that include mostly college-age adults.

This chapter provides three behavioral anomalies that may underlie some of the glaring violations of standard theory in the LTC market. There is overwhelming evidence of brain changes in the aging process, including many of the regions shown earlier to be critical to reward learning and decision-making. Therefore, in the face of potentially both cognitive and neurological decline, standard measures of welfare through revealed preference may be highly problematic. Nevertheless the existing evidence regarding effects of aging on decision-making is often contradictory. Many of these contradictions reflect the preliminary nature of current knowledge on the underlying biological processes, but they also point to the difficulty and complexity of the issues associated with aging noted earlier in the chapter. Future studies are needed to untangle these difficult but important questions.

NOTES

1. However, higher risk of long-term care needs may not disrupt planned consumption of individuals who are eligible for Medicaid. For Medicaid beneficiaries, long-term care costs will be covered without further depletion of assets and income. Therefore, the impact of long-term care on lifetime consumption smoothing decisions of Medicaid eligibility will be minimal due to the fact that their limited economic resources can continue to be devoted to their own or their dependent's consumption.

2. This is called "quantity rationing" in the economics literature, which serves to sort out agents by their preferences, given imperfect information about the agents' types.

3. Brown and Finkelstein estimated a load of −0.04 cents on the dollar for women. That is, those with insurance will get back $1.04 in expected present discounted value benefit for every dollar paid out (Brown & Finkelstein, 2004a). In comparison, acute health insurance policies have typical loads of .06–.10 (Newhouse, 2002).

4. That is, it is unlikely people can estimate the precise probabilities of becoming disabled or needing long-term care.

5. Note that unlike in the case of risk or ambiguity seeking behavior, it is possible for an insurer to sell an actuarially fair policy. This will occur if the insurer is sufficiently patient relative to the insured.

REFERENCES

American Association of Homes and Services for the Aging. (2006). *Financing long-term care: A framework for America*. AU :9

Bäckman, L., & Farde, L. (2005). The role of dopamine systems in cognitive aging. In: R. Cabeza, L. Nyberg & D. C. Park (Eds), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging*. Oxford, New York: Oxford University Press.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex*, *10*(3), 295–307.

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral Cortex*, *6*(2), 215–225.

Bleichrodt, H., & Pinto, J. L. (2005). The validity of qalys under non-expected utility. *The Economic Journal*, *115*(503), 533–550.

Brown, J., & Finkelstein, A. (2004a). *Supply or demand: Why is the market for long-term care insurance so small?* National Bureau of Economic Research, Inc. AU :10

Brown, J. R., & Finkelstein, A. (2004b). *The interaction of public and private insurance: Medicaid and the long-term care insurance market*. AU :11

Brown, J. R., Kling, J. R., Mullainathan, S., & Wrobel, M. V. (2008). *Why don't people insure late life consumption: A framing explanation of the under-annuitization puzzle*. National Bureau of Economic Research, Inc. AU :12

Buckner, R., Head, D., Parker, J., Fotenos, A., Marcus, D., Morris, J., & Snyder, A. (2004). A unified approach for morphometric and functional data analysis in young, old, and demented adults using automated atlas-based head size normalization: Reliability and validation against manual measurement of total intracranial volume. *NeuroImage*, *23*(2), 724–738.

Buckner, R. L. (2004). Three principles for cognitive aging research: Multiple causes and sequelae, variance in expression and response, and the need for integrative theory. In: R. Cabeza, L. Nyberg & D. Park (Eds), *Cognitive neuroscience of aging*. New York: Oxford University Press.

Cabeza, R., Nyberg, L., & Park, D. C. (2005). *Cognitive neuroscience of aging: Linking cognitive and cerebral aging*. Oxford, New York: Oxford University Press.

Camerer, C., & Weber, M. (1992). Recent developments in modeling preferences – Uncertainty and ambiguity. *Journal of Risk and Uncertainty*, *5*(4), 325–370.

Camerer, C. F. (2001). Prospect theory in the wild: Evidence from the field. In: D. Kahneman & A. Tversky (Eds), *Choice, values, and frames*. Cambridge: Cambridge University Press.

Cohen, M., Jaffray, J. Y., & Said, T. (1985). Individual behavior under risk and under uncertainty: An experimental study. *Theory and Decision*, *18*(2), 203–228.

Congressional Budget Office. (2004). *Financing long-term care for the elderly*. AU :13

De Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision-making in the human brain. *Science*, *313*(5787), 684–687.

Denburg, N. L., Cole, C. A., Hernandez, M., Yamada, T. H., Tranel, D., Bechara, A., & Wallace, R. B. (2007). The orbitofrontal cortex, real-world decision making, and normal aging. *Annals of the New York Academy of Sciences*, *1121*(1), 480–498.

Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. *Quarterly Journal of Economics*, *75*(4), 643–669.

Fabiani, M., & Wee, E. (2001). Age-related changes in working memory function: A review. In: C. Nelson & M. Luciana (Eds), *Handbook of developmental cognitive neuroscience*. Cambridge, MA: MIT Press.

Glimcher, P. W., & Rustichini, A. (2004). Neuroeconomics: The consilience of brain and decision. *Science*, *306*(5695), 447–452.

Green, L., Fry, A. F., & Myerson, J. (1994). Discounting of delayed rewards: A life-span comparison. *Psychological Science*, *5*(1), 33–36.

Heckman, J. J. (2007). The economics, technology, and neuroscience of human capability formation. *Proceedings of the National Academy of Sciences, USA*, *104*(33), 13250–13255.

Hogarth, R. M., & Kunreuther, H. (1989). Risk, ambiguity, and insurance. *Journal of Risk and Uncertainty*, *2*(1), 5–35.

Hsu, M., Bhatt, M., Adolphs, R., Tranel, D., & Camerer, C. F. (2005). Neural systems responding to degrees of uncertainty in human decision-making. *Science*, *310*(5754), 1680–1683.

Huettel, S. A., Stowe, C. J., Gordon, E. M., Warner, B. T., & Platt, M. L. (2006). Neural signatures of economic preferences for risk and ambiguity. *Neuron*, *49*(5), 765–775.

Kahneman, D., & Tversky, A. (1979). Prospect theory – Analysis of decision under risk. *Econometrica*, *47*(2), 263–291.

Knutson, B., Adams, C. M., Fong, G. W., & Hommer, D. (2001). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience*, *21*(16), 159RC.

Kovalchik, S., Camerer, C. F., Grether, D. M., Plott, C. R., & Allman, J. M. (2005). Aging and decision making: A comparison between neurologically healthy elderly and young individuals. *Journal of Economic Behavior and Organization*, *58*(1), 79–94.

Kramer, A. F., Fabiani, M., & Colcombe, S. (2006). Contributions of cognitive neuroscience to the understanding of behavior and aging. In: J. E. Birren & K. W. Schaie (Eds), *Handbook of the psychology of aging*. New York, NY: Academic Press.

Laibson, D. (1997). Golden eggs and hyperbolic discounting. *Quarterly Journal of Economics*, *112*(2), 443–477.

Marquis, M. S., & Holmer, M. R. (1996). Alternative models of choice under uncertainty and demand for health insurance. *The Review of Economics and Statistics*, *78*(3), 421–427.

Marron, D. B. (2006). *Medicaid spending growth and options for controlling costs*. Washington, DC. AU :14

Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In: M. L. Commons, J. E. Mazur, J. A. Nevin & H. Rachlin (Eds), *Quantitative analyses of behaviour: The effect of delay and of intervening events on reinforcement value*. Hillsdale, NJ: Lawrence Erlbaum.

McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science*, *306*(5695), 503–507.

McNamara, P. E., & Lee, N. (2004). Long-term care insurance policy dropping in the U.S. from 1996 to 2000: Evidence and implications for long-term care financing. *Geneva Papers on Risk and Insurance – Issues and Practice*, *29*(4), 640–651.

Mukerji, S. (2003). Risk, ambiguity and decision. *The Economic Journal*, *113*(485), F187–F188.

Mulvey, J., & Stucki, B. (1999). Retirement planning for baby boomers: The role of long-term care insurance. *Journal of Financial Service Professionals*, *53*(5), 53–58.

Newhouse, J. P. (2002). *Pricing the priceless: A health care conundrum*. Cambridge, MA: MIT Press.

Odean, T. (1998). Are investors reluctant to realize their losses? *The Journal of finance*, *53*(5), 1775–1798.

O'Doherty, J., Critchley, H., Deichmann, R., & Dolan, R. J. (2003). Dissociating valence of outcome from behavioral control in human orbital and ventral prefrontal cortices. *Journal of Neuroscience*, *23*(21), 7931–7939.

O'Doherty, J., Dayan, P., Schultz, J., Deichmann, R., Friston, K., & Dolan, R. J. (2004). Dissociable roles of ventral and dorsal striatum in instrumental conditioning. *Science*, *304*(5669), 452–454.

O'Donoghue, T., & Rabin, M. (1999). Doing it now or later. *American Economic Review*, *89*(1), 103–124.

Peters, E., Finucane, M. L., MacGregor, D. G., & Slovic, P. (2000). The bearable lightness of aging: Judgment and decision processes in older adults. In: Commission on Behavioral and Social Sciences and Education (Ed.), *The aging mind: Opportunities in cognitive research*. Washington, DC: National Academy of Sciences.

Raiffa, H. (1961). Risk, ambiguity, and the savage axioms – Comment. *Quarterly Journal of Economics*, *75*(4), 690–699.

Raz, N. (2004). The aging brain: Structural changes and their implications for cognitive aging. In: R. A. Dixon, L. Bäckman & L.-G. Nilsson (Eds), *New frontiers in cognitive aging*. Oxford, New York: Oxford University Press.

Raz, N. (2005). The aging brain observed in vivo: Differential changes and their modifiers. In: R. Cabeza, L. Nyberg & D. C. Park (Eds), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging*. Oxford, NY: Oxford University Press.

Read, D., & Read, N. L. (2004). Time discounting over the lifespan. *Organizational Behavior and Human Decision Processes*, *94*(1), 22–32.

Robbins, T. W., James, M., Owen, A. M., Sahakian, B. J., Lawrence, A. D., McInnes, L., & Rabbitt, P. M. A. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: Implications for theories of executive functioning and cognitive aging. *Journal of the International Neuropsychological Society*, *4*(5), 474–490.

Samanez-Larkin, G. R., Gibbs, S. E. B., Khanna, K., Nielsen, L., Carstensen, L. L., & Knutson, B. (2007). Anticipation of monetary gain but not loss in healthy older adults. *Nature Neuroscience*, *10*(6), 787–791.

Schretlen, D., Pearlson, G. D., Anthony, J. C., Aylward, E. H., Augustine, A. M., Davis, A., & Barta, P. (2000). Elucidating the contributions of processing speed, executive ability, and frontal lobe volume to normal age-related differences in fluid intelligence. *Journal of the International Neuropsychological Society*, *6*(1), 52–61.

Schultz, W. (2000). Multiple reward signals in the brain. *Nature Reviews Neuroscience*, *1*(3), 199–207.

Schultz, W. (2006). Behavioral theories and the neurophysiology of reward. *Annual Review of Psychology*, *57*, 87–115.

Schultz, W., Tremblay, L., & Hollerman, J. R. (2000). Reward processing in primate orbitofrontal cortex and basal ganglia. *Cerebral Cortex*, *10*(3), 272–283.

Sokol-Hessner, P., Hsu, M., Delgado, M. R., Camerer, C., & Phelps, E. A. (In progress). AU :15 *Intentional cognitive strategies reduce individuals' loss aversion*.

State Farm Insurance. (2006). *Long-term care insurance* [PDF Brochure]. State Farm 2006 [cited 2006]. Available at http://www.statefarm.com/_pdf/ltc/ZH_23558.pdf

Task Force on Long Term Health Care Policies. (1987). *Report to the congress and the secretary*. Washington, DC: Government Printing Office.

Thaler, R. H., & Benartzi, S. (2004). Save More Tomorrow (TM): Using behavioral economics to increase employee saving. *Journal of Political Economy*, *112*(1), S164–SS87.

Tom, S. M., Fox, C. R., Trepel, C., & Poldrack, R. A. (2007). The neural basis of loss aversion in decision-making under risk. *Science*, *315*(5811), 515–518.

Tversky, A., & Kahneman, D. (1992). Advances in prospect-theory-cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, *5*(4), 297–323.

Verhoef, L. C. G., Dehaan, A. F. J., & Vandaal, W. A. J. (1994). Risk attitude in gambles with years of life – Empirical support for prospect-theory. *Medical Decision Making*, *14*(2), 194–200.