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-prefering 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

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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. 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 Budget 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>
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<tr>
<th>Table 1. Benefits and Annual Premium of a State Farm Series #97059 Policy for the State of Illinois.</th>
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<tr>
<td>Buy Today</td>
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<tr>
<td>(Costs below Adjusted to Keep Pace with Inflation)</td>
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<tr>
<td>Age 55</td>
</tr>
<tr>
<td>Daily benefit</td>
</tr>
<tr>
<td>Annual premium</td>
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<tr>
<td>Daily benefit at age 85 with inflation protection</td>
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<td>Total benefit dollars at age 85</td>
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<td>Total premium to age 85</td>
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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
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. 1. Brain Differences between Young and Old, with and without Dementia (Adapted from Buckner et al., 2004.)
in the visual cortex, there is substantial degradation in prefrontal cortices (for survey, see Raz, 2005) (Fig. 2).

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.
(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, & Homer, 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.
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

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. 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 \( \alpha \)-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 \( \alpha \)-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).

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.

<table>
<thead>
<tr>
<th>Probability Levels</th>
<th>Risk</th>
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<tbody>
<tr>
<td>(.01)</td>
<td>1,500</td>
</tr>
<tr>
<td>(.35)</td>
<td>35,000</td>
</tr>
<tr>
<td>(.65)</td>
<td>45,000</td>
</tr>
<tr>
<td>(.90)</td>
<td>60,000</td>
</tr>
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</table>

Source: Adapted from 17.
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.

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.](image-url)
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).

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
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
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 $u(c_t) + \beta \sum_{i=1}^{\infty} \delta^i u(c_{t+i})$ 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 $\beta \delta^i u(c_{t|t})$, whereas an exponential discounter would value this at $\delta^i u(c_{t|t})$. 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

![Commonly Used Discount Functions](image)
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](image_url)

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).

![Figure 12](image1.png)  **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).

![Figure 13](image2.png)  **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.

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