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Age-Related Changes in Decision Making

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Abstract
Purpose of Review In light of global population trends, the decision-making capacity of older adults is a pressing societal concern. This review focuses on age differences in four key dimensions: valuation, risk taking, temporal discounting, and decision strategies.
Recent Findings Aging is associated with structural, functional, and neurochemical changes in neural networks implicated in decision making. However, these changes do not lead to universal deficits. Older adults are not always risk-averse, and their ability to postpone gratification tends to exceed that of younger adults. Age-related changes in motivation influence predecisional information search, valuation of decision outcomes, and selection of decision strategies. Furthermore, age differences are most pronounced when decision tasks tap fluid, rather than crystallized, cognitive abilities.
Summary The effects of aging on decision making are heterogeneous and reflect an interplay of cognitive, motivational, and social factors. Seniors' decisions in health care and finance present critical translational targets for this research.

Keywords Older adults · Choice · Risk taking · Discounting · Valuation · Decision strategies

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Introduction

Population aging is a global phenomenon, with the population aged 60 or over growing faster than any other age group [1]. In light of this demographic shift, there is significant pressure on public and private sectors to accommodate the growing numbers of seniors while minimizing the economic burden carried by younger age groups. One of the consequences of this societal challenge is the need for a better understanding of age-related changes in decision making. Decision-making competence is critical to successful aging in many respects. First, cumulative effects of day-to-day lifestyle decisions (e.g., diet, physical activity, social engagement) contribute to long-term outcomes, including quality of life, work productivity, and longevity. These outcomes, in turn, can have major economic and social ripple effects (e.g., labor market, public health care, caregiver burden). Second, single high-stakes decisions in domains such as motor vehicle operation, finance, and health care have a direct impact on the lives of older adults and their communities [2].

In the past 20 years, research on aging and decision making has seen unprecedented growth. This is illustrated by the emergence of a new interdisciplinary field, the "neuroeconomics of aging" [3], which applies neuroscientific, psychological, and economic perspectives to the study of the aging decision maker. Neuroimaging research has revealed significant age-related changes in both structure and function of the brain. In addition to a steady decline in whole-brain volume across the lifespan, there is evidence of reduced connectivity of white-matter tracts in normal aging, particularly in frontal and dorsal cortical regions involved in executive functions and strategic behavior [4]. There are also age-related alterations in the operation of functional brain networks, sometimes attributed to compensation or to neural differentiation [5]. In addition, there are well-documented neurochemical changes with age. For example, the dopaminergic system, critical

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for reward processing and cognition, shows pronounced age-related decline [6].

In this review, we focus on four major themes of decision making that have received considerable study: value, risk, time, and strategies. According to normative models of decision making, the attractiveness of choice options is defined by their expected utility, a probability-weighted subjective value [7]. Although these models are simplifications of human decision making, value and probability (or risk) are nevertheless central aspects of many decisions. Time affects choice when future outcomes must be considered in a decision, whereas strategies come into play when decision makers must cope with information-rich, complex choice scenarios.

Value

Decisions depend critically on the subjective value of each choice option. These values are typically the result of learning and may fluctuate moment to moment as a function of the current state of the organism and the environmental context [8••]. Valuation may also change in a more sustained fashion, reflecting age-related changes in brain function, as well as age-varying motivational priorities.

Processing of value signals (e.g., rewards such as food, money, or social reinforcers) occurs across anticipatory and consummatory stages and is critically supported by a "reward network" that encompasses dopaminergic neurons in the ventral tegmental area, as well as their projections in the ventral striatum and the ventromedial prefrontal cortex [9]. While age-related decline in striatal responses during reward anticipation has been observed in several studies [10–12], this seems to reflect age-related declines in learning, rather than changes in primary reward processing in older adults. That is, in "learning-free" tasks that do not require the acquisition of reward contingencies, younger and older adults show similar anticipatory brain responses to reward signals [13–16]. Similarly, striatal sensitivity to reward *outcomes* appears to be stable across the lifespan [15, 17]. With respect to losses, the picture is less clear. Some studies have reported reduced striatal activity during loss anticipation in older adults [15, 18], whereas one study found similar neural responses in younger and older adults [16]. Taken together, the evidence so far suggests that neural valuation processes—at both anticipatory and consummatory stages—are relatively intact in aging. However, a definitive conclusion about age differences in the neural response to loss signals would be premature.

An important limitation in the existing literature on age-related changes in valuation and reward processing is the use of monetary incentives in many studies. The monetary amounts at stake on individual task trials are often small (e.g., $0.10–$5.00) and may not adequately capture neural and behavioral patterns associated with high-stakes decisions [15–17]. Furthermore, despite evidence that monetary reward is a potent reinforcer across the lifespan [12], there may be subtle differences in how younger and older adults perceive and respond to financial incentives, particularly when age groups are not matched on socioeconomic characteristics [14•, 19]. In a study including both social rewards (smiling faces) and monetary rewards, older adults showed a stronger response for social rewards in the nucleus accumbens, a structure within the ventral striatum. In contrast, younger adults activated this region more strongly for monetary rewards [14•]. This intriguing result highlights the need for more research on potential lifespan changes in neural valuation processes for different types of rewards.

In addition to decisions that affect primarily ourselves, often in life we make decisions that benefit others (e.g., charitable donations). In a seminal study with younger adults, charitable contributions were shown to elicit positive affect and increased activity in the ventral striatum, similar to rewards that benefit the self, suggesting that individuals perceive donations as "personally rewarding" [20]. In light of aging research supporting an age-related increase in altruistic behavior (e.g., [21]), Hubbard and colleagues used a multi-method approach combining measures from psychology, behavioral economics, and neuroscience to explore age differences in general benevolence (GB), an altruistic trait. Results showed that the different measures converged on a single GB factor, which showed a strong positive association with age [22••]. Overall, these results highlight the importance of social context in valuation and decision making, particularly as individuals age.

Greater valuation of socially meaningful rewards in older age may reflect normative lifecycle and motivational changes. With advancing age, social networks become smaller due to physical limitations (e.g., increased fragility) and age-related role losses (e.g., death of spouse). Social exchange theory applies the economic theory of supply and demand to interpersonal relationships, whereby social behaviors are viewed as a result of an exchange process [23]. Therefore, as the number of social interactions decreases, their value increases. Another perspective, socioemotional selectivity theory, proposes that shrinking time horizons cause older adults to prioritize socially meaningful and emotionally gratifying information [24, 25]. This theory is supported by findings of an age-related positivity effect in attention and memory (i.e., greater processing of positive, relative to neutral and negative, stimuli [26]). Positivity has been associated with reduced amygdala sensitivity to negative stimuli [27, 28] and to reduced striatal sensitivity to losses [15]. However, given conflicting findings in the literature [29–31], the jury is still out regarding the generality and the neural correlates of age-related positivity effects in valuation.

Risk

Risk enters the picture when decisions have uncertain outcomes. Older adults are often assumed to be more risk-averse than younger adults, but this stereotype is not well supported in the literature [32]. For example, a meta-analysis of laboratory studies of risky decision making found no age differences when risky decisions were made from description [33]. Decisions from description involve explicit outcome probabilities, as is the case for weather forecasts (e.g., "30 % chance of rain") or prescription drug package inserts (e.g., "5 % chance of developing a skin rash"). In contrast, in decisions from experience, outcome probabilities must be estimated on the basis of past experience [34]. For this class of decisions, the meta-analysis revealed age differences in risk taking, but the direction of these differences depended on the learning demands of the task [33]. This suggests that younger and older adults may differ in their ability to learn about risks, rather than in their risk attitudes per se (although see [35]). In support of the learning hypothesis, a recent study employing an experience-based risky choice task showed that age differences in risk taking emerged only when the number of decision options—and therefore the information load—was high [36].

Neuroimaging research on age differences in risky decision making is limited, and small sample sizes make it difficult to generalize findings [8••]. Most studies examining risky decisions from description have found similar striatal and prefrontal brain responses to risk for younger and older adults [37, 38]. In contrast, age differences do seem to emerge in risky decisions from experience. One study showed reduced risk taking and increases in mean fMRI signals in the anterior insula in older adults [39], and a recent meta-analysis showed the anterior insula to be associated with risk assessment [40]. Furthermore, suboptimal risk taking in experience-based decisions may result from older adults' difficulties tracking the expected value of choice options, perhaps due to age-related increases in noisy dopaminergic signal transmission [41]. Supporting this hypothesis, fMRI signal variability in a region sensitive to expected value, the ventral striatum, [40] was greater for older adults and was associated with less optimal choices during an experience-based financial investment task [42].

The asymmetric pattern of age differences in risky decisions from description and decisions from experience maps onto a more general distinction between crystallized intelligence (i.e., the knowledge and skills accumulated over the lifespan) and fluid intelligence (i.e., learning and reasoning ability [43]). Preserved crystallized intelligence may allow older adults to make adaptive risky decisions when risks are described and do not require learning. Age-related decline in fluid intelligence, on the other hand, may negatively affect experience-based decisions that depend on new learning [8••, 44, 45].

In addition to age-related cognitive changes, lifespan changes in motivation and goal orientation may also contribute to altered risk preferences. According to loss prevention theory, aging is associated with a shift from a promotion focus (i.e., growth-oriented and acquisitive goals) toward a prevention focus (i.e., maintenance and loss-prevention goals) [46]. Similar predictions are made by socioemotional selectivity theory [24], which posits that reduced time horizons associated with aging lead to a preference for emotionally gratifying experiences. As noted, older adults' preference for positive information has sometimes been shown to affect cognitive performance in domains such as attention and memory [26]. In light of this positivity effect, older adults may avoid risky behaviors when there is potential for negative outcomes [47]. Indeed, one recent study assessing risk perceptions and attitudes found that age differences in risk taking may be domain-dependent. In the domain of health and safety, characterized by relative scarcity for older adults, there was an age-related decline in risk seeking. In social domains, in contrast, older adults were more risk-seeking than younger adults. For example, older adults indicated a greater willingness to take social risks such as attending a social event by themselves or disagreeing with an authority figure [48••]. Increased social risk propensity in older age may be associated with changes in social network composition. In particular, social circles become smaller with age (e.g., death of spouse, loss of social roles), but they also become more tightly knit due to an increased prioritization of socially meaningful goals [48••]. Greater social risk taking may be more "affordable" to older adults because their social relationships may be stronger than those of younger adults.

A finding that does not clearly fall in line with the predictions of either the loss-prevention account [46] or the socioemotional selectivity account [24] concerns the impact of choice framing on risk taking in younger and older adults. A recent meta-analysis [49] showed that when decision scenarios were framed in terms of gains, younger adults were more likely to take risks than older adults, whereas when scenarios were framed in terms of losses, there was no overall age difference in risk taking. These findings indicate that age differences in risk taking not only reflect age-related cognitive and motivational changes but may also depend on contextual factors such as the framing of the choice options.

How stable are risk attitudes over time? A recent longitudinal study assessed the lifespan stability of risk-taking propensity in a large German sample [50]. Risk-taking propensity was a moderately stable personality trait, with significant mean-level differences across the lifespan for both behavioral and self-report measures of risk taking. These findings lend confidence that previous studies using cross-sectional designs indeed reflected age-related, rather than cohort-specific, differences in risk taking.

Finally, it should be noted that most of the research on aging and risk taking has been conducted in North American and Western European countries, rendering generalization to other settings difficult. A recent cross-cultural study with older adults from 77 countries showed an overall age-related decline in risk propensity, as well as systematic variation among countries. Specifically, countries experiencing greater hardship showed less age-related reduction in risk taking curves than countries experiencing less hardship [51•]. Results from this study are the first to highlight the role of environmental resources on aging and risk taking.

Overall, the literature on aging and risk suggests that—at least for behavioral measures of risk taking—age differences may arise as a function of the "fluid" cognitive demands of the decision task. If one considers self-reported risk preferences in addition to behavioral laboratory measures of risk taking, many other factors emerge. These include age-related goal orientations, risk domain (e.g., health vs. social), framing of choice options, and cultural and socioeconomic variables.

Time

Many decisions have long-term consequences: Save money or spend it? Exercise or relax? The importance of future consequences is particularly salient during intertemporal decisions, that is, choices between outcomes that become available at different points in time [52]. The subjective value of outcomes decreases hyperbolically with increasing delay, sometimes leading to a preference for smaller-sooner over larger-later rewards. This phenomenon, known as temporal discounting [52], is maladaptive in the long run because it reduces the overall reward accumulated by the decision maker [53]. Laboratory studies in which participants are asked to choose between hypothetical monetary rewards available at varying delays have shown that aging is associated with reduced temporal discounting [54–56]. In other words, older adults are more willing than younger adults to forgo smaller-sooner rewards in favor of larger-later rewards. Interestingly, the picture is different when the choice is between a smaller-sooner and a larger-later loss. Here, both younger and older adults show minimal temporal discounting and typically opt for smaller-sooner over larger-later losses [56, 57].

One criticism of this literature is that hypothetical rewards may not elicit behavior representative of real-world decision making. Although most research suggests that hypothetical and real rewards produce similar choice patterns, some controversy remains with respect to their psychological equivalence [58, 59]. However, studies with younger and older adults using real monetary rewards have mirrored those using hypothetical rewards and have confirmed the age-related decrease in temporal discounting [54, 56].

Research into age differences in the neurobiological mechanisms of intertemporal choice is relatively limited to date. According to one prominent hypothesis [60], age-related decline in dopaminergic neuromodulation [6] contributes to a reduced response to immediate reward in older adults, which in turn reduces temporal discounting. To date, only two neuroimaging studies have explored this hypothesis, although neither of them measured or manipulated dopamine levels directly. Using fMRI, both studies found that younger adults showed greater activation in the ventral striatum for immediate relative to delayed reward options, whereas older adults did not show this pattern [54, 61]. Elsewhere, reduced ventral striatal activity has been associated with lower impulsivity [62], suggesting that older adults' greater preference for delayed options may reflect age-related decline in impulsivity. An interesting alternative interpretation is that older adults may be savvier than younger adults when forecasting the future value of delayed rewards [61]; see also [56, 63]. By this account, older adults' lack of striatal sensitivity to delay—and their reduced discounting tendency—would reflect an increase in life experience, rather than a decrease in impulsivity.

It is important to note that intertemporal decision making shows considerable interindividual variability within age groups, in addition to differences between groups. For example, older adults with high performance on the Iowa gambling task (IGT), a laboratory task of decision making often used as a marker of prefrontal function, also showed less temporal discounting than those with low IGT performance [57]. Furthermore, fMRI studies have shown that greater resting-state functional connectivity within the reward network is associated with steeper temporal discounting in both younger [64] and older adults [65]. Finally, in a study examining the role of brain structure in intertemporal choice in older adults [66•], the tendency to delay gratification was positively correlated with the cortical surface area of the dorsolateral prefrontal cortex, an area implicated in cognitive control and emotion regulation. These findings illustrate that individual differences in brain structure and function contribute to differences in intertemporal choice across the lifespan.

Age differences in intertemporal decisions may also reflect age differences in time perception. Similar to other physical dimensions, time is experienced in a non-linear manner [67]. For example, a 10-day delay is perceived as significantly longer if it occurs in the present than if it occurs in 5 years [68]. Research in younger adults has shown that delayed rewards become more attractive when the future event is framed as close in time [67, 69]. In light of evidence that older adults experience time as more compressed [70] and fast-paced [71] than younger adults, it may be the case that older adults exhibit less discounting of future rewards because they perceive these rewards as more proximal. On the other hand, older adults' uncertainty about their personal time horizons may also limit their willingness to postpone rewards, particularly if future exploitation of these rewards is contingent on scarce resources such as physical health and social support. In these cases, older adults may prefer smaller-sooner rewards, exhibiting a "now or never" attitude [24].

Two interesting current developments in the literature on intertemporal choice concern the impact of stress and of social factors, but both have been studied primarily in younger adults. Acute stress has been shown to increase discounting rates in younger adults [72], although see [73], but it is not yet clear how stress affects temporal discounting and delay of gratification in older adults. This question is of obvious practical significance, since many consequential decisions (e.g., about medical treatments) are made under stressful conditions. Social factors come into play when intertemporal decisions affect others (e.g., [74–76]). In one study on "surrogate" intertemporal choice, there was a positive relationship between social distance and temporal discounting on behalf of others [76]. However, there are also findings suggesting that decisions made on behalf of strangers are less short-sighted than decisions made for oneself [74, 75]. The impact of psychological distance on intertemporal choice for others has not yet been examined in older adults. In light of the critical importance of partner and family support around key decisions facing older adults (e.g., end-of-life care, personal finance), more research is needed to understand the influence of time discounting on surrogate decision making.

Strategy

The bulk of the literature reviewed so far included laboratory studies employing relatively simple two-choice decisions, but real-world decisions are often significantly more complex. One source of complexity is uncertainty about choice outcomes, which requires learning by trial and error through passive exposure or active exploration ("decisions from experience"). Another source of complexity is the presence of multiple options that vary along multiple dimensions. For example, consumers routinely choose among products that vary on attributes such as costs, benefits, risks, and delays. Effective use of decision strategies—systematic goal-directed mental operations—is critical for ensuring high-quality choice outcomes in the face of complexity [77].

Across multiple cognitive domains—memory retrieval, arithmetic, and decision making—a growing literature suggests that aging is associated with declines in overall strategy repertoire, strategy execution, and effective strategy selection [78, 79•]. Compared with younger adults, older adults seek out less information [29, 80], are more strongly biased by recent outcomes [81], and are more likely to choose simple heuristics, such as "win-stay-lose-shift," over computationally intense strategies that maximize expected value [82]. These age differences are expressed particularly under high cognitive demand (e.g., [36, 80, 83, 84]) and likely result from age-related declines in dopaminergic neuromodulation [6] and fluid intelligence (e.g., [85]). However, age differences in strategy use can also help buffer the impact of declining fluid capabilities on older adults' decision performance. Several studies have shown preserved or even improved decision quality among older adults (e.g., [86, 87]) and have tied this to adaptive shifts in strategy selection [88••]. A recent fMRI study examining a complex dynamic decision-making task, for example, showed no age differences in choice performance, but revealed significant age differences in strategy use. In particular, older adults engaged "reactive" decision-making strategies by recruiting lateral prefrontal regions, whereas younger adults were more likely to use expected value-based strategies by recruiting ventral striatal and medial prefrontal regions [89•]. This suggests that age-related shifts in strategy selection may serve an adaptive function by helping older adults to preserve decision quality under cognitively taxing circumstances.

An interesting question in modern society is how the size of the choice set—the number of available options—affects decision makers. While more choice is generally perceived as desirable, an overabundance of options can reduce choice satisfaction and motivation [90]. Older adults, in particular, display a preference for smaller choice sets across a variety of domains [91, 92]. The mechanisms driving older adults' preference for smaller choice sets are not well understood. In one study, no significant correlations between choice preference and relevant personality traits or cognitive variables were found [92]. When faced with many options, older adults seem to rely more heavily on a satisficing ("good enough") heuristic compared with younger adults, who in turn are more likely to adopt a maximizing ("find the best") strategy [93]. Finally, in line with the predictions of socioemotional selectivity theory and the age-related positivity effect [24], a landmark study on healthcare package choice showed that older adults preferentially reviewed positive choice attributes before finalizing their decisions [94], whereas younger adults did not show this bias. This suggests that age-varying motivational priorities guide strategic aspects of decision behavior, in addition to more "basic" aspects such as valuation, time perception, and risk taking.

In summary, strategies are key to successful decision making in the face of complexity as defined by the number of options, the number of attributes, or the learning demands of the decision task. There is significant evidence for age-related differences in strategy use. In particular, converging evidence suggests that reliance on less information and use of simpler strategies allow older adults to maintain performance despite reduced information processing capacity. This adaptivity is critically important in high-stakes domains such as health care, consumer choice, and personal finance. The role of individual-difference factors, such as fluid and crystallized abilities, personality traits, and motivational context in strategy selection, is still poorly understood, as are the neural mechanisms that drive age differences in strategic decision making.

Conclusion

The study of the aging and decision making has made great strides in the past 20 years. Despite age-related reductions in the structural and functional integrity of neural circuits involved in reward-based learning and valuation, healthy older adults' decision performance is not uniformly impaired. Age-related declines are most likely when decision tasks pose high demands on fluid abilities such as new learning and executive control or when they require the use of computationally intensive decision strategies. In contrast, tasks that tap crystallized capabilities tend to show little age-related change and may even place older adults at an advantage over their younger counterparts. Older adults are not generally risk-averse, and their ability to delay gratification tends to exceed that of younger adults. Age-related positivity and loss-prevention goals appear to influence older adults' predecisional information search, their responses to gains and losses, and their strategy selection. More research is needed to apply these insights to the design of senior-friendly decision tools in areas such as health care and personal finance. Additionally, more work is needed to understand the impact of social and interpersonal factors, as well as culture, education, numeracy, and personality traits on decision making across the lifespan.

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Compliance with Ethical Standards

Conflict of Interest Erika P. Sparrow and Dr. Julia Spaniol declare that they have no conflict of interest.

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