CHAPTER

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Age-Associated Executive Dysfunction, the Prefrontal Cortex, and Complex Decision Making

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p0015 Theories abound regarding how the "healthy" brain ages, and some of these go beyond conventional wisdom, which holds that aging is more or less synonymous with memory loss. Although memory does tend to decline with age, many older people experience far more dramatic declines in non-memory-related cognitive abilities, such as difficulties with concentration, problem-solving, and decision making. Unlike memory, which is strongly linked to the medial temporal region of the brain, these other abilities (referred to as "executive functions") are closely linked to the frontal lobes.

p0020 Older adulthood is a time of complex and critical decision making, in spite of age-related decline in frontal brain regions. To illustrate, older adults are faced with many complex and critical decisions regarding retirement, health care, finances, and living situations, and their ability to make such decisions successfully has a profound impact on the individual and society as a whole. Unfortunately, numerous neurologically and psychiatrically healthy older adults (i.e., persons not diagnosed with a neurologic or psychiatric disease, not suffering from Alzheimer's disease or any other of the "known" degenerative dementias) do not make advantageous decisions: they make poor financial choices, are taken advantage of by adult children, or get swindled.

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p0025 We have proposed that the vulnerability of such older adults is caused, at least in part, by a specific neurobehavioral change: the prefrontal cortex of their brain is deteriorating and thereby affecting cognitive abilities referable to this brain region. New functional neuroimaging findings, along with results from behavioral, psychophysiological, and structural imaging studies of the brain, indicate that these seniors may be losing their ability to make complex choices that require effective emotional processing to analyze short-term and long-term considerations. Older adults in this category may fall prey to the promise of an immediate reward or a simple solution to a complicated problem. They may fail to detect the longer-range adverse consequences of their actions. Finally, they may assume long-term benefits in situations where there are none. We see these characteristics as direct consequences of neurological dysfunction in systems that are critical for bringing emotion-related signals to bear on decision making.

p0030 The decision-making problems mentioned set the groundwork for older adults to be obvious targets for fraud victimization. (However, the notion that older adults are disproportionately victimized has not gone unchallenged; see Ross, Grossmann, and Schryer, 2014, for a cautionary discussion of such data.) Deceiving the elderly is not a new problem, but it is one that has been growing in prevalence. To illustrate, financial abuse of elders aged 65 and older has risen from 8% in 1950 to an astounding 20% in 2010 (Infogroup/ORC, 2010; Kemp & Liao, 2006). These recent statistics may even underestimate the extent of the problem, with only 1 in 25 cases being reported (NCEA, 2005). In other words, money loss due to elderly fraud was 2.9 billion dollars as of 2011, an increase from 2.6 billion dollars in 2008 (MetLife, 2011). Sadly, these numbers do not take into account the devastation fraud can have on the elderly and their families, often wiping out entire savings and years of work in a single action, not to mention the psychological distress and loss of dignity that frequently ensues. Despite legislative emphasis on this issue (e.g., Death Planning Made Difficult, 2000), research efforts examining older consumers' real-world decision-making abilities are sorely lacking. The reasons why some elderly people are vulnerable to such schemes, and more generally prone to making poor decisions, are not well understood (Bruine de Bruin, Parker, & Fischhoff, 2012; Finucane et al., 2002; Moye & Marson, 2007; Samanez-Larkin, Wagner, & Knutson, 2011).

p0035 In this chapter, we will demonstrate how changes to the prefrontal cortex affect a wide range of decisions. We will review early examples from the neuroscience literature. We will then discuss age-related changes of the brain, specifically literature supporting the claim that the frontal lobes undergo disproportionate age-related changes. Next, implications of these changes for decision making across diverse tasks, such as the Iowa Gambling Task (IGT), will be discussed. We conclude with the assertion that these behavioral changes are due to a common cause that we term *age-associated executive dysfunction*, an impairment in emotion-related signals that are essential to decision making.

s0010 GUIDING OBSERVATIONS, THEORETICAL FRAMEWORKS, AND KEY EMPIRICAL TESTS

p0040 The following section reviews guiding observations, theoretical frameworks, and key empirical tests used in our decision-making work, including the famous case of Phineas Gage, the somatic marker hypothesis (SMH), the frontal aging hypothesis, and the creation of the IGT.

s0015 Phineas Gage

p0045 Phineas Gage's historical accident in 1848 provided crucial early clues about the importance of the prefrontal sector of the brain for reasoning and decision making, social behavior, and personality. Gage's work-related accident resulted in a tamping iron being driven through the front part of his head, entering just under the eye, piercing the frontal lobes of his brain, and exiting through the top front part of his head. Surprisingly, Gage survived and recovered from this notable accident, and exhibited normal intelligence, memory, speech, sensation, and movement. However, Gage displayed profound changes in abilities subsumed by the frontal lobes. Before the accident, he used good judgment, and had been responsible, socially well-adapted, and well-liked by peers and supervisors. Afterward, Gage exhibited impairments in many aspects of decision making, most notably poor judgment and social conduct. In addition, he demonstrated rather dramatic changes in personality involving irresponsibility, dishonesty, and unreliability. In short, he was "no longer Gage" (p. 340; Harlow, 1868).

p0050 The importance of the case of Phineas Gage can be more fully appreciated when one considers just how difficult it has been to unravel the cognitive and behavioral functions that are subserved by the prefrontal region of the human brain. The prefrontal sector, situated anterior to the motor/premotor cortices and superior to the Sylvian fissure, comprises an enormous expanse of the brain, forming nearly half of the entire cerebral mantle. In humans in particular, this region has expanded disproportionately. Throughout the history of neuropsychology, the psychological capacities associated with the prefrontal region have remained elusive and have been likened to a riddle (Teuber, 1964).

s0020 The Somatic Marker Hypothesis

p0055 The SMH is a neural theory of how emotions play a key role in decision making, and how this process depends on the ventromedial prefrontal cortex (VMPC) of the brain (Damasio, 1994); this theory was inspired by case studies of brain lesion patients such as Phineas Gage. The term somatic refers to body and brain-related signals, which we experience as emotions and feelings. According to the SMH, when faced with complex decisions, we make choices that are in our best interest only after properly weighing potential short-term and long-term outcomes. A key idea of this hypothesis is that when these outcomes are ambiguous or uncertain, then emotions, feelings, and the brain's ability to maintain an internal equilibrium are essential to making a decision. The VMPC is critical for triggering various bodily changes (somatic states) in response to stimuli such as cues for reward or punishment. As we make decisions under uncertainty, our assessment of their immediate and future potential consequences may trigger numerous responses that conflict with each other—a highly favorable potential consequence may trigger excitement and elation, while an aversive consequence may trigger pain and dread. The end result, though, is the emergence of an overall positive or negative signal—basically a "go" or "stop" signal (Damasio, 1994).

p0060 Damasio (1994) has proposed that numerous and conflicting signals may be triggered simultaneously, but sooner or later, stronger ones trump weaker ones. In this way, emotional processes are critical for decision making that is advantageous in the long run. However, people deprived of appropriate emotional signals—e.g., because of damage to the VMPC—may fail to perceive potential adverse long-term consequences (Bechara, Tranel, & Damasio, 2000). In this sense, too little emotion can be bad for advantageous decision making, just as too much emotion can be. In adapting the SMH, therefore, Denburg, Tranel, and Bechara (2005), Denburg, Recknor, Bechara, and Tranel (2006), and Denburg, Cole, et al. (2007) proposed that some ostensibly normal older people, who are free of obvious neurological or psychiatric disease, experience changes in reasoning and decision making because of dysfunction in a neural system that includes the brain's ventromedial prefrontal system. That is, they are losing their ability to make complex choices that depend critically on the use of emotion-related information to help guide an optimal blend of short-term and long-term considerations. They may be overly swayed by the promise of immediate reward or a simple solution to a complicated problem (approaches that are commonly used in fraudulent and misleading marketing practices), and fail to detect the longer-range adverse consequences of their actions. Moreover, they may fail to recognize the implausibility of any long-term benefit at all (as is the case for many telemarketing schemes). This was postulated as a direct consequence of neurological dysfunction in systems that are critical for bringing emotion-related signals to bear on decision making. Interestingly, these same brain regions have been implicated in functional neuroimaging studies investigating purchase decisions (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007), decision making under uncertainty (Bechara et al., 2000), and decision making under risk (Weller, Levin, Shiv, & Bechara, 2007), among healthy younger adults.

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s0025 The Frontal Aging Hypothesis

p0065 Researchers have suggested that areas of the brain implicated in the SMH are more affected by aging than other areas of the brain. One theory, referred to as the frontal aging hypothesis (West, 1996), proposes that some older people have disproportionate age-related changes of frontal lobe brain structures and of associated cognitive abilities. This theory has gained support from several sources of evidence, including neuropsychological, electrophysiological, neuroanatomical, and functional neuroimaging studies.

p0070 Neuropsychological studies have demonstrated similarities in the behavioral presentation of older adults and patients with acquired lesions of the prefrontal cortex, such as deficits in cognitive flexibility (Salthouse, Atkinson, & Berish, 2003), planning (Allain et al., 2005; Sorel & Pennequin, 2008), attention and inhibition (Braver et al., 2001), perseverative behavior (Gunning-Dixon & Raz, 2003), self-monitoring (Ridderinkhof, Span, & Van Der Molen, 2002), and decision making (Denburg, Tranel, et al., 2005; Denburg, Cole, et al., 2007). Electrophysiological studies, utilizing event-related brain potentials, have also supported the notion of disproportionate frontal lobe decline with age (Fabiani, Friedman, & Cheng, 1998).

p0075 Further evidence for differential aging of the frontal lobe, and specifically the prefrontal cortex, has been demonstrated through various neuroanatomical studies (e.g., Cowell et al., 1994; DeCarli, Murphy, McIntosh, & Horwitz, 1994; Haug & Eggers, 1991; Murphy et al., 1996; Salat, Kaye, & Janowsky, 1999; Sullivan et al., 2001; Waldemar et al., 1991). To illustrate, Raz et al. (1997) conducted a volumetric magnetic resonance imaging (MRI) study of adults ranging in age from 18 to 77. General linear model analyses revealed that the greatest age effects occurred in prefrontal cortex gray matter ($r_{age,\ prefrontal\ volume} = -0.55$), with an average rate of volumetric decline of 4.9% per decade. Consistent with the Raz et al. (1997) findings, Salat et al. (1999) also found that the prefrontal cortex exhibited greater sensitivity to aging than the rest of the cerebral cortex. Both of these studies state that the underlying mechanism driving such prefrontal degeneration with age is currently unknown, although altered neurotransmitter systems have been proposed as one potential explanation. Similarly, Jernigan et al. (2001) examined the age-related volume loss of each cerebral lobe in a large sample of adults aged 30–99, and found that the frontal lobes were disproportionately affected by cortical volume loss and increased white matter abnormality.

p0080 Few longitudinal studies have been conducted to assess brain volume changes associated with normal aging. Resnick, Pham, Kraut, Zonderman, and Davatzikos (2003) followed 92 healthy, non-demented individuals (mean age of 70) participating in the Baltimore Longitudinal Study of Aging over a 5-year period, procuring cerebral MRIs at baseline,

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3-year, and 5-year intervals. Participants lost an average of 5.4 cm^3 in brain volume and gained an average of 1.4 cm^3 of ventricular volume per year. Reductions in frontal lobe volume were most salient, with particular decrement of the orbital and inferior frontal cortices. A reduction in parietal lobe volume was found next, further followed by reductions in the temporal and occipital lobes. These results suggest that there are significant reductions in brain volume with normal aging, and the frontal lobes may be more susceptible to such changes. Given the central role that the frontal lobes play in decision making (Kable & Glimcher, 2007; Rangel, Camerer, & Montague, 2008) and related theories such as the SMH (Damasio, 1994), this raises the concern that these reductions in brain volume may lead to impaired decision making and hints at the importance of designing tests to identify these impairments.

s0030 The Creation of the Iowa Gambling Task

p0085 The pervasive real-world decision-making deficits of patients with
[AU1] lesions to the VMPC, such as Phineas Gage (see Damasio, 1994; Tranel, 1994, for reviews), have been elusive to capture with standard neuropsychological testing. It was against this backdrop that Bechara, Damasio, Damasio, and Anderson (1994) developed the test now known as the IGT, which finally did correlate with such patients' deficits in their everyday lives.

p0090 The IGT (Bechara, 2007) provides a close analog to real-world decision making by factoring in reward, punishment, and unpredictability. The task is designed to create a conflict between the lure of immediate reward and delayed, probabilistic punishment. The IGT is a computer-administered test in which participants make 100 card selections from four decks of cards, taking about 10–15 min to administer. On each trial, choosing a card gives an immediate monetary reward. At unpredictable points, the selection of some cards results in losing a sum of money. Two decks are predetermined to provide relatively lower immediate gain and even lower long-term loss, yielding an overall net gain of money (i.e., decks C and D, dubbed "the good decks"); the other two decks are predetermined to provide relatively higher immediate gain but even higher long-term loss, yielding an overall net loss of money (i.e., decks A and B, dubbed "the bad decks"). Participants are not informed of the number of trials or the gain/loss schedule.

p0095 Participants are instructed that they should try to win as much money as possible and avoid losing as much as possible. They are told that they are free to switch from any deck to another at any time, as often as they wish, that they will not know when the game will end (after 100 trials), and that they should keep playing until the computer stops. They are given the following hint: Some decks are worse than the others. You may find all of them bad, but some are worse than the others. No matter how much you find yourself losing, you can still win if you stay away from the worst decks.

p0100 An overall score provides a single indicator of whether the participant's decision making was advantageous or disadvantageous. The total score is calculated subtracting the number of selections from the disadvantageous decks, from the number of selections from the advantageous deck, i.e., [(deck C´ + deck D´) – (deck A´ + deck B´)]. A positive total score indicates advantageous decision making, whereas a negative total score indicates disadvantageous decision making. Poor performance on the IGT would seem to be a promising test for age-related changes in decision making given its ability to detect abnormal decision making related to VMPC damage and prior research suggesting the VMPC is disproportionately affected by aging.

s0035 RESEARCH ON AGING

s0040 Iowa Gambling Task Studies

p0105 *IGT Behavioral*. Impaired decision making on the IGT among a subgroup of seemingly healthy older adults has been documented by Denburg and colleagues (Denburg, Recknor, et al., 2006; Denburg, Tranel, et al., 2005). In their first study (Denburg, Tranel, et al., 2005) comparing IGT performance of healthy (with no diagnosed neurological or psychiatric disease) older adults ($n = 40$; aged 56–85 years) to healthy younger adults ($n = 40$; aged 26–55 years), the authors reported that the performance of about one-third of seemingly healthy older adults (a replication study yielded a very similar rate of impairment; Denburg, Recknor, et al., 2006) on the task is akin to that of neurological patients with VMPC injury: both exhibit a preference for choices that lead to high immediate reward but greater long-term punishment. This seemingly healthy subgroup is referred to as the "impaired" decision makers[1]. They contrast with a subgroup of older adults—deemed "unimpaired"—who perform normally on the task and select responses that have small immediate, but higher long-term reward. Of note, none of the younger participants qualified as impaired. IGT performance for the groups of participants is depicted in Figure 1. The y-axis of this graph represents the net advantageous choices

[1] Denburg, Tranel, et al. (2005), Denburg, Recknor, et al. (2006), and Denburg, Cole, et al. (2007) have taken the aforementioned overall score a step further, by evaluating whether the total score differed significantly from zero (using the binomial test), and in which direction (Siegel, 1956, p. 37), ultimately classifying participants as impaired (significantly different than zero in the negative direction) or unimpaired (significantly different than zero in the positive direction).

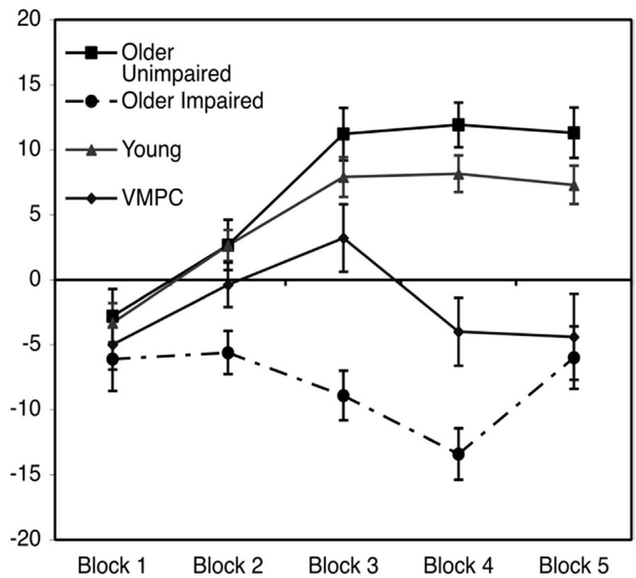
f0010 

FIGURE 1 Decision-making performance on the Iowa Gambling Task in the older unimpaired and older impaired, young, and ventromedial prefrontal cortex (VMPC) participants, graphed as a function of trial block (±SEM).

of the subjects (that is, the number of choices from good decks minus the number of choices from bad decks), and the *x*-axis displays the 100 decks choices in five blocks of 20 selections each. For perspective, we have also plotted the performance of a group of patients with stable focal lesions of the VMPC. This demonstrates that the older unimpaired group is at least as good as normal, healthy younger adults, and the impaired group is at least as bad (if not worse) as the VMPC patient group.

p0110 The impaired older group was compared to the unimpaired older group on a variety of demographic variables (e.g., age, education, sex distribution) and neuropsychological test scores (e.g., attention, working memory, language, anterograde memory, psychomotor speed, and executive functions) with no significant differences emerging. These studies (Denburg, Tranel, et al., 2005; Denburg, Recknor, et al., 2006) clearly demonstrate that there is a substantial subset of older adults who are susceptible to decision-making deficits in spite of age-appropriate scores across all manner of neuropsychological tests. The remainder of this chapter will deal with our ongoing efforts to distinguish these two groups of seemingly healthy older adults (i.e., older-unimpaired vs older-impaired participants).

p0115 *IGT Psychophysiological*. The results of the previous IGT behavioral study were extended to include psychophysiological measurements (Denburg, Recknor, et al., 2006), building upon prior work that had shown that lesions of the VMPC interfered with participants' ability to generate discriminatory skin conductance responses (SCRs) prior to card selection in the IGT (Bechara, Damasio, Tranel, & Damasio, 1997). Denburg, Recknor, et al. (2006) sought to determine whether a disruption in the anticipatory SCR might explain the deficit in the subset of older adults who were impaired on the IGT. The results of this study revealed that older adults who were unimpaired on the IGT generated anticipatory SCRs that were capable of discriminating between good and bad decks. By contrast, the anticipatory SCRs of older adults who were impaired on the IGT did not discriminate between good and bad decks. This lack of discriminatory SCRs provides another link between the significant subset of older adults that are impaired on the IGT and patients with stable focal lesions of the VMPC. It is interesting to note, however, that the anticipatory SCRs generated by the unimpaired older adults (Denburg, Recknor, et al., 2006) were different than those generated by young adults (Bechara et al., 1997). While younger adults generate higher SCR values in anticipation of selections from the disadvantageous decks, the unimpaired older adults generate higher SCR values prior to selections from the advantageous deck.

p0120 From the point of view of the SMH, it seems plausible that the normal aging process may interfere with the ability to assign somatic markers. The third of older adults who fail the IGT may be failing for the same reason that VMPC patients fail: aging may reduce these individuals' ability to assign somatic markers to outcomes. Those older adults who are able to perform well on the IGT do so using apparently reversed somatic markers. Rather than marking the bad decks in a negative way, they are positively marking the good decks to facilitate approach. The use of positive rather than negative somatic markers in later life is in line with research demonstrating a positivity bias associated with older age (Carstensen & Charles, 1999; Mather & Carstensen, 2003). Perhaps there is a natural shift in decision-making behavior from avoiding negative stimuli to seeking out positive stimuli, and this process is disrupted somehow in the impaired older adults.

p0125 *Hypersensitivity to Reward*. Additional evidence for this shift toward positive stimuli among older adults comes from performance on an alternative version of the IGT, referred to as Variant E′F′G′H′. Like Original A′B′C′D′, Variant E′F′G′H′ contains four decks each with an equal number of cards, is administered on a computer, allows participants to pick from any deck they wish, and ends after 100 card selections (Bechara, 2007; Bechara et al., 2000). Unlike Original A′B′C′D′, this version always delivers an immediate punishment followed, intermittently, by a delayed reward. The game is rigged such that the decks with the larger immediate punishment (decks E and G) also yield a larger delayed reward, while the decks with the smaller immediate punishment (decks F and H) yield a smaller delayed reward. If more cards are chosen from decks E and G (the "good" decks), there will be a net gain in money; however, a greater number of picks from decks F and H (the "bad" decks) will result in a net loss of money.

p0130 To perform advantageously on E′F′G′H′ IGT, one must choose high initial punishment with higher delayed reward versus low initial punishment with lower delayed reward. Bauer et al. (2013) found that older adults performed better on the Variant IGT than on the Original IGT. That is, younger adults perform comparably and advantageously on both versions of the IGT, whereas older adults' performance on E′F′G′H′ significantly outpaces their performance on A′B′C′D′, with E′F′G′H′ being advantageous and not reliably different than their younger counterparts performance (Bauer et al., 2013). In summary, the findings point to an age-related increase in hypersensitivity to reward. This explanation would account for the apparent tendency for older adults to perform less well on the IGT when the contingencies call for opting against higher upfront reward (as in A′B′C′D′), and to perform better when the contingencies call for opting for higher long-term reward (as in E′F′G′H′).

s0045 Neuroimaging Studies

p0135 To complement neuropsychological studies, our team has used neuroimaging to explore the inner workings of the brains of older impaired decision makers. Comparing the brain MRI results of 20 impaired older adults with those of 20 unimpaired older adults, we found that the impaired group displayed a comparative thinning of left rostral anterior cingulate, an area within the broader region of the VMPC (Denburg, 2009). This region is critical for complex, emotion-related decision making (Gläscher et al., 2012). Of note, there were no group differences in temporal lobe regions.

p0140 We have also used fluorodeoxyglucose-positron emission tomography (FDG-PET) to examine the brain's metabolism and cell functioning. Our resting FDG-PET imaging study involved 48 older adults, 24 with impaired decision making and 24 with unimpaired decision making, as measured by the IGT. Results indicated that older impaired decision makers had lower metabolism in medial prefrontal regions (activity in this area covaries with emotional regulation, self-awareness, social conduct, and subjective value) as compared to older unimpaired decision makers. Such regions include the frontal inferior operculum, frontal superior medial gyri, and anterior cingulate. In addition, lower metabolism in the insula (activity in this area covaries with interoceptive awareness and body representation) among the impaired decision makers was observed (Denburg & Harshman, 2010). Notably, there were no group differences in medial temporal lobe brain regions that are associated with learning and memory (Scoville & Milner, 1957).

p0145 These FDG-PET results link intriguingly to our overall framework for explaining why some older adults seem to have impaired decision-making abilities: Several areas of their brains have lower metabolism compared with the brains of older adults who are unimpaired. These anterior brain regions, which include those that are critical for decision making and representing emotional states, belong to the brain circuitry involved in the SMH. Equally noteworthy, the impaired and unimpaired groups show no consistent metabolic or structural differences in their temporal lobe structures, including medial temporal lobe sectors that are important for memory. These findings, which support our neuropsychological and MRI results, suggest that abnormalities in areas involved in emotions and complex decision making—rather than areas involved in memory—may make some older adults especially susceptible to fraud. These findings are significant because they suggest that older adults who make poor decisions are not "demented," but rather display relatively localized abnormalities in regions of the prefrontal cortex known previously to be important for judgment and making complex decisions, including consumer decisions (Knutson et al., 2008).

p0150 A recent study by Halfmann, Hedgcock, Bechara, and Denburg (2014) further confirmed differing neurofunctional patterns between older impaired versus older unimpaired decision makers. Using functional magnetic resonance imaging (fMRI), two groups of older adults, previously categorized as impaired ($n=15$) or unimpaired ($n=16$) based on A′B′C′D′ IGT performance, were administered an alternative version of the IGT, developed to reduce practice effects, termed K′L′M′N′ (Xiao et al., 2013), in which the differences between the advantageous and disadvantageous decks are considerably more subtle than in A′B′C′D′. These two groups did not differ in their performance on standard neuropsychological instruments (e.g., attention, memory, processing speed).

p0155 Here, we highlight two of the findings of Halfmann et al. (2014): (1) The older impaired group showed relatively greater activation than the older unimpaired group in more anterior brain regions (e.g., the VMPC) during the early (prechoice) phase of the IGT; and (2) the older impaired group showed relatively greater activation than the older unimpaired group in more posterior brain regions (e.g., the precuneus activity in this area covaries with mental imagery, self-consciousness, and source memory) during the later (prefeedback and feedback) phases of the IGT. We believe the aforementioned differences in compensatory mechanisms (e.g., VMPC) during the early (prechoice) phase, and differences in reward processing (e.g., posterior cingulate cortex—functional data are more mixed, but activity covaries with mind-wandering and emotional memory—and precuneus) during the later (feedback) phase likely contribute to the observed behavioral disparities in decision making on the IGT. We additionally note that the neurofunctional differences we observed between older impaired and unimpaired decision makers largely occurred in the absence of differences in regions that subserve working memory or motor functions (e.g., dorsolateral prefrontal cortex and parahippocampal gyrus). This, along with the previously described findings, provides strong evidence linking IGT-associated decision-making impairments in seniors to emotional-processing deficits that are localized in the VMPC.

s0050 Consumer Decision-Making Studies

p0160 While the previously discussed laboratory tests and psychophysiological measures are useful at determining the correlates of age-related changes in decision making, experimenters ultimately want to confirm that these findings translate to real-world situations. To that end, we have created a novel consumer task, entitled Advertising Task (Denburg, Cole, et al., 2007). This task is based on a set of real advertisements that had been deemed deceptive by the Federal Trade Commission (FTC, 1991, 1998). These advertisements were deemed deceptive for a number of reasons, ranging from the withholding of crucial information about the product to the use of biased graphs. All advertisements were recreated in printed form, as would be found in a magazine or newspaper. A counterpart was created for each of the deceptive advertisements, which disclosed the important product information that had been withheld. The advertisements were then separated into two booklets composed of one-half deceptive, or limited-disclosure, ads, and the other half of nondeceptive, or full-disclosure, ads. Following an incidental presentation of the advertisement stimuli to participants, comprehension of the ad's claims and interest in purchasing the product are assessed in a questionnaire format.

p0165 *Lesion Patient Performance*. Asp and colleagues (2013) sought to identify a neuroanatomical correlate for vulnerability to consumer fraud among neurological patients with acquired, focal brain lesions. Eighteen patients with VMPC damage, 21 patients with lesions outside of the prefrontal cortex, and 10 healthy, age- and education-matched comparison participants were presented the Advertising Task. The behavioral results indicated that patients with damage to the VMPC demonstrated reliably poorer comprehension of the ad's claims and endorsed more intention to purchase the products, relative to the brain-damaged control and healthy comparison groups. A lesion overlap map of those who performed abnormally on a version of our advertising task revealed that the greatest overlap was in the lower medial prefrontal areas. This study serves as an anatomical cross-validation of the basic theme of this work, that is, that the prefrontal cortex is crucial to effective consumer decision making.

p0170 *Older Adult Performance*. Denburg, Cole, et al. (2007) tested the hypothesis that those older adults who were impaired on the IGT would also fail to make appropriate decisions in more complex and realistic circumstances.

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Here, the Advertising Task was administered to a group of young (unimpaired) gamblers and two groups of older adult decision makers, one with impaired IGT performance and one unimpaired on the IGT, in such a way that each individual participant was only exposed to one version of each ad.

p0175 As can be seen in Figure 2(A) and (B), the younger, older impaired, and older unimpaired were indistinguishable in terms of comprehension of the ads claim and purchase intentions in the nondeceptive condition (i.e., when the stimuli are entirely forthcoming, with no deceptive content). By contrast, the older impaired decision makers demonstrated poorer comprehension of deceptive ads and were more likely to say that they would purchase the product featured in them, compared with unimpaired decision makers (both old and young).

p0180 This is exactly what criminals would like to happen: That their deception promotes a miscomprehension of what the product can and cannot do, coupled with an increased desire to purchase the product. More generally, this study provides direct evidence that the subset of older adults with "impaired" decision-making abilities is more vulnerable to real-word fraudulent advertising.

p0185 Taken together, the studies with the Advertising Task provide evidence that older adults with impaired IGT performance, as well as neurological patients with acquired damage to the VMPC, demonstrate real-world deficits in consumer decision making. Furthermore, the data demonstrate that the VMPC is critical for providing the skepticism needed to identify misleading information in advertisements. In fact, preliminary evidence from an fMRI study fMRI demonstrated that increased susceptibility to deception was correlated with less activity in the VMPC (Koestner, Hedgcock, Halfmann, & Denburg, 2013). Finally, while this

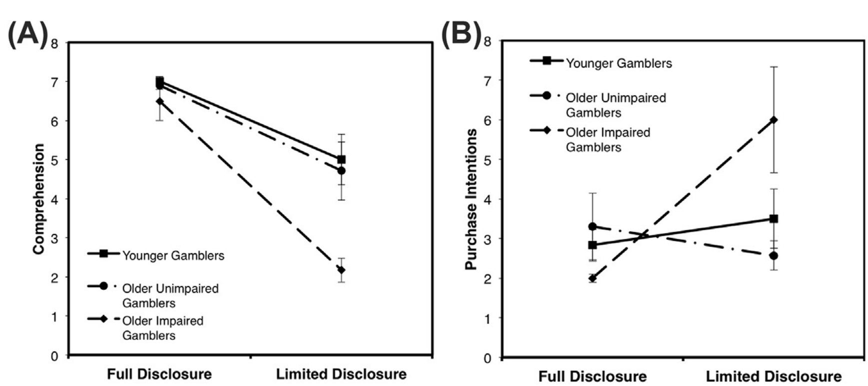

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FIGURE 2 Mean comprehension of claims response (A) and purchase intentions response (B). Data are presented by group (older unimpaired vs older impaired vs younger) and by advertisement version (full disclosure vs limited disclosure).

particular study only shows that older impaired decision makers are more susceptible to deceptive advertisements, it leaves open room for future research to determine the full extent of these individuals' real-world disabilities.

s0055 Financial Decisions

p0190 *Temporal Discounting*. Many of the decisions faced by older adults (e.g., retirement savings) involve weighing future outcomes versus immediate desires. People often prefer smaller, immediate gains ($20 today) over larger, delayed gains ($25 a month from now), a preference behavior termed "temporal" or "time discounting." Temporal discounting also occurs in the domain of losses: Individuals tend to assign a larger subjective cost to sooner, smaller losses than later, but objectively larger losses. In other words, individuals tend to have difficulty delaying gratification and would rather delay negative consequences. This has largely been studied in younger adults, with greater rates of temporal discounting predicting an array of negative real-world outcomes such as credit card and debt behavior (Meier & Sprenger, 2010), credit scores (Meier & Sprenger, 2012), mortgage behaviors (Johnson, Atlas, & Payne, 2011), and job performance (Burks, Carpenter, Götte, & Rustichini, 2012). Temporal discounting need not be about money—it could be about food, exercise, or vaccinations. Optimal decision making is likely a function of knowing how to balance gratification and loss.

p0195 Halfmann, Hedgcock, and Denburg (2013) examined older individuals who performed either advantageously or disadvantageously on the IGT, and found that disadvantageous performance on the IGT was associated with steeper rates of discounting. As shown in Figure 3, older impaired adults tended to choose the later, larger option more frequently in the loss condition (Figure 3(A)) and the sooner, smaller option more frequently in the gain condition (Figure 3(B)), relative to their older unimpaired counterparts. Thus, these data demonstrate that previously characterized aging trajectories (i.e., strong vs weak decisional capacity on the IGT, with weaker performance suggestive of compromised emotional processing) are associated with distinct patterns of preferences in intertemporal choice.

p0200 Several groups have investigated the importance of emotion to the temporal discounting of immediate and delayed gains. There is a concept, referred to as future anhedonia, in which delayed gains are perceived as fundamentally less emotionally salient than immediate gains. Among younger adults, Kassam, Gilbert, Boston, and Wilson (2008) asked participants to rate their affective reactions to positive present events, as well as positive future events. From these ratings, a future anhedonia index was calculated. They found that future anhedonia predicted the within-subject

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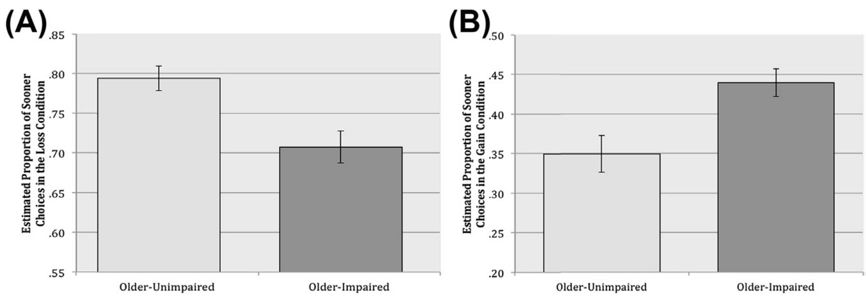
f0020 

FIGURE 3 Estimated proportion of sooner choices (±SEM) in the loss condition (A) and gain condition (B). Data are presented by group (older unimpaired and older impaired adults).

rate of temporal discounting. Participants who expected to feel less pleasure in the future (i.e., future anhedonia) were less willing to wait for delayed gains.

p0205 This effect was replicated in a life-span sample of adults by Löckenhoff, O'Donoghue, and Dunning (2011). They showed that anticipation of future emotions modified the relationship between age and discounting, such that younger adults, compared to older adults, predicted future monetary gains would be less pleasing and less arousing the further in the future they occurred. Moreover, rather than cognitive factors influencing the relationship between age and discounting, dispositional affective factors such as self-reported emotional problems and social involvement were more likely to modify the relationship between age and discounting (Löckenhoff et al., 2011).

p0210 Taken together, the results of the aforementioned three studies suggest that intact emotional processing (as seen in older unimpaired and those adults with a lack of future anhedonia) is a crucial individual differences variable in intertemporal choice and is associated with reduced temporal discounting in older adults.

s0060 IGT Impairment Can Facilitate Certain Decisions

p0215 Many kinds of decisions are negatively impacted by age-related cognitive changes. But there are occasions when IGT impairment can actually signal improved decision making. Framing is an excellent example of how this can happen.

p0220 *Framing Effects*. Framing effects are decision biases that occur when objectively equivalent information is presented in either positive or negative terms. A classic example of the simplest type of framing—attribute framing—involves preference shifts for ground beef when the product is presented as percent lean versus percent fat (Levin, Schneider, & Gaeth, 1998). Prior research indicates that this decision bias is associated with emotional processing (De Martino, Kumaran, Seymour, & Dolan, 2006; Hedgcock, Levin, Halfmann, & Denburg, under review; Kahneman & Frederick, 2007). This suggests impairments in emotional processing might actually decrease this decision bias, making people more economically rational.

p0225 Hedgcock et al. (under review) tested this hypothesis by presenting attribute framing questions to older adults who were categorized by their IGT performance: 18 older unimpaired and 15 older impaired adults. It was predicted that the older impaired group would be *less* influenced by attribute framing (relative to the older unimpaired) as their previous failure on the IGT indicates impaired emotional processing. Results supported this prediction. Attribute valence (positive or negative) had a significant effect on preferences for older unimpaired participants but did not significantly affect older impaired participants.

p0230 In sum, this demonstrates that it is too simplistic to assume age-related cognitive changes will negatively affect all kinds of decisions. Rather, it is important to consider how specific cognitive changes will influence decision processing. For tasks such as the IGT, emotional processing improves task performance by biasing preferences away from disadvantageous decks. This means diminished emotional processing will lead to less preference shift toward good decks and lower payouts. But for tasks such as attribute framing, emotional processing hurts task performance by biasing preferences based on valence of terms. This means diminished emotional processing will lead to more consistent preferences that are less affected by framing.

s0065 Personality Traits

p0235 Investigations across the adult life span have identified personality as an important individual differences variable that is related to decision-making ability (e.g., Davis, Patte, Tweed, & Curtis, 2007). In our own work, we have shown that neuroticism (but not the remainder of the "big five" traits consisting of extraversion, openness, agreeableness, and conscientiousness) is relevant to complex decision making among older adults. Individuals high on trait neuroticism are prone to experience negative affective states, such as fear, sadness, embarrassment, guilt, and disgust. Neuroticism has also been shown to moderate brain activity to emotional stimuli (see Servaas et al., 2013, for an extensive meta-analysis on this topic). In our own work (Denburg et al., 2009), we found an interaction between IGT performance in older adults and trait neuroticism, whereby older adults with high trait neuroticism (as measured by the NEO-Five Factor Inventory or NEO-FFI) performed the most poorly on the IGT. By contrast, there was no significant relationship between trait neuroticism and IGT performance among younger adults.

p0240 We have also explored the contribution of personality factors to poor IGT performance in 58 healthy older adults ranging in age from 60 to 88 years. Rather than utilizing a self-report instrument of personality (e.g., NEO-FFI), Nguyen et al. (2013) sought out the perspective of an informant. The source of information is a relevant issue to older adults with age-related brain changes, as we know that brain-damaged individuals can be inaccurate secondary to reductions in insight (e.g., Leathem, Murphy, & Flett, 1988; Prigatano & Schacter, 1991). Moreover, Cummings et al. (1994) demonstrated that valid ratings can be achieved by knowledgeable informants utilizing rating scales with behavioral guidelines.

p0245 The *Iowa Scales of Personality Change* (ISPC; Barrash, Anderson, Hathaway-Nepple, Jones, & Tranel, 1997) is a behavior-rating scale that assesses personality changes associated with acquired neuropathological conditions (e.g., stroke, tumor, traumatic brain injury), as rated by an informant, typically a family member or close friend. Two ratings are made for each of the 30 personality characteristics: "before" (typical functioning over the adult years prior to the onset of a neuropathological condition) and "now" (typical functioning over the past several months, after the onset of a neuropathological condition). For the present study with healthy older adults, the ISPC was modified to reflect a developmental perspective (Denburg & Barrash, 2007). In this adaptation, all references to a "neurological condition" were removed, "before" ratings explicitly reflected typical personality functioning over the middle-aged years, and "now" ratings explicitly reflected typical personality functioning over the past several months.

p0250 The results indicated that it was not personality disturbances generally (even such characteristics as irascibility, disturbed social behavior, and distress), but rather disturbances in executive personality characteristics specifically, that were related to compromised decision making. More precisely, disturbances in executive personality characteristics—lack of planning, poor judgment, lack of persistence, perseveration, lack of initiative, impulsivity, and indecisiveness—were significantly associated with decision-making deficits on the IGT.

p0255 In sum, trait neuroticism and executive personality disturbances may reflect neurological "soft" signs indicative of decline in prefrontal brain regions, which in turn place older adults at risk for compromised real-world decision making. Support for this notion comes from the epidemiologic literature in which trait personality has been associated with dementia. A meta-analysis conducted by Low, Harrison, and Lackersteen (2013) revealed that neuroticism was associated with an increased risk of dementia, while conscientiousness was protective (openness was possibly protective, and agreeableness and conscientiousness were unrelated to dementia risk).

s0070
CONCLUSIONS AND IMPLICATIONS

s0075
Conclusions

p0260 In conclusion, deficits in emotional signaling caused by disproportionate age-related change in the ventromedial sector of the prefrontal cortices contribute to decision-making impairments that put some elderly people at risk for faulty real-world decision making (but see Hedgcock et al., under review, discussed previously, for an exception to this notion). The idea that emotional signals are crucial for advantageous decision making, which is a central tenet of the SMH, provides a testable account of this phenomenon at both behavioral and neural levels, as witnessed by the empirical work reviewed in this chapter.

p0265 Could an older adult who exhibits poor decision making be in an early stage of Alzheimer's disease or at greater risk for developing the disease? Although we cannot definitively answer the second part of this question, our studies indicate that isolated impaired decision making among older adults is a discrete phenomenon. It is distinct from Alzheimer's disease in terms of the brain regions affected, the course and progression of the syndrome, and the likely brain abnormalities involved. Furthermore, its clinical symptoms appear to be far more subtle than those of a dementia (see "Nomenclature," below, for further discussion). Of note, we have followed longitudinally many of the older adults in our studies for a decade or more, and there has been no emergence of other forms of dementia, such as frontotemporal dementia, at a rate higher than would be expected for the general population.

p0270 There are several gaps in our program of research that we hope to flesh out in the future. One future direction is to expand our examination of middle-aged adults. For example, harkening back to our psychophysiological finding—that unimpaired older adults demonstrate a somatic signaling that is opposite to that found among unimpaired younger adults—it would be important to know at what age this reversal in emotional signaling occurs. We are also very interested in the management of decision-making dysfunction, be it pharmacologically (e.g., with a serotonin agonist) or psychologically (e.g., with evidence-based brief psychotherapy).

s0080
Implications

p0275 *Nomenclature*. In the related fields of clinical neuropsychology, behavioral neurology, and neuropsychiatry, the notion that normal, healthy older adults have age-related changes in their memory abilities is so widely accepted that there are multiple terms to characterize this phenomenon, including "age-associated memory impairment" (AAMI) and "benign senescent forgetfulness." Conversely, as of yet, a formal term for age-associated changes in decision making (and other cognitive abilities referable to the integrity of the brain's frontal lobe) has not emerged, and in fact, has hardly been discussed. Having such a term would undoubtedly help to facilitate research and funding, identify at-risk individuals, and influence public policy. In this vein, we would like to propose the rubric of *age-associated executive dysfunction (AAED)* to designate normal, healthy older adults who demonstrate disproportionate decline in decision making and other executive functions.

p0280 *Identification*. Identification is crucial. Identifying older adults at risk for bad decisions because their prefrontal cortex is declining should be prioritized at a level comparable to the early detection of cancer or heart disease. Once detected, such at-risk elders could be provided explicit assistance or could, in extreme circumstances, have their prerogative to make weighty decisions circumscribed or abrogated (e.g., decisions shifted to a conservator or power of attorney).

p0285 Unfortunately, identification remains very challenging. We cannot always rely on the older adult to report his or her own problems, and executive dysfunction may be more difficult to detect by others in day-to-day interactions, as problems with decision making, judgment, planning, and the like may be less obvious than other cognitive problems, such as forgetfulness. People with frontal lobe dysfunction also suffer frequently from impaired awareness and insight (also known as anosognosia); they may be unaware of their own deficits and the ways in which their behavior affects other people. Neurological patients with impaired awareness may deny that they have anything wrong with them, even though their deficits are patently obvious to everyone around them. These patients are particularly liable to place themselves in harm's way, and a significant number of older adults who have fallen victim to financial scams may have such impairment. This makes it more important—and at the same time very difficult—to detect a person's potential impairment.

p0290 One of the studies reviewed does offer some promise in terms of identification. Nguyen et al. (2013) suggest that spouses and other close family members can indeed identify and quantify executive personality deficits (e.g., indecisiveness, perseveration) in their loved ones, and that these collateral observations are predictive of poorer older adult decision making, as measured by the IGT. Given how difficult it is to detect risk for future victimization among seemingly healthy, normal older adults, identifying older individuals with such personality traits and providing them closer monitoring by professionals, family, and the legal system, may be a worthwhile first step toward the protection of vulnerable elders.

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s0090 References

Allain, P., Nicoleau, S., Pinon, K., Etcharry-Bouyx, F., Barre, J., Berrut, G., et al. (2005). Executive functioning in normal aging: a study of action planning using the zoo map test. *Brain and Cognition*, *57*, 4–7.

Barrash, J., Anderson, S. W., Hathaway-Nepple, J., Jones, R. D., & Tranel, D. (1997). *The Iowa scales of personality change*. Iowa City: University of Iowa, Department of Neurology.

Bauer, A., Timpe, J., Edmonds, E. C., Bechara, A., Tranel, D., & Denburg, N. L. (2013). Myopia for the future or hypersensivity to reward? Performance of older adults on two versions of the Iowa Gambling Task. *Emotion*, *13*, 19–24.

Bechara, A. (2007). *Iowa Gambling Task (IGT) professional manual*. Lutz: Psychological Assessment Resources.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, *275*, 1293–1295.

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain*, *123*, 2189–2202.

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., et al. (2001). Context processing in older adults: evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology*, *130*, 746–764.

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2012). Explaining adult age differences in decision-making competence. *Journal of Behavioral Decision Making*, *25*, 352–360.

Burks, S., Carpenter, J., Götte, L., & Rustichini, A. (2012). Which measures of time preference best predict outcomes: evidence from a large-scale field experiment. *Journal of Economic Behavior & Organization*, *84*, 308–320.

Carstensen, L. L., & Charles, S. T. (1999). Emotion in the second half of life. *Current Directions in Psychological Science*, *7*, 144–149.

Cowell, P. E., Turetsky, B. I., Gur, R. C., Grossman, R. I., Shtasel, D. L., & Gur, R. E. (1994). Sex differences in aging of the human frontal and temporal lobes. *Journal of Neuroscience*, *14*, 4748–4755.

Cummings, J. L., Mega, M., Gray, K., Rosenberg-Thompson, S., Carusi, D. A., & Gombein, J. (1994). The neuropsychiatric inventory: comprehension assessment of psychopathology in dementia. *Neurology*, *44*, 2308–2314.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: Putnam.

Davis, C., Patte, K., Tweed, S., & Curtis, C. (2007). Personality traits associated with decision-making deficits. *Personality and Individual Differences*, *42*, 279–290.

Death Planning Made Difficult. (2000). *The danger of living trust scams, hearing before the Special Committee on aging, United States Senate, 106th Cong., 2nd sess*. Washington, DC: U.S. Government Printing Office.

DeCarli, C., Murphy, D. G. M., McIntosh, A. R., & Horwitz, B. (1994). Discriminant analysis of Alzheimer's disease. *Archives of Neurology*, *51*, 1088–1090.

Denburg, N. L. (May 2009). Neural basis of decision-making in aging. In *Invited talk presented at the NIA workshop on Advancing Integrative Psychological Research on Adaptive and Health Aging Preconference (APS),* Berkeley, California.

Denburg, N. L., & Barrash, J. (2007). *Iowa scales of personality change: Adaptation for healthy adults*. Iowa City, Iowa: University of Iowa College of Medicine, Department of Neurology.

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

Denburg, N. L., & Harshman, L. (2010). Why so many seniors get swindled: brain anomalies and poor decision-making in older adults. In *The Dana Foundation's cerebrum: Emerging ideas in brain science* (pp. 123–131). New York: Dana Press.

Denburg, N. L., Recknor, E. C., Bechara, A., & Tranel, D. (2006). Psychophysiological anticipation of positive outcomes promotes advantageous decision-making in normal older persons. *International Journal of Psychophysiology*, *61*, 19–25.

Denburg, N. L., Tranel, D., & Bechara, A. (2005). The ability to decide advantageously declines prematurely in some normal older persons. *Neuropsychologia*, *43*, 1099–1106.

Denburg, N. L., Weller, J. A., Kaup, A. R., LaLoggia, A., Yamada, T., Cole, C. A., et al. (2009). Poor decision-making among older adults is related to elevated levels of neuroticism. *Annals of Behavioral Medicine*, *37*, 164–172.

Fabiani, M., Friedman, D., & Cheng, J. C. (1998). Individual differences in P3 scalp distribution in older adults, and their relationship to frontal lobe function. *Psychophysiology*, *35*, 698–708.

Federal Trade Commission. (1991). *Federal trade commission decisions* (Vol. 114). Lewis Galoob Toys Inc. pp.187–217.

Federal Trade Commission Bureau of Consumer Protection. (1998). *Complying with the Made in USA Standard* (Federal Trade Commission Report).

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

Gläscher, J., Adolphs, R., Damasio, H., Bechara, A., Rudrauf, D., Calamia, M., et al. (2012). Lesion mapping of cognitive control and value-based decision making in the prefrontal cortex. *Proceedings of the National Academy of Sciences*, *109*, 14681–14686.

Gunning-Dixon, F. M., & Raz, N. (2003). Neuroanatomical correlates of selected executive functions in middle-aged and older adults: a prospective MRI study. *Neuropsychologia*, *41*, 1929–1941.

Halfmann, K., Hedgcock, W., Bechara, A., & Denburg, N. L. (2014). Functional neuroimaging of the Iowa Gambling Task in older adults. *Neuropsychology*, *28*, 870–880.

Halfmann, K., Hedgcock, W., & Denburg, N. L. (2013). Age-related differences in discounting future gains and losses. *Journal of Neuroscience, Psychology, and Economics*, *6*, 42–54.

Harlow, J. M. (1868). Recovery from the passage of an iron bar through the head. *Publications of the Massachusetts Medical Society*, *2*, 327–347.

Haug, H., & Eggers, R. (1991). Morphometry of the human cortex cerebri and corpus striatum during aging. *Neurobiology of Aging*, *12*, 336–338.

Hedgcock, W., Levin, I., Halfmann, K., & Denburg, N. The role of emotional processing in risk and attribute framing. under review.

Infogroup/ORC. (2010, June). Elder Investment Fraud and Financial Exploitation: A Survey Conducted for Investor Protection Trust. Available from http://www.investorprotection.org/downloads/EIFFE_Survey_Report.pdf.

Jernigan, T. L., Archibald, S. L., Fennema-Notestine, C., Gamst, A. C., Stout, J. C., Bonner, J., et al. (2001). Effects of age on tissues and regions of the cerebrum and cerebellum. *Neurobiology of Aging*, *22*, 581–594.

Johnson, E., Atlas, S., & Payne, J. (2011). *Time preferences, mortgage choice, and Strategic Default*. New York, NY: Columbia University, Columbia Business School. Unpublished manuscript.

Kable, J. W., & Glimcher, P. W. (2007). The neural correlates of subjective value during intertemporal choice. *Nature Neuroscience*, *10*, 1625–1633.

Kahneman, D., & Frederick, S. (2007). Frames and brains: elicitation and control of response tendencies. *Trends in Cognitive Sciences*, *11*, 45–46.

Kassam, K. S., Gilbert, D. T., Boston, A., & Wilson, T. D. (2008). Future anhedonia and time discounting. *Journal of Experimental Social Psychology*, *44*, 1533–1537.
Kemp, B., & Liao, S. (2006). Elder financial abuse: tips for the Medical Director. *Journal of the American Medical Directors Association*, *7*, 591–593.
Knutson, B., Rick, S., Wimmer, G. E., Prelec, D., & Loewenstein, G. (2007). Neural predictors of purchases. *Neuron*, *53*, 147–156.
Knutson, B., Wimmer, G. E., Rick, S., Hollon, N. G., Prelec, D., & Loewenstein, G. (2008). Neural antecedents of the endowment effect. *Neuron*, *58*, 814–822.
Koestner, B., Hedgcock, W., Halfmann, K., & Denburg, N. L. (2013). Scamming depression era elders: neuroanatomical basis for poor decision making among older adults. In *Paper presented at the annual meeting of the Association for Consumer Research*, Chicago, IL.
Leathem, J. M., Murphy, L. J., & Flett, R. A. (1998). Self- and informant-ratings on the patient compensation rating scale in patients with traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, *20*, 694–705.
Levin, I. P., Schneider, S. L., & Gaeth, G. J. (1998). All frames are not created equal: a typology and critical analysis of framing effects. *Organizational Behavior and Human Decision Processes*, *76*, 149–188.
Löckenhoff, C. E., O'Donoghue, T., & Dunning, D. (2011). Age differences in temporal discounting: the role of dispositional affect and anticipated emotions. *Psychology and Aging*, *26*, 274–284.
Low, L. F., Harrison, F., & Lackersteen, S. M. (2013). Does personality affect risk for dementia? A systematic review and meta-analysis. *American Journal of Geriatric Psychiatry*, *21*, 713–728.
Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision-making in the human brain. *Science*, *313*, 684–687.
Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological Science*, *14*, 409–415.
Meier, S., & Sprenger, C. (2010). Present-biased preferences and credit card borrowing. *American Economic Journal*, *2*, 193–210.
Meier, S., & Sprenger, C. D. (2012). Time discounting predicts creditworthiness. *Psychological Science*, *23*, 56–58.
MetLife Mature Market Institute. (2011, June). The MetLife study of Elder Financial Abuse: Crimes of Occasion, Desperation, and Predation Against America's Elders. Available from https://www.metlife.com/assets/cao/mmi/publications/studies/2011/mmi-elder-financial-abuse.pdf.
Moye, J., & Marson, D. C. (2007). Assessment of decision-making capacity in older adults: an emerging area of practice and research. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *62*, 3–11.
Murphy, D. G., DeCarli, C., McIntosh, A. R., Daly, E., Mentis, M. J., Pietrini, P., et al. (1996). Sex differences in human brain morphometry and metabolism: an in vivo quantitative magnetic resonance imaging and positron emission tomography study on the effect of aging. *Archives of General Psychiatry*, *53*, 585–594.
National Center on Elder Abuse. (2005). Elder Abuse Prevalence and Incidence Fact Sheet. Available from http://www.ncea.aoa.gov/resources/publication/finalstatistics050331.pdf.
Nguyen, C. M., Barrash, J., Koenigs, A. L., Bechara, A., Tranel, D., & Denburg, N. L. (2013). Decision-making deficits in normal elderly persons associated with executive personality disturbances. *International Psychogeriatrics*, *25*, 1811–1819.
Prigatano, G. P., & Schacter, D. L. (1991). *Awareness of deficit after brain injury: Clinical and theoretical issues*. New York: Oxford University Press.
Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience*, *9*, 545–556.

10005-HESS-9780124171480

Raz, N., Gunning, F. M., Head, D., Dupuis, J. H., McQuain, J., Briggs, S. D., et al. (1997). Selective aging of the human cerebral cortex observed in vivo: differential vulnerability of the prefrontal gray matter. *Cerebral Cortex*, *7*, 268–282.

Resnick, S. M., Pham, D. L., Kraut, M. A., Zonderman, A. B., & Davatzikos, C. (2003). Longitudinal magnetic resonance imaging studies of older adults: a shrinking brain. *The Journal of Neuroscience*, *23*, 3295–3301.

Ridderinkhof, K. R., Span, M. M., & Van Der Molen, M. W. (2002). Perseverative behavior and adaptive control in older adults: performance monitoring, rule induction, and set shifting. *Brain and Cognition*, *49*, 382–401.

Ross, M., Grossmann, I., & Schryer, E. (2014). Contrary to psychological and popular opinion, there is no compelling evidence that older adults are disproportionately victimized by consumer fraud. *Perspectives of Psychological Science*, *9*, 427–442.

Salat, D. H., Kaye, J. A., & Janowsky, J. S. (1999). Prefrontal gray and white matter volumes in healthy aging and Alzheimer's disease. *Archives of Neurology*, *56*, 338–344.

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related decline in normal adults. *Journal of Experimental Psychology*, *132*, 566–594.

Samanez-Larkin, G. R., Wagner, A. D., & Knutson, B. (2011). Expected value information improves financial risk taking across the adult life span. *Social Cognitive and Affective Neuroscience*, *6*, 207–217.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery and Psychiatry*, *20*, 11–21.

Servaas, M. N., van der Velde, J., Costafreda, S. G., Horton, P., Ormel, J., Riese, H., et al. (2013). Neuroticism and the brain: a quantitative meta-analysis of neuroimaging studies investigating emotion processing. *Neuroscience and Biobehavioral Reviews*, *37*, 1518–1529.

Siegel, S. (1956). *Nonparametric statistics for the behavioral sciences*. New York: McGraw Hill.

Sorel, O., & Pennequin, V. (2008). Aging of the planning process: the role of executive functioning. *Brain and Cognition*, *66*, 196–201.

Sullivan, E. V., Adalsteinsson, E., Hedehus, M., Ju, C., Moseley, M., Lim, K. O., et al. (2001). Equivalent disruption of regional white matter microstructure in ageing healthy men and women. *NeuroReport*, *12*, 99–104.

Teuber, H. L. (1964). The riddle of frontal lobe function in man. In J. M. Warren, & K. Akert (Eds.), *The frontal granular cortex and behavior*. New York: McGraw-Hill.

Waldemar, G., Hasselbach, S., Anderson, A. R., Delecluse, F., Petersen, P., Johnsen, A., et al. (1991). 99mTc-*d,l*-HMPAO and SPECT of the brain in normal aging. *Journal of Cerebral Blood Flow Metabolism*, *11*, 508–521.

Weller, J. A., Levin, I. P., Shiv, B., & Bechara, A. (2007). Neural correlates of adaptive decision making for risky gains and losses. *Psychological Science*, *18*, 958–964.

West, R. (1996). An application of prefrontal cortex function theory of cognitive aging. *Psychological Bulletin*, *120*, 272–292.

Xiao, L., Wood, S. M., Denburg, N. L., Moreno, G. L., Hernandez, M., & Bechara, A. (2013). Is there a recovery of decision-making function after frontal lobe damage? A study using alternative versions of the Iowa Gambling Task. *Journal of Clinical and Experimental Neuropsychology*, *35*, 518–529.

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ABSTRACT

The chapter begins with a review of several guiding observations, theoretical frameworks, and empirical tests important to the neuroscientific study of decision making. Next, behavioral, psychophysiological, and neuroimaging studies are presented to support the contention that some seemingly normal older persons have deficits in reasoning and decision making secondary to dysfunction in a neural system that includes the ventromedial prefrontal cortices. We propose that this brain region is critical for bringing emotion-related signals to bear on decision making. Dysfunction in this neural system has real-world implications, such as making older adults vulnerable to victimization by fraudulent sales tactics. We conclude by discussing the need for a formal term for age-associated changes in decision making, and propose *age-associated executive dysfunction* to designate older adults who demonstrate disproportionate decline in executive functions referable to the prefrontal cortex. Having such a term would help to facilitate research and funding, identify at-risk individuals, and influence public policy.

Keywords: Aging; Decision making; Emotion; Framing; Fraud; Iowa Gambling Task; Neuroimaging; Prefrontal cortex; Reward; Skin conductance response.