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The Orbitofrontal Cortex, Real-World Decision Making, and Normal Aging

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Abstract

The present series of three studies aims at investigating the hypothesis that some seemingly normal older persons have deficits in reasoning and decision making due to dysfunction in a neural system which includes the ventromedial prefrontal cortices. This hypothesis is relevant to the comprehensive study of aging, and also addresses the question of why so many older adults fall prey to fraud. To our knowledge, this work represents the first of its kind to begin to identify, from an individual-differences perspective, the behavioral, psychophysiological, and consumer correlates of defective decision making among healthy older adults. Our findings, in a cross-sectional sample of community-dwelling participants, demonstrate that a sizeable subset of older adults (approximately 35–40%) perform disadvantageously on a laboratory measure of decision making that closely mimics everyday life, by the manner in which it factors in reward, punishment, risk, and ambiguity. These same poor decision makers display defective autonomic responses (or somatic markers), reminiscent of that previously established in patients with acquired prefrontal lesions. Finally, we present data demonstrating that poor decision makers are more likely to fall prey to deceptive advertising, suggesting compromise of real-world judgment and decision-making abilities.

Keywords

aging; frontal lobe; decision making

INTRODUCTION

This article presents a series of three studies that begin to identify, from an individual-differences perspective, the behavioral,¹ psychophysiological,² and consumer (Denburg *et al.*, manuscript submitted for publication) correlates of defective decision making among seemingly healthy older adults. The basic hypothesis for these studies involves the idea that some normal older persons, who are free of obvious neurologic or psychiatric disease, have deficits in reasoning and decision making on account of dysfunction in a neural system which includes the ventromedial prefrontal cortices (VMPC).

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It is important to be clear right from the outset about our anatomic terminology, because some confusion tends to surround the use of the terms orbitofrontal and ventromedial regions of the prefrontal cortex. The orbitofrontal region includes the rectus gyrus and orbital gyri, which constitute the inferior surface of the frontal lobes lying immediately above the orbital plates. In humans, lesions that involve this region are not usually restricted to the orbitofrontal cortex, but they extend into neighboring cortex and involve different sectors of the medial and ventral regions of the prefrontal cortex, as well as the subgenual part of the anterior cingulate (i.e., Brodmann's areas 25, lower 24, 32, medial aspect of 11, 12, and 10, and the white matter adjacent to all of these areas). Therefore, in most of our studies of patients with lesions in this region, we refer to the damage as involving the VMPC regions, and not strictly the orbitofrontal region.

Our hypothesis is relevant to the comprehensive study of aging, and it is also relevant to the pressing practical issue of why so many older adults fall prey to fraud. The theoretical framework that guides this work is built around the "frontal lobe hypothesis" of cognitive aging,^{3,4} which in broad terms implies that some older adults have disproportionate age-related change of prefrontal brain structures, and, concomitantly, of associated cognitive functions. The frontal lobe hypothesis is supported by multiple sources of evidence that are steadily mounting, involving neuropsychological,^{5–14} neuroanatomic,^{15–21} and functional neuroimaging^{22,23} studies. The hypothesis has not been without its critics,^{24,25} but it provides a plausible and testable account of at least some age-related neurocognitive phenomena.⁴

SIGNIFICANCE

Older adulthood has been characterized as a period of critical and complex decision making, and for many of the decisions that older adults make, there is a lot at stake. For example, the elderly deal with such issues as investment of savings and retirement income, purchase of insurance and living trusts, estate planning, anticipating and planning possible nursing home placement, purchase of a burial site, funeral costs, out-of-pocket medical costs, and sudden changes in financial roles following the death of a spouse. For most, these decisions are made while the person is on a fixed income. Such decisions would be a challenge even for intelligent young adults; however, when one considers possible executive dysfunction, in conjunction with fraudulent and vicious marketing extant in the social system, the degree of decision-making difficulty is greatly augmented in older adults.

Beginning in 1996 and continuing to the present, the U.S. Senate and House of Representatives have held numerous hearings focused on the fact that a sizable proportion of the elderly are falling prey to both misleading and fraudulent advertising.²⁶ Despite recent legislative emphasis on this issue, research efforts examining older consumers' vulnerability to fraud are sorely lacking. In the studies that follow, we argue that cognitive vulnerability generally, and impairments in decision-making ability specifically, even in the context of relatively intact memory and intellect, can explain why older adults are frequently the victims of unscrupulous business activities.

STUDY 1: BEHAVIORAL CORRELATES OF DEFECTIVE DECISION MAKING

Researchers at the University of Iowa, Division of Behavioral Neurology and Cognitive Neuroscience, have been long interested in a critical set of functions associated with prefrontal brain structures, especially the processes of reasoning, decision making, and how these interface with emotional processing. It has been shown that younger patients with acquired VMPC damage manifest notable real-world decision-making impairments²⁸ and, moreover, have impaired self-awareness of such deficits. Thus, guided by rationale derived from our work with lesion patients, we examined the possibility that a sizable number of elderly suffer from a decline in cognitive functions critical for decision making, in spite of relatively intact memory

and general intellect. In turn, the first manifestation of this cognitive decline may be exercising poor judgment and decision making in many important real-life matters.

In the initial study in this series, neurologically and psychiatrically healthy older and younger adults were administered a well-validated decision-making paradigm, called the Iowa Gambling Task (IGT). The IGT provides a close analogue to real-world decision making in the manner in which it factors reward, punishment, and unpredictability,²⁹ and taxes decision-making functions mediated by the VMPC region.^{30–33} Here, we hypothesized that a subset of older adults would manifest decision-making deficits on the IGT.

An age- and sex-stratified community-dwelling sample of 80 adults was dichotomized on age, using a conventional demarcation point,³³ to form a Younger Group (aged 26–55 years [$M = 41.0$ years]; 50% female) and an Older Group (aged 56–85 years [$M = 70.4$ years]; 53% female). Each participant was tested individually in a 3-hour session that included the IGT and a battery of standard neuropsychological tests. A structured interview (as in Tranel *et al.*³⁴) was used to determine that all participants enrolled in the study were deemed exceptionally healthy. Exclusionary criteria included major surgeries with complications; neurological events, such as cerebrovascular insults, seizures, or head injury with loss of consciousness exceeding 5 min; medications, especially those that might produce untoward effects on cognition; and a history of significant psychiatric disease necessitating inpatient treatment and/or interfering with daily functioning.

The computerized IGT was administered in the standard fashion,³⁰ involving 100 card selections from four decks. Some card selections are followed by a reward only (monetary gain); others are followed by a reward and a punishment (monetary loss). The task is manipulated such that decks with lower immediate reward have lower long-term punishment, and thus yield an overall net gain (decks C and D, referred to as “Good” decks); decks with higher immediate reward have higher long-term punishment, and thus yield an overall net loss (decks A and B, referred to as “Bad” decks). Participants are not informed about the number of trials or the reward/punishment schedules, and the schedules cannot be deduced mathematically. To quantify performance on the IGT, the 100 choices are divided into five discrete blocks of 20 cards each, and for each Trial Block, we calculate a performance score by subtracting the number of disadvantageous deck choices (A and B) from the number of advantageous deck choices (C and D), $[(C + D) - (A + B)]$. Scores below zero thus indicate “disadvantageous” performance (an overall loss of money), and scores greater than zero indicate “advantageous” performance (an overall gain of money).

The normal pattern of performance in healthy, non-elderly individuals is to begin the first Trial Block by selecting more from the Bad decks than from the Good decks, because the Bad decks have the appeal of more immediate reward. As the game progresses, however, steep penalties are encountered in the Bad decks, and participants gradually shift their selections toward the Good decks. By the final couple of Trial Blocks, participants select predominantly from the Good decks. FIGURE 1 depicts such a positively sloped performance, graphed as a function of Trial Block, which begins a bit below the zero mark and gradually rises into the positive range as participants begin selecting cards in a more and more advantageous manner. By contrast, in patients with neurologic damage to the VMPC, the ability to shift decision making in a favorable direction is impaired, and the patients continue to choose preferentially from the Bad decks for the duration of the game (FIG. 1).³⁰

IGT performances of the Younger and Older Groups were analyzed with a 2×5 ANOVA using Age Group (Younger versus Older) as the between-subjects factor, and Trial Block (1–5) as the within-subjects factor. It was our expectation that this analysis would yield an interaction: the Younger Group was expected to show the typical positively sloped line, whereas the Older

Group, which we believed would contain a subset of participants who performed disadvantageously, was expected to show a flatter slope across Trial Blocks. We also looked at individual performance profiles in each of the Groups. We collapsed across Trial Blocks and calculated for each participant a single index of performance, specifically, the sum of Good deck choices minus the sum of Bad deck choices $[(C+D)-(A+B)]$. Under the assumption that random behavior on the IGT would yield a score of zero in this formula, we categorized each participant as “unimpaired” or “impaired,” based on whether the overall performance index differed significantly from zero (using the binomial test), and in which direction. Participants who had indices that were significantly different from zero in the positive direction were categorized as “unimpaired,” and participants who had indices that were significantly different from zero in the negative direction were categorized as “impaired.”

The Group results accorded with our predictions (FIG. 2): the Younger Group started below zero, and then gradually shifted toward the Good decks as the game progressed. The Older Group did not demonstrate this shift: after the first Trial Block, their performance hovered around the zero-line for the entire task. The statistical analysis of these data yielded the predicted two-way interaction between Age Group and Trial Block ($F(4,312) = 3.65, P < 0.05$). The Age Group ($F(1,78) = 11.89, P < 0.01$) and Trial Block ($F(4,312) = 14.00, P < 0.0001$) main effects were also significant.

Regarding performances of individual participants, in the Younger Group, 37 of 40 participants were “unimpaired,” achieving overall indices significantly above zero (3 were “impaired,” obtaining indices significantly below zero). This outcome is consistent with our previous studies, which have indicated that nearly all younger normal participants perform in an advantageous manner on the IGT (cf.30). In the Older Group, we found that 15 participants were “unimpaired,” obtaining overall indices significantly above zero ($M_{age} = 70.3$ years; 40% female), whereas 14 were “impaired,” obtaining overall indices significantly below zero ($M_{age} = 71.1$ years; 50% female). (Another 11 participants were considered “borderline,” because their indices did not differ significantly from zero in either the positive or negative direction. Because this outcome is inconclusive, we will not consider this subgroup any further.) Thus, consistent with our expectation, a subset of the Older participants performed abnormally on the IGT, failing to shift their selections toward advantageous outcomes. In regard to the proportion of participants in each Age Group who were unimpaired versus impaired, there was a significant difference between the Younger and Older Groups ($\chi^2 = 18.80, P < 0.0001$), reflecting the much higher rate of impaired performance in the Older participants.

We conducted a follow-up analysis, focused specifically on the Older-Unimpaired and Older-Impaired Groups. The performance profiles of these two Groups diverged markedly (FIG. 3). The Older-Unimpaired Group began by selecting more cards from the Bad decks, but then demonstrated a strong and sustained shift toward the Good decks as the task progressed. The Older-Impaired Group did not show this shift, as they chose predominantly from the Bad decks all the way through the task (in a manner reminiscent of patients with ventromedial prefrontal lesions). A 2×5 ANOVA using Group (Older-Unimpaired versus Older-Impaired) as a between-subjects factor and Trial Block (Blocks 1–5) as a within-subjects factor yielded a significant two-way interaction [$F(4,108) = 10.53, P < 0.0001$], substantiating the trends evident in FIGURE 3.^a (The Group ($F(1,27) = 104.83, P < 0.0001$) and Trial Block [$F(4,108) = 3.91, P < 0.05$] main effects were also significant.)

In summary, the findings from this study support the notion that a subset of older individuals has significant difficulty with reasoning and decision making, as indexed by the IGT. This

^aBecause the two Groups differed slightly in Trial Block 1, we used the Block 1 score as a covariate in a 2×4 ANCOVA using the same factors as in the primary ANOVA. The Group $\times$ Trial Block interaction remained significant ($F(3,78) = 8.16, P < 0.0001$).

impairment occurred in the absence of any frank neurologic or psychiatric disease, and there was no evidence that it could be explained by pre-morbid factors (e.g., educational level), overall health status, or weaknesses in other cognitive realms such as attention, memory, or language (confirmed by detailed neuropsychological testing of the participants). Moreover, within the age range subsumed by our Older participant sample (56–85), there was no indication that age per se accounted for the decision-making impairment. The rate of impairment in our sample was not trivial: 14 of 40 older participants were deficient, compared to only 3 of 40 younger participants.

STUDY 2: PSYCHOPHYSIOLOGICAL CORRELATES OF DEFECTIVE DECISION MAKING

Defective decision making in patients with acquired VMPC damage has been discussed in the framework of the *somatic marker hypothesis*, which posits that decision making is often assisted by emotional processes and somatic “markers,” originating not only from the body itself, but also from several large-scale cortical and subcortical brain networks, including the VMPC, amygdala, insular cortices/somatosensory cortices, and possibly the basal ganglia, as well as signals from the peripheral nervous system.^{30,36,37} In previous studies, electrodermal activity, specifically the skin conductance response (SCR), has been used in our laboratory as a dependent measure of somatic state activation and somatic “signaling” activity.³⁸

In previous work, we have shown that healthy, non-elderly individuals generate anticipatory SCRs prior to a Bad deck selection, while age-matched VMPC patients (mean age $\cong$ 44 years) fail to generate such SCRs.³¹ In other words, young participants generate discriminatory anticipatory SCRs during the IGT, with the largest SCRs observed just prior to a Bad deck selection, and smaller SCRs just prior to a Good deck selection. By contrast, VMPC patients generate small and relatively equivalent SCRs to both types of selections, and thus do not display such discrimination.³⁹ These findings have been taken as evidence that the somatic “signaling” that normally facilitates decision making under conditions of uncertainty and risk is disrupted in VMPC patients.

In another study in the current series, our objective was to add an investigation of the psychophysiological correlates of decision making in older adults, to determine whether the integrity of anticipatory SCRs might be compromised in the subset of older individuals that demonstrates impaired IGT performance. We hypothesized that the “somatic signaling” process would be attenuated in the impaired decision makers, but not in the unimpaired ones. Specifically, we predicted that (1) Older-Impaired participants would not generate discriminatory anticipatory SCRs during the IGT; and (2) Older-Unimpaired participants would generate discriminatory anticipatory SCRs during the IGT.

Using the same rationale and procedures as in the previous study (Study 1: Behavioral Correlates of Defective Decision Making), 40 new older adult participants were recruited. Thus, the overall sample comprised 80 healthy, community-dwelling older adults, aged 56–85 (40 previous participants, 40 new participants). The two samples did not differ with respect to demographic variables, such as age, education, and gender distribution (P s $>$ 0.05).

The IGT was administered according to the standard protocol of our laboratory, involving computer administration and psychophysiological (i.e., SCR) measurement. As before, we carried out the following analysis of the IGT behavioral data. Under the assumption that random behavior on the IGT would yield a score of zero for the formula, $[(C + D) - (A + B)]$, we categorized each older adult participant as “Unimpaired” or “Impaired,” based on whether their IGT performance score collapsed across the five Trial Blocks differed significantly from zero, and in which direction, using the binomial test. Participants who had overall performance

scores that were significantly different from zero in the positive direction were categorized as “Unimpaired” on the IGT, and participants who had performance scores that were significantly different from zero in the negative direction were categorized as “Impaired” on the IGT. (As in the previous study, this left a middle group of participants whose scores did not significantly differ from zero in either direction, and we refer to this group as “Borderline.”)

While playing the IGT, participants were connected to a polygraph. SCRs were recorded from two Ag/AgCl electrodes attached to the thenar and hypothenar eminences of each hand. Every turn of a card from any deck coincided with a mark on the SCR polygram. The inter-trial interval was set to 6 s, although, given time for deliberation, the average time between card choices was approximately 10 s.³⁹ For the present study, we were interested in anticipatory SCRs generated during the IGT, and this corresponds to the time window between the *end* of the 5-s period following the choice of a card and *before* the next click of a card (i.e., the time period during which participants are pondering their choice).

The SCR data were acquired through an MP100 WS system (BIOPAC Systems, Inc., Santa Barbara, CA) at the rate of 100 samples per second. The IGT SCR data were analyzed using AcqKnowledge III software (BIOPAC Systems, Inc.) for the MP100 WS system. Quantification of the SCR wave involved elimination of the downward drift using a mathematical transformation function named “Difference,” followed by visual inspection of the wave for experimental artifacts. The primary dependent SCR variable was “area under the curve” in microSiemens per second ($\mu\text{S/s}$), during the “anticipation phase”; again, this was the time window between the end of the 5-s period following choice of a card and before the next click of a card.

Initial descriptive statistics on the SCR data revealed that, within participant group, the means and standard deviations were similar in magnitude (as is common for electrodermal data of this type).⁴⁰ We also noted that, between participant groups, the variances were unequal (i.e., heterogeneity of variance). For these reasons, the SCR data were analyzed with non-parametric techniques. Specifically, we utilized the Wilcoxon matched-pairs signed-ranks test and the Mann–Whitney *U* test as non-parametric alternatives to the *t* test and *F* test, respectively, to analyze the SCR data.

The results of the binomial test revealed 24 Older-Impaired participants and 36 Older-Unimpaired participants. The data from six participants were excluded, in three cases secondary to a lack of measurable SCRs (2 men, 1 woman), and in three cases secondary to experimenter error (3 men). One of those excluded was “Impaired” and five were “Unimpaired,” which left 23 Older-Impaired decision makers and 31 Older-Unimpaired decision makers in the final sample of psychophysiological data.

The first prediction was confirmed. Using Wilcoxon paired samples signed-ranks test, we found that the Older-Impaired participants failed to generate discriminatory anticipatory SCRs ($P = 0.93$); in fact, their anticipatory SCRs were nearly identical for the advantageous and disadvantageous decks. The second prediction was also confirmed. The Older-Unimpaired participants demonstrated discriminatory anticipatory SCRs ($P < 0.05$). Specifically, this Group generated larger amplitude (i.e., greater area under the curve) SCRs to the advantageous decks compared to the disadvantageous decks, as shown in FIGURE 4.

It is important to explore whether these findings can be explained by a basic between-Group difference in overall SCR responsivity. A Mann–Whitney *U* test failed to demonstrate any reliable between-Group differences ($P_s > 0.05$), as the magnitude of SCRs was generally comparable between the Impaired and Unimpaired participants.

This study provides an extension of our previous work exploring the nature of decision making in healthy older adults.¹ Specifically, we demonstrated that the decision-making defect has a psychophysiological correlate; namely, Older-Impaired participants lacked discriminatory SCRs to advantageous versus disadvantageous choices, whereas Older-Unimpaired participants demonstrated reliable anticipatory psychophysiological discrimination of good and bad choices.

The psychophysiological findings supported our basic hypothesis regarding the absence of somatic “signaling” in the impaired participants. Specifically, the Older-Impaired participants failed to generate discriminatory anticipatory SCRs. It was interesting, though, that the pattern of results was different from that observed previously in patients with bilateral VMPC damage.³⁹ Those patients failed to acquire anticipatory SCRs to either the advantageous or disadvantageous choices. By contrast, the Older-Impaired participants *did* acquire anticipatory SCRs, although those responses did not discriminate good from bad choices.

Interestingly, the Older-Unimpaired participants generated discriminatory anticipatory SCRs, consistent with our second prediction. However, the direction of the anticipatory SCR discrimination was reversed in the Older-Unimpaired participants compared to that found in previous studies involving healthy, non-elderly (young) participants. That is, the Older-Unimpaired participants produced higher-amplitude SCRs to the advantageous decks, while young participants produce higher-amplitude SCRs to the disadvantageous decks. Taken at face value, the pattern of anticipatory discrimination during successful IGT performance differs in important ways for young and older adults.

In conclusion, older adults with strong decision-making abilities, as measured by the IGT, show discriminatory anticipatory SCRs, and it appears that positive (rather than negative) somatic markers play a significant role in shaping their advantageous decisions. By contrast, older adults with poor decision-making abilities do not appear to be differentially influenced by either positive or negative somatic markers, although they may be influenced by both types of markers in a manner unlike patients with acquired VMPC lesions.

STUDY 3: CONSUMER CORRELATES OF DEFECTIVE DECISION MAKING

A growing body of literature in marketing examines age differences in consumer reactions to printed marketing materials, primarily from an information-processing perspective.^{41–46} Such studies have suggested that under certain environmental conditions, older consumers are more likely than younger consumers to miscomprehend and incorrectly use printed marketing information. For example, not only are older adults less likely to decipher implied claims, but older adults are more vulnerable to the “truth effect” (the tendency to believe repeated information more than new information) because older adults have relatively poor context or source memory, but relatively intact familiarity of repeated claims.^{43,44} Furthermore, there is preliminary evidence linking the integrity of the prefrontal cortex to frequently studied consumer behaviors, such as comprehension, information search, and decision making.^{46–48}

In the last study in the current series, we questioned how age differences in reactions to deceptive advertising are related to decision making ability (and potentially the integrity of VMPC structures) (Denburg *et al.*, manuscript submitted for publication). We proposed that IGT performance would predict susceptibility to the influence of deceptive advertising. Specifically, it was predicted that Older-Impaired decision makers would be more vulnerable to deceptive advertising than either Older-Unimpaired or Younger comparison participants. By adopting this neuroscientific perspective, we hoped to understand age differences in consumer behavior at a more fundamental (neural) level, and to refine existing theories.⁴⁹

Using the same rationale, procedures, and participants as in the previous study (Study 1: Behavioral Correlates of Defective Decision Making), 20 Unimpaired Younger adults participated. Additionally, from the earlier study, the 15 Older Adult participants that were labeled as “Unimpaired” and the 14 Older Adults that were “Impaired” also participated. In all, then, there were three Groups: (1) Younger; (2) Older-Unimpaired (good IGT decision makers); and (3) Older-Impaired (bad IGT decision makers). The samples did not differ with respect to demographic variables, such as age, education, and gender distribution ($P > 0.05$). There were two dependent measures, IGT behavioral performance and vulnerability to deceptive advertising.

In a preliminary session, participants individually came to the laboratory to perform the IGT and a battery of neuropsychological tests. At a second testing session on a separate day, we invited each participant to participate in an “advertising study.” In this study, prior to looking through an advertising booklet, they learned that they could take as long as they liked to review the booklet and that we would ask about their opinions of the advertisements later in a written questionnaire.

Participants were exposed to actual advertisements with deceptive and non-deceptive claims. The deceptive claims have been drawn from those cases deemed problematic by the Federal Trade Commission (FTC) as published in *FTC Decisions*, and hence, the advertisements we used had documented external validity. For each FTC advertisement, non-deceptive counterparts were created. Deceptive and non-deceptive advertisements were admixed to create two advertising booklets. A deceptive advertisement is one in which a discrepancy arises between the factual performance of the product and consumers’ beliefs about the product.^{42, 50}

Each advertising booklet contained five advertisements, plus two “control” ads (one at the beginning and the other at the end, in an effort to minimize primary and recency effects). After incidental reading of the advertisement booklet, a questionnaire was administered which examined participants’ (a) purchase intentions and (b) comprehension of claims.⁵² All the advertisements were in color and were professionally designed; none specifically mentioned price. A short paragraph description separated the advertisements. For example, “Please read the following advertisement. It will appear in magazines such as *Women’s Day* and *Sports Illustrated* during the Fall.” To better illustrate how the advertisements differed based on manipulation, we offer the Luggage advertisement as an example and present the Group results.

The manipulation for the Luggage advertisement involved disclosure that the luggage is made in Mexico versus no such disclosure. Both the deceptive and non-deceptive Luggage advertisements contained color pictures and a verbal description of the three-piece luggage set. Both versions started with the headline “Legacy brings you the finest American Quality Luggage.” The FTC wrote that an advertisement that bears the headline “American Quality” is “likely to convey to consumers a claim that the product is of US origin,” and thus would not be compliant with the “Made in the USA standard” if it were of foreign origin, unless the advertisement disclosed where the product was manufactured. So, the non-misleading advertisement contained the statement “After manufacture in Mexico, each piece is carefully inspected in Tennessee at our corporate headquarters before it is shipped to you.” The misleading version made the same claim but omitted the words “in Mexico.”

The comprehension-of-claims variable for the Legacy Luggage was analyzed with a 2×3 ANOVA using advertisement version (Limited Disclosure versus Full Disclosure) as the within-subjects factor and Group (Younger versus Older-Impaired versus Older-Unimpaired) as the between-subjects factor (FIG. 5). We found a significant effect for version [$F(1,43) = 37.27, P < 0.01$] as well as a significant version by Group interaction [$F(2,43) = 3.68, P <$

0.03]. We conducted follow-up *t* tests and found that the Groups who viewed the Legacy Luggage ad that made a full disclosure about where the luggage was made did not differ in their comprehension of claims for the luggage set. However, among the Groups who viewed the deceptive Legacy Luggage ad, which did not disclose where the luggage was made, the Older-Impaired Group was significantly more likely than the Older-Unimpaired Group ($t = 3.44, P < 0.01$) or the Younger Group ($t = 3.56, P < 0.01$) to believe that the Legacy Luggage set was made in the United States.

Similarly, the purchase intentions variable for the Legacy Luggage was analyzed with a 2×3 ANOVA using advertisement version (Limited Disclosure versus Full Disclosure) as the within-subjects factor and Group (Younger versus Older-Impaired versus Older-Unimpaired) as the between-subjects factor (FIG. 6). We found a significant effect for version [$F(1,43) = 5.64, P < 0.03$] as well as a significant version by Group interaction [$F(2,43) = 4.31, P < 0.02$]. We conducted follow-up *t* tests and found that the Groups who viewed the Legacy Luggage ad that made a full disclosure about where the luggage was made did not differ in their purchase intentions for the luggage set. However, among the Groups who viewed the deceptive Legacy Luggage ad that did not disclose where the luggage was made, the Older-Impaired Group was significantly more likely than the Older-Unimpaired Group ($t = 2.7, P < 0.02$) or the Younger Group ($t = 1.99, P < 0.06$) to indicate higher purchase intentions for deceptively advertised luggage. Therefore, we conclude that the Older-Unimpaired participants and the Younger participants responded more similarly to deceptive advertising than the Older-Impaired participants.

This research begins to identify a neuroscientific explanation for age differences in responses to deceptive advertising. Future research is needed to pin down more closely the relationship between decision making performance and age-associated changes in vulnerable brain regions. An important area for future neurobiological and consumer research is to identify the extent to which bad decision makers can recruit or be trained to use compensatory processing to improve accuracy of beliefs and judgments.^{42,45,52}

From a marketing context, these studies suggest that there is considerable heterogeneity in the older consumer market. Prior research has suggested the need for segmenting markets according to lifestyle and other demographic variables using something called “gerontographics.”⁵⁴ Our research suggests that the integrity of prefrontal cortex functioning may be one important segmenting variable. Indexing the integrity of prefrontal cortex functioning is not simple, but as neuroscience develops, it may be possible to identify otherwise healthy older adults who have dysfunction in prefrontal cortex. These individuals could be made aware that they may be particularly susceptible to misleading advertising.

CONCLUDING COMMENT

Given the well-documented association between decision making on the IGT and integrity of ventromedial prefrontal structures, we take the current findings as suggestive of the possibility that some ostensibly normal older adults have disproportionate aging of VMPC. To the extent that this turns out to be correct, it has some very important implications. Perhaps the most alarming example is older adults’ heightened vulnerability to advertising fraud. In fact, the Federal Bureau of Investigation (FBI) has estimated that there are 14,000 fraudulent telemarketing firms operating in the United States, with 80% of these aiming their activities at older individuals.⁵⁴ Our own work in this area has already provided preliminary suggestion of a link between ventromedial prefrontal dysfunction, faulty decision making, and vulnerability to misleading advertising.

The issue of whether a sizable number of older individuals have decision-making deficits has provocative societal implications. These include not only the aforementioned problem of older persons being targeted by fraudulent advertising, but also the fact that, at a time of heightened vulnerability, these older persons face a host of critical life decisions ranging from driving and housing decisions to choice of medical care and allocation of personal wealth. In fact, it is hard to overemphasize the ramifications of impaired decision making for older adults. From a public policy perspective, our research has immediate implications for the voluntary and regulatory control of advertising.

The series of studies summarized here provides strong support for the notion that some neurologically and psychiatrically healthy older adults can have decision making impairments in the absence of other neuropsychological defects. Whether this finding turns out to have a structural or functional neurologic correlate remains to be seen, but the finding is at least broadly consistent with the frontal lobe hypothesis of aging, articulated by West⁴ and others, and further supported by several recent lines of evidence.^{56,57}

It will be important to tackle these open questions with other neuroscience approaches, including functional imaging (e.g., fMRI), and it will also be important to identify the neuropathologic process or processes that are giving rise to VMPC dysfunction in some older persons. For instance, is this dysfunction a harbinger of a progressive degenerative disease, such as Alzheimer's disease or Pick's disease? Longitudinal work and postmortem neuropathology studies will be needed to help answer such questions. Another intriguing and open question concerns sex differences. Recent work has provided preliminary evidence of sex-related functional asymmetry of the VMPC, whereby in men the right-sided VMPC sector is more important than the left for functions, such as complex decision making, emotional regulation, and social conduct, whereas in women the left-sided VMPC sector appears to be more important than the right for such functions.⁵⁸ Future work in older adults should take into account possible sex differences, and we would predict that such differences may turn out to be a lot more than trivial, at both behavioral and neural levels.

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FIGURE 1.

Decision-making performance on the IGT in patients with acquired damage to VMPC and demographically matched normal comparisons participants, graphed as a function of Trial Block ($\pm$ SEM, standard error of the mean).

FIGURE 2.

Decision-making performance on the IGT in Younger and Older participants, graphed as a function of Trial Block ($\pm$ SEM).

FIGURE 3. Decision-making performance on the IGT in Older-Unimpaired participants and Older-Impaired participants, graphed as a function of Trial Block ($\pm$ SEM).

FIGURE 4. Mean ($\pm\text{SEM}$) anticipatory SCRs in microSiemens (μS) as measured during the IGT. Data are presented by Group (Older-Unimpaired versus Older-Impaired) and by Deck Type (Good versus Bad).

FIGURE 5.

Mean comprehension of claims response. Data are presented by Group (Older-Unimpaired versus Older-Impaired versus Younger) and by Advertisement Version (Full Disclosure versus Limited Disclosure).

FIGURE 6. Mean purchase intentions response. Data are presented by Group (Older-Unimpaired versus Older-Impaired versus Younger) and by advertisement version (Full Disclosure versus Limited Disclosure).