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The ability to decide advantageously declines prematurely in some normal older persons

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Abstract

The prefrontal region of the brain, including the ventromedial sector which supports reasoning and decision-making, may undergo disproportionate aging in some older persons, but the empirical evidence is decidedly mixed. To help resolve this, we tested 80 neurologically and psychiatrically healthy Younger (aged 26–55) and Older (aged 56–85) adults on a "Gambling Task", which provides a close analog to real-world decision-making by factoring in reward, punishment, and unpredictability, yielding a sensitive index of ventromedial prefrontal function. A subset of the Older group manifested a decision-making impairment on the Gambling Task, in spite of otherwise intact cognitive functioning. This finding raises the possibility of disproportionate aging of the ventromedial prefrontal cortex in these individuals. Our finding has important societal and public policy implications (e.g., choosing medical care, allocating personal wealth), and may also help explain why many older individuals are targeted by and susceptible to fraudulent advertising.

Keywords: Decision-making; Aging; Frontal lobe; Executive functioning; Cognition; Public policy

1. Introduction

There is neuropsychological (e.g., Daigneault, Braun, & Whitaker, 1992; Dempster, 1992; Haaland, Price, & LaRue, 2003; Hartley, 1993; Moscovitch & Winocur, 1992; Robbins et al., 1998; Shimamura & Jurica, 1994; West, Murphy, Armilio, Craik, & Stuss, 2002), neuroanatomical (e.g., Coffey et al., 1992; Cowell et al., 1994; Jernigan et al., 2001; Raz et al., 1997; Raz, Gunning-Dixon, & Acker, 1998; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; Salat, Kaye, & Janowsky, 1999, 2001), and functional neuroimaging (e.g., Gur, Gur, Orbist, Skolnick, & Reivich, 1987; Melamed, Lavy, Shlomo, Cooper, & Rinot, 1980) evidence that the prefrontal region of the brain may undergo disproportionate aging effects in older adults, in the absence of frank neurological or psychiatric disease. Such evidence has been taken as suggestive of a "frontal aging hypothesis", according to which there is differential decline with aging of neural structures in the prefrontal region, and of their associated cognitive functions (West, 1996).

This frontal aging hypothesis has not gone unchallenged. The hypothesis has been criticized on the grounds that it provides too narrow a view of age-related changes in brain and behavior (Band, Ridderinkhof, & Segalowitz, 2002; Greenwood, 2000). More specifically, opponents argue that comparable age effects exist for measures sensitive to non-frontal brain regions. In response, recent efforts have shifted towards a more integrated view, e.g., that age-related changes in frontal systems can exert not only direct effects, but also effects on other, non-frontal brain systems and associated behavioral manifestations (e.g., Milham et al., 2002). Nevertheless, the frontal aging hypothesis remains a plausible account of at least some age-related neurocognitive phenomena (West, 2000).

Against this background, we have been interested in a critical set of functions associated with prefrontal integrity, namely, reasoning and decision-making. These capacities depend intimately on structures in the ventromedial prefrontal sector; hence, age-related decline in these structures could

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lead to a concomitant decline in reasoning and decision-making. There is real-world evidence for this idea. For example, there has been an alarming increase in the numbers of elderly persons who are targeted and victimized by misleading and fraudulent advertising (AARP, 1996). In fact, a plausible neurobiological hypothesis is that some older adults fall prey to fraudulent advertising because of decision-making impairments related to ventromedial prefrontal dysfunction.

The study reported here begins to explore this urgent and critical issue. We studied neurologically and psychiatrically healthy Older adults, and a comparison group of Younger adults, using a well-validated decision-making paradigm called the “Gambling Task”. The Gambling Task provides a close analog to real-world decision-making in the manner in which it factors reward, punishment, and unpredictability (Bechara, Damasio, Damasio, & Anderson, 1994). Multiple sources of evidence have indicated that the Gambling Task taxes decision-making functions mediated by the ventromedial prefrontal region (Bechara, Damasio, & Damasio, 2000a; Bechara, Tranel, & Damasio, 2000b; Ernst et al., 2002; Schmitt, Brinkley, & Newman, 1999).

In our extensive use of the Gambling Task over the past decade, we have observed anecdotally that some normal adults do not seem to learn the task normally, and fail to develop a beneficial response strategy. Moreover, it has been our impression that this “abnormal” profile tended to occur more often in older normal participants, than in younger normal participants. These preliminary observations prompted the prediction for the current study, namely, that a subset of Older adults would manifest decision-making deficits on the Gambling Task. And in this context, it is worth noting another relevant background observation that comes from a recent study in which our Gambling Task was administered to 90 normal participants, aged 20–80 (MacPherson, Phillips, & Della Sala, 2002). The authors did not find an overall effect of age on Gambling Task performance. However, the Gambling Task data reported by MacPherson et al. (2002) (see their Fig. 3, p. 605) indicated that the oldest group of subjects showed the flattest learning curve on the Gambling Task; in fact, relative to our normative data for the Gambling Task, this group did not develop a strong bias towards beneficial responses, even in the latter sections of the task. In other words, MacPherson et al.’s (2002) data also hinted at the possibility that a subset of older participants may have decision-making deficits on the Gambling Task.

2. Methods

2.1. Participants

An age- and sex-stratified sample of 80 adults was recruited from the community. Equal numbers of men and women in each 5-year age band ranging from 26 to 85 years old were included. The sample was dichotomized on age, using a conventional demarcation point (Schaie, 1996), to form a Younger group (aged 26–55 years) and an Older group (aged 56–85 years). Each participant was tested individually in a 3 h session that included the Gambling Task and a battery of standard neuropsychological tests. Participants were financially compensated for their participation. Following administration of the neuropsychological tests, participants were administered a semi-structured interview (as in Tranel, Benton, & Olson, 1997). Participants were questioned about major surgeries and their possible complications; neurological events, such as cerebrovascular disease, seizures, or head injury with a loss of consciousness exceeding five minutes; medications, especially those that might produce untoward effects on cognitive functioning; and a history of significant psychiatric disease necessitating inpatient treatment and/or interfering with daily functioning. Three older participants were ultimately excluded secondary to one or more of the aforementioned neurological or psychiatric conditions.

2.2. Measures

The neuropsychological tests (see Table 1) provided broad coverage of cognitive functioning and mood, allowing us to investigate whether Gambling Task performance was influenced by such factors. A board-certified neurologist, blind to the objectives of the current study, rated the overall physical health status of the older participants on a scale of 1 (no health problems) to 6 (severe health problems), based on review of medical records and medication regimen.

The Gambling Task was administered according to the standard protocol (see Bechara et al. (2000b) for complete methodology). The task entails a series of 100 card selections from four decks (participants are not informed of the number of trials). Some card selections are followed by a reward (monetary gain); others are followed by a reward and a punishment (monetary loss). The task is rigged so that decks with lower immediate reward have lower long-term punishment, and thus yield an overall net gain (decks C and D, dubbed “Good” decks); decks with higher immediate reward have higher long-term punishment, thus yielding an overall net loss (decks A and B, dubbed “Bad” decks). Participants are not informed about the reward/punishment schedules, and they cannot deduce them mathematically.

2.3. Data analyses

The primary dependent variable was Gambling Task performance. This was quantified by dividing the 100 trials into five discrete blocks of 20 each, and then for each trial block, calculating the number of cards selected from the good decks and the number selected from the bad decks. For each participant and each trial block, we calculated a performance score by subtracting the number of bad deck picks (A and B) from the number of good deck picks (C and D). Scores below zero indicate “disadvantageous” performance (a net loss of money), and scores greater than zero indicate “advantageous” performance (a net gain of money).

Table 1
Demographic and cognitive characteristics of older participants

Characteristic[a]	Statistic[b]	Participant group		p[c]	Effect size[d] (d statistic)	Confidence interval[d] (95% CI)	Correlation with CD–AB[e] in older participants (n = 40)
		Older–Unimpaired (n = 15)	Older–Impaired (n = 14)				
Age	M	70.3	71.1	ns	.10	−.63 to .82	.07
	S.D.	8.3	8.0				
Education	M	15.6	14.2	ns	−.58	−1.31 to .17	.21
	S.D.	1.8	2.9				
Gender	% Females	40	50	–	–	–	–
Handedness	% RH	93	100	–	–	–	–
Health status	M	1.60	1.64	ns	−.06	−.67 to .79	.09
	S.D.	0.6	0.7				
Riskiness	M	0.6	0.7	ns	−.15	−.70 to .98	−.06
	S.D.	0.8	0.5				
BDI	M	4.9	4.9	ns	−.00	−.74 to .74	−.18
	S.D.	4.2	3.8				
WAIS-III digit span	M	16.0	17.3	ns	−.29	−.46 to 1.03	−.08
	S.D.	4.6	4.3				
Benton faces	M	22.4	21.9	ns	−.20	−.95 to .56	.17
	S.D.	2.3	1.6				
WRAT-3 reading	M	51.0	48.9	ns	−.63	−1.35 to .14	.25
	S.D.	3.1	3.6				
AVLT 30 min delay	M	10.6	9.3	ns	−.46	−1.20 to .30	.12
	S.D.	2.7	2.9				
BVRT errors	M	3.3	4.5	ns	−.65	−.15 to 1.40	−.30
	S.D.	1.6	2.1				
Verbal fluency	M	41.6	38.7	ns	−.33	−1.07 to .42	.17
	S.D.	7.8	9.0				
Trail making test A	M	33.1	34.9	ns	−.21	−.54 to .95	−.01
	S.D.	10.4	12.6				
Trail making test B	M	74.5	82.8	ns	−.28	−.47 to 1.02	−.03
	S.D.	27.8	31.3				
WCST perseverative errors	M	7.3	9.7	ns	−.67	−.20 to 1.48	−.23
	S.D.	4.0	3.1				
WCST categories	M	6.0	5.8	ns	−.48	−1.29 to .36	.13
	S.D.	0.0	0.6				

[a] Shown are age, education, gender, handedness, health status, and risk-taking behavior ("riskiness") of the older participants who either were not (Older–Unimpaired) or were (Older–Impaired) impaired on the Gambling Task. Raw scores are provided for each of the neuropsychological variables. Shown are Beck depression inventory (BDI); Wechsler Adult Intelligence Scale-third edition (WAIS-III) Digit Span; Benton Facial Recognition Test (Benton faces); Wide Range Achievement Test-revision 3 (WRAT-3) reading subtest; Rey Auditory–Verbal Learning Test 30 min delayed recall (AVLT 30 min delay); Benton Visual Retention Test number of errors (BVRT errors); phonemic verbal fluency (Verbal fluency); Trail Making Test—forms A and B; and Wisconsin Card Sorting Test (WCST number of perseverative errors committed and categories achieved).

[b] Means and standard deviations (S.D.) are given for each variable unless otherwise indicated.

[c] Post hoc comparisons were computed using independent-samples t-tests; ns: nonsignificant.

[d] Most effect sizes were small, and all confidence intervals included zero.

[e] All correlations with the Gambling Task dependent variable [(C + D) − (A + B)] were ns.

To set a context for interpreting Gambling Task performance (see Bechara et al. (2000b)), it can be noted that the normal pattern of performance in non-elderly individuals is for participants to begin the first trial block by selecting more from the bad decks than from the good decks, because the bad decks have the allure of more immediate reward. As the game progresses, though, and steep penalties are encountered in the bad decks, participants gradually shift their selections toward the good decks. By the final couple of trial blocks, participants select predominantly from the good decks. When graphed as a function of trial block, this profile of card selections is manifest as a positively sloped line, 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 (Fig. 1). By contrast, in neurological patients with damage to ventromedial prefrontal cortices, the ability to shift decision-making in a favorable direction is impaired, and the patients continue to choose frequently from the bad decks for the duration of the game (Fig. 1).

In the current study, we analyzed the Gambling Task performances of the Younger and Older groups with a 2×5 ANOVA using age group (Younger versus Older) as a between-subjects factor and trial block (1–5) as a 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

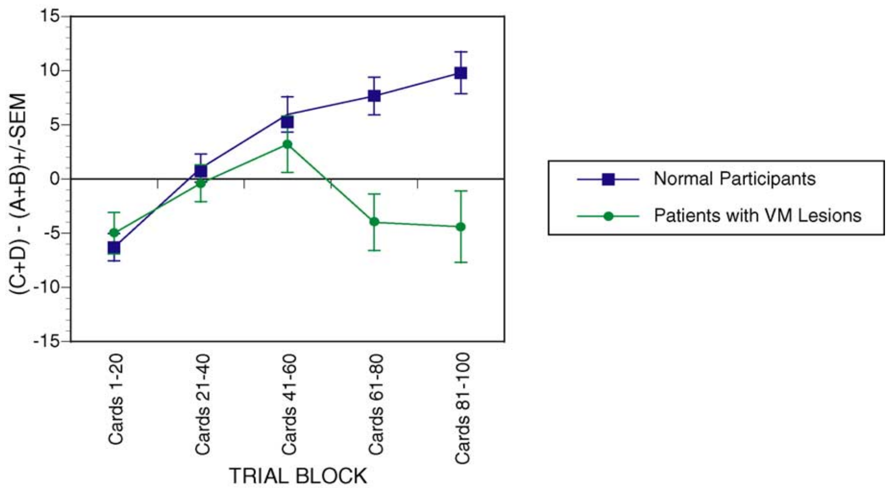

Fig. 1. Decision-making performance on the Gambling Task in normal non-elderly participants and in neurological patients with ventromedial prefrontal lesions, graphed as a function of trial block (±S.E.M.; standard error of the mean). Normal participants begin by selecting more from the bad decks (A and B), but as the game progresses, they gradually shift their selections toward the good decks (C and D). The ventromedial prefrontal patients do not exhibit this advantageous shift in decision-making (data taken from Bechara et al. (2000b)).

flatter slope across trial blocks, resembling the MacPherson et al. (2002) findings. 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 Gambling Task 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 (Siegel, 1956; p. 37). Participants who had indexes that were significantly different from zero in the positive direction were categorized as "Unimpaired," and participants who had indexes that were significantly different from zero in the negative direction were categorized as "Impaired".

3. Results

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

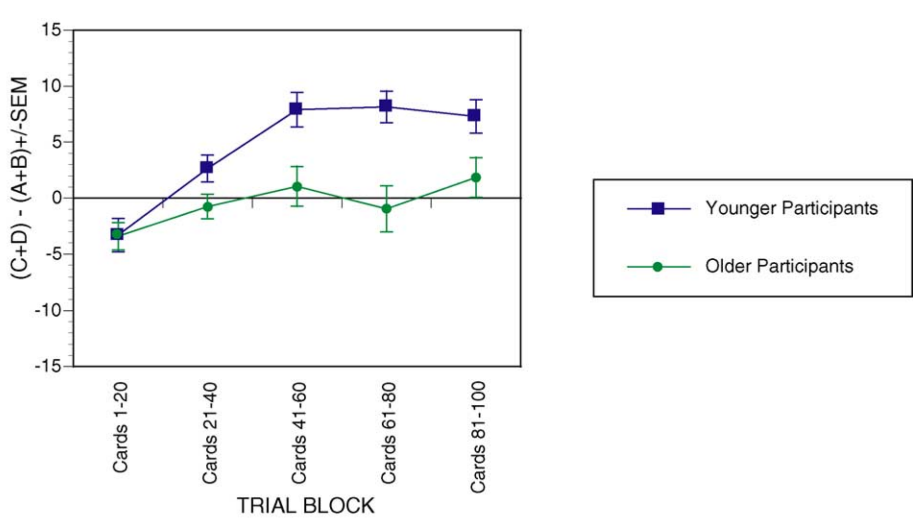

Fig. 2. Decision-making performance on the Gambling Task in the Younger and Older participants, graphed as a function of trial block (±S.E.M.). The Younger group performed in the normal fashion: they began by selecting more from the bad decks (A and B), but then as the game went on, they shifted toward the good decks (C and D). The Older group did not demonstrate this shift in decision-making, but instead, continued selecting about equally from the good and bad decks.

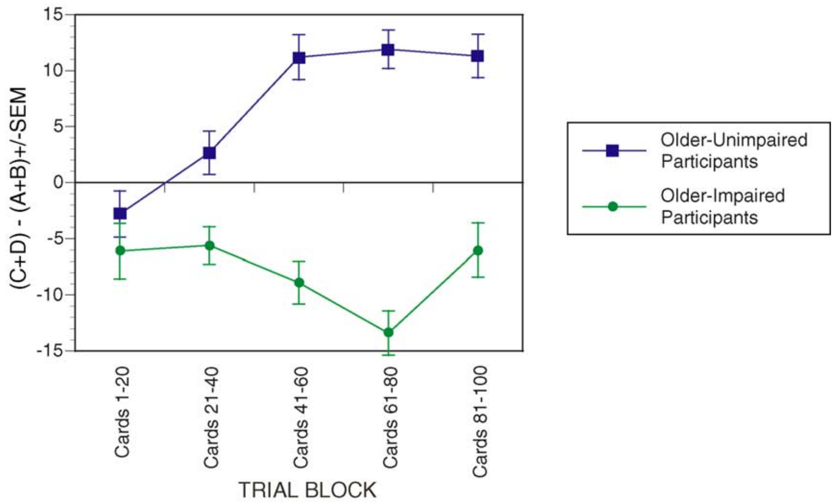

Fig. 3. Decision-making performance on the Gambling Task in the Older–Unimpaired and Older–Impaired participants, graphed as a function of trial block (±S.E.M.). The Older–Unimpaired group performed in the normal fashion: they began by selecting more from the bad decks (A and B), but then as the game went on, they shifted toward the good decks (C and D). The Older–Impaired group did not demonstrate this shift in decision-making, and continued to select predominantly from the bad decks for the duration of the game.

and trial block ($F(4,312) = 3.65$, $p < .05$). The age group ($F(1,78) = 11.89$, $p < .01$) and trial block ($F(4,312 = 14.00$, $p < .0001$) main effects were also significant.

Regarding performances of individual participants, in the Younger group, 37 of 40 participants were "Unimpaired", achieving overall indexes significantly above zero (three were "Impaired", obtaining indexes 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 Gambling Task (cf. Bechara et al., 2000b). In the Older group, we found that 15 participants were "Unimpaired", obtaining overall indexes significantly above zero, whereas 14 were "Impaired", obtaining overall indexes significantly below zero. Another 11 participants were considered "borderline", because their indexes did not differ significantly from zero in either the positive or negative direction. This outcome is inconclusive, and we will not consider this subgroup further. Thus, consistent with our expectation, a subset of the Older participants performed abnormally on the Gambling Task, failing to shift their selections towards 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 ($\chi^2 = 18.80$, $p < .0001$), reflecting the 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 stayed predominantly with the bad decks all the way through the task (in a manner somewhat 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 ($F(4,108) = 10.53$, $p < .0001$), substantiating the pattern evident in Fig. 3.[1] (The group ($F(1,27) = 104.83$, $p < .0001$) and trial block ($F(4,108) = 3.91$, $p < .05$) main effects were also significant.) By way of additional interest, we further compared statistically the Older–Unimpaired and Younger participants in the same manner as previously described. The results revealed a main effect of trial block ($F(4,212) = 22.58$, $p < .0001$), but no group main effect and no interaction, suggesting that a subgroup of older participants perform as well as their younger counterparts on the Gambling Task.

Lastly, we compared the Older–Unimpaired and Older–Impaired groups on demographic, health status, and neuropsychological variables. We did this in two ways. First, the groups were contrasted using independent samples *t*-tests (alpha corrected for multiple related comparisons). Second, we conducted a one-way multivariate analysis of variance (MANOVA) on the neuropsychological data as a more powerful statistical contrast of the Older–Unimpaired and Older–Impaired groups. Effect sizes and confidence intervals for these comparisons were also calculated, as were correlations between the neuropsychological measures and Gambling Task performance. The outcomes for the univariate analyses are presented in Table 1, and the data indicated a strong similarity of the groups on all variables. There were no significant differences in age, education, gender, handed-

[1] Because 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 × trial block interaction remained significant ($F(3,78) = 8.16$, $p < .0001$).

ness distribution, estimated intellect, memory, language, visual perception, attention/concentration, executive function abilities, or emotional status. Also, the two groups did not differ in terms of their health status, or in terms of their self-rated "risk-taking" tendencies. These outcomes were corroborated by the effect size calculations: all of the confidence intervals for the effect sizes included zero. Finally, none of the correlations between the neuropsychological variables and Gambling Task performances was significant, and most were well below |.30|. For the MANOVA, nonsignificant findings were also obtained ($F(9,14) = 0.70$, $p > .60$).

4. Discussion

The findings from this study support the notion that some older individuals have significant difficulty with reasoning and decision-making, as indexed by our Gambling Task. This impairment occurred in the absence of frank neurological or psychiatric disease, and there was no evidence that it could be explained by premorbid factors (e.g., educational level), overall health status, or weaknesses in other cognitive realms such as attention, memory, visual perception, or language. 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. (And, if one were to construe the 11 "borderline" older adults as deficient too, the rate of impairment might even be higher.) Given the well-documented association between decision-making on the Gambling Task 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 ventromedial prefrontal cortices.

Before moving on to the broader implications of our findings, we would like to revisit the MacPherson et al. (2002) findings that were touched upon briefly in the Introduction. As noted, those authors did not find an overall effect of age on the Gambling Task, and together with other findings from their study, they took this to indicate that they did not have evidence for disproportionate aging of ventromedial prefrontal cortices in their sample. Our current findings appear to contradict this conclusion, at least insofar as the Gambling Task data are concerned. However, a careful inspection of MacPherson et al.'s (2002) data lead to a different interpretation. First, the absence of a main effect of age on the Gambling Task stems from the fact that the two younger groups in MacPherson et al.'s (2002) study demonstrated rather flat learning curves, and in the latter two trial blocks, the groups demonstrated only a weak preference for the good decks over the bad decks. Second, the older group in MacPherson et al.'s (2002) study generated a Gambling Task profile that was nearly identical to the one we obtained in our Older group (we plotted the two groups together, for the sake of comparison, and found that the two curves were essentially superimposed on one another). Thus, it is in the younger participants, not the older ones, where the data from our study and MacPherson et al.'s (2002) study diverge.

Taking a step back from the data, the most obvious "outlier" in these studies is the performance profile of the younger participants in MacPherson et al.'s (2002) study. Those authors, in fact, acknowledged that there were oddities in their Gambling Task data, including the fact that their subjects tended to prefer the B and D decks. Whatever the explanation, we have extensive experience with the Gambling Task in normal younger participants, and we have consistently observed a robust learning effect whereby the subjects develop a strong bias towards the C and D decks as the task progresses. This is especially true in the second half of the task, where normal younger subjects tend to prefer the C and D decks at around a 3:1 ratio. Had MacPherson et al. (2002) compared their older group to our normal younger participants, they would have observed exactly the same outcome we did: the older group would have had a shallower learning curve. The other aspect of this discussion that is important pertains to the individual subject level. Overall, the older group in MacPherson et al.'s (2002) study was virtually identical to our Older group, in terms of Gambling Task performance. We found that our Older group was comprised of very distinct subgroups, one of which performed very well on the Gambling Task, and one of which did not. The same subgroup composition might obtain for the MacPherson et al. (2002) Older group, but the authors did not report such data, and they do not mention whether there were trends in that direction. In short, insofar as the older participants are concerned, the two studies (MacPherson et al.'s and ours) actually generated highly similar group results.

The issue of whether a sizeable number of older individuals have decision-making deficits has provocative societal implications. Older adulthood is a time of critical and complex decision-making during which the older adult is faced with decisions regarding medical care, safety operating an automobile, investment of savings and retirement income, estate planning, purchase of a burial site, and sudden role change following the death of a spouse, to name just a few. Furthermore, there is an expanding body of evidence suggesting that older persons are often targeted by fraudulent advertising. 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 (AARP, 1996). Thus, it is hard to overemphasize the ramifications of impaired decision-making for older adults. On a practical note, the Gambling Task may offer a sensitive means of detecting declines in decision-making, thereby facilitating early identification and intervention.

Also, the decision-making impairments of older adults may often be overlooked. In the wake of some two decades of intense and constant focus on the tragedy of Alzheimer's disease, older adults are readily brought to medical attention when they begin to manifest worrisome memory impairments; however, they may not elicit comparable concern if they have decision-making impairments, which may be dismissed as "eccentric behavior". This is reminiscent of neurological patients with ventromedial prefrontal damage, who because they lack blatant defects in memory, IQ, and such, are frequently misdiagnosed as having psychiatric disease (Stuss & Benson, 1986).

Our study has some limitations. We did not obtain a direct measure of real-world decision-making in the participants; hence, we cannot address the question of whether participants who manifested impaired decision-making on the Gambling Task do in fact have analogous deficits in their day-to-day lives. Nor did we obtain a neuroanatomical measure of ventromedial prefrontal integrity (e.g., a quantification of gray and white matter volumes). This measurement is important to address directly the issue of whether participants with poor decision-making do in fact have neuroanatomical changes in the ventromedial prefrontal sector. Thus, important empirical questions remain unanswered, and we have begun to explore these very topics (e.g., Denburg, Bechara, Cole, & Tranel, 2001).

The most significant question left unresolved here is why some older persons evidence poor decision-making ability. As discussed previously, the decision-making deficit may be attributable to disproportionate early decline in ventromedial prefrontal cortices. Alternatively, perhaps the strongest competing explanation for poor decision-making in older adults involves the potential for dysfunction of medial temporal lobe brain structures, such as that seen in the pre-clinical stages of Alzheimer's disease. Longitudinal studies are critical to address these possibilities. Age-related slowing in learning and individual differences in personality dimensions, such as impulsivity, remain viable alternatives. Regardless of the explanation, there can be little question that the current findings echo an alarm that has been sounded in regard to the potential exploitation of older persons by advertising and marketing fraud.

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References

American Association of Retired Person (AARP) (1996). *Telemarketing Fraud and Older Americans: An AARP Survey*. Washington, DC: Author.

Band, G. P. H., Ridderinkof, K. R., & Segalowitz, S. (2002). Explaining neurocognitive aging: Is one factor enough? *Brain and Cognition*, *49*, 259–267.

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

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

Coffey, C. E., Wilkinson, W. E., Parashos, I. A., Soady, S. A. R., Sullivan, R. J., Patterson, L. J., et al. (1992). Quantitative cerebral anatomy of the aging human brain: A cross-sectional study using magnetic resonance imaging. *Neurology*, *42*, 527–536.

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.

Daigneault, S., Braun, C. M. J., & Whitaker, H. A. (1992). Early effects of normal aging on perseverative and non-perseverative prefrontal measures. *Developmental Neuropsychology*, *8*, 99–114.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, *12*, 45–75.

Denburg, N. L., Bechara, A., Cole, C., & Tranel, D. (2001). Iowa gambling task performance in elderly persons predicts susceptibility to the influence of misleading advertising. *Society for Neuroscience*, 27.

Ernst, M., Bolla, K., Mouratidis, M., Contoreggi, C., Matochik, J. A., Kurian, V., et al. (2002). Decision-making in a risk-taking task: A PET study. *Neuropsychopharmacology*, *26*, 682–691.

Greenwood, P. M. (2000). The frontal aging hypothesis evaluated. *Journal of the International Neuropsychological Society*, *6*, 705–726.

Gur, R. C., Gur, R. E., Orbist, W. D., Skolnick, B. E., & Reivich, M. (1987). Age and regional cerebral blood flow at rest and during cognitive activity. *Archives of General Psychiatry*, *44*, 617–621.

Haaland, K. Y., Price, L., & LaRue, A. (2003). What does the WMS-III tell us about memory changes with normal aging. *Journal of the International Neuropsychological Society*, *9*, 89–96.

Hartley, A. A. (1993). Evidence for the selective preservation of spatial selective attention in old age. *Psychology and Aging*, *8*, 371–379.

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.

MacPherson, S. E., Phillips, L. H., & Della Sala, S. (2002). Age, executive function, and social decision making: A dorsolateral prefrontal theory of cognitive aging. *Psychology and Aging*, *17*, 598–609.

Melamed, E., Lavy, S., Shlomo, B., Cooper, G., & Rinot, Y. (1980). Reduction in regional cerebral blood flow during normal aging in man. *Stroke*, *11*, 31–34.

Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., et al. (2002). Attentional control in the aging brain: Insights from an fMRI study of the Stroop task. *Brain and Cognition*, *49*, 277–296.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315–372). Hillsdale, NJ: Lawrence Erlbaum Associates.

Raz, N., Gunning-Dixon, F. M., & Acker, J. D. (1998). Neuroanatomical correlates of cognitive aging: Evidence from structural magnetic resonance imaging. *Neuropsychology*, *12*, 95–114.

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.

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

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.

Salat, D. H., Kaye, J. A., & Janowsky, J. S. (2001). Selective preservation and degeneration within the prefrontal cortex in aging and Alzheimer's disease. *Archives of Neurology*, *58*, 1403–1408.

Schaie, K. W. (1996). Intellectual development in adulthood. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of Psychology and Aging* (pp. 266–286). San Diego: Academic Press.

Schmitt, W. A., Brinkley, C. A., & Newman, J. P. (1999). Testing Damasio's somatic marker hypothesis with psychopathic individuals: risk takers or risk averse? *Journal of Abnormal Psychology*, *108*, 538–543.

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

Shimamura, A. P., & Jurica, P. J. (1994). Memory interference effects and aging: Findings from a test of frontal lobe function. *Neuropsychology*, *8*, 408–412.

Stuss, D. T., & Benson, D. F. (1986). *The frontal lobes*. New York: Raven Press.

Tranel, D., Benton, A., & Olson, K. (1997). A 10-year longitudinal study of cognitive changes in elderly persons. *Developmental Neuropsychology*, *13*, 87–96.

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

West, R. L. (2000). In defense of the frontal lobe hypothesis of cognitive aging. *Journal of the International Neuropsychological Society*, *6*, 727–729.

West, R. L., Murphy, K. J., Armilio, M. L., Craik, F. I. M., & Stuss, D. (2002). Lapses in attention and performance variability reveal age-related increases in fluctuations in executive control. *Brain and Cognition*, *49*, 402–419.